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Using Photovoice to Promote Preservice Teachers' Socioscientific Reasoning Skills

Conghui Liu, Gayle Buck

Curriculum and Instruction, Indiana University Bloomington, USA

Abstract: Socioscientific issues (SSI) are complex, open-ended social issues with embedded scientific content and processes. These issues are often controversial, ill-structured problems and lack clear-cut solutions. Fostering the reasoning skills necessary to navigate these issues is essential in science education. This action research study focused on enhancing preservice teachers' socioscientific reasoning (SSR). Specifically, photovoice was added to a water quality unit in a scientific inquiry course for preservice teachers to take photos and analyze the scientific data through photos. Results showed that learners better understood the four competencies of socioscientific reasoning after completing the photovoice activity. They demonstrated a higher level of complexity and skepticism but lower levels of ongoing inquiry and perspective-taking. The findings resulted in revisions that focused more on the issue's social aspects and more discussion on the information that is not available regarding the issue in the activity and how that information may be generated.

Keywords: Socioscientific issues; Socioscientific reasoning, photovoice; preservice teachers; action research.
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Introduction

The natural world is complex and scientific knowledge is vital to understanding humanity's most pressing environmental challenges. Unfortunately, many of our educational systems have yet to adequately prepare students to enter the world with the necessary knowledge to understand and explore this complexity. This is due, in part, to an emphasis on discrete facts and experiences that bear little resemblance to how science is understood and completed. Over the past several decades, socioscientific issues (SSIs) have gained much attention due to their effectiveness in promoting such needed sensemaking (Sadler, 2011; Zeidler, 2014). SSI-based instruction is student engagement in navigating and contextualizing complex social issues connected with scientific phenomena. These are complex, open-ended social issues with embedded scientific content and process. They are often controversial, ill-structured problems and lack clear-cut solutions. Examples of SSIs include climate change, pollution, and conservation. Not surprisingly, given the complexity of the topics, the associated teaching and learning processes are complex. Understanding and engaging in discussions on such issues involve content knowledge, critical thinking, informal and formal reasoning, decision-making, and argumentation skills. While research has shown that SSI can successfully foster these in students, more research is needed on the nuances of instruction that lead to such achievement.

Given the promise of SSI regarding navigating and contextualizing complex social issues associated with scientific phenomena, the purpose of this study was to develop, implement, and explore an intervention in a water quality unit for socioscientific reasoning (SSR) development—the reasoning competencies needed to make informed decisions around SSIs. The intervention incorporated photovoice. Photovoice has been widely used as a method or strategy, especially as a promising participatory action research tool in various studies since Wang and Burris (1994) introduced it as a process of taking photos or documentation and telling stories related to the photos. The approach enables the readers and researchers to analyze and understand the event through the lens of the research object and their realities (Wang & Burris, 1994). Wang (2006)also indicates the potential of using photovoice to engage youth in participatory action research. It received broad attention in education with its potential to engage students in local community topics and became a new instructional tool in different settings, including place-as-pedagogy, conservation and sustainability practices, STEM, and decolonizing education (Cook, 2014; Derr & Simons, 2020). The availability to see complex issues from different points of view makes photovoice an excellent instructional tool in SSIs, especially in environmental and conservation contexts (Cook & Buck, 2010)**.**

Theoretical Grounding

SSI

By engaging students in personally meaningful issues that require consideration of social aspects, SSIs provide contextualized learning that promotes students' functional scientific literacy. Developing scientific literacy is one of the ultimate goals of science education. Roberts and Bybee (2014) espoused two visions of scientific literacy. Vision I emphasizes the inward of science and focuses on understanding science content. In contrast, Vision II focuses on the external of science where students engage with science ideas and practices in society (Roberts & Bybee, 2014). Educators have advocated for SSIs for their effectiveness in promoting Vision II of scientific literacy through decision-making by examining data from different sources, thinking from diverse perspectives, and understanding the complexity of connections inherent in the topics.

The discussion on SSIs dates back to the 1980s, and over the past two decades, research has been conducted to examine SSIs' benefits and challenges. Many researchers have studied the benefit of teaching science in SSI contexts. Zeidler concluded four themes regarding SSI's impact on science teaching and learning from the existing literature. These included: the pedagogical application of classroom practice, epistemological beliefs, and the development of conceptual and psychological knowledge structures, affording a contextualized setting of NOS, and the development of morality. The four themes also stand out in studies following Zeidler's (2014) chapter, and some have drawn interest from educators.

How students frame content knowledge of and about socioscientific topics and how that knowledge can transfer through different contexts has long been a question of SSI-based instruction. Klosterman and Sadler (2010) explored how and to what extent SSI instruction contributes to developing science content knowledge. Their results showed that SSI-based instruction significantly improves students' content knowledge and cultivates a more accurate, detailed, and sophisticated understanding of the topics. This provided significant evidence in support of the effectiveness of using SSIs as contexts for teaching and learning science content. Sadler et al. (2011) reaffirmed their finding that engaging in SSIs can support the learning of both science content directly aligned with the SSI context and the more abstract scientific formalisms in standard documents and assessments if the issue is authentic and is of interest to the students. Other studies around content knowledge development also support the positive

effects of using SSIs. However, the patterns of how students construct content knowledge and connect new knowledge to prerequisite knowledge in SSIs remain unclear (Zeidler, 2014).
In Science education, students are expected to develop argumentation skills and the ability to reason through scientific evidence to make claims. Many factors could influence students' development of argumentation skills. Dawson and Venville (2010) conducted a case study that explored a science teacher's practice for developing students' argumentation skills with SSIs. Based on previous research and his understanding of students' content knowledge, the teacher chose two SSIs – a genetically modified tomato and genetics testing for cystic fibrosis. Although it is unclear how the relative impact of SSI compared with the other three factors, the study offers evidence that SSI could be an excellent context to support the argumentation.

The ill-structured, open-ended nature of socioscientific issues (SSIs), which have multiple potential solutions, makes them an ideal context for students to practice and develop these skills, ultimately building functional scientific literacy, which is the goal of science education. Students can gain experience evaluating and synthesizing multiple perspectives and constructing well-supported arguments by engaging with these complex problems. Many studies have examined the development of students' argumentation skills through SSI-based instruction. Topcu et al. (2010) examined the influence of context by testing how and to what extent different SSI contexts affect the informal reasoning processes of 39 Turkish preservice teachers. They found similar patterns in the argument levels across various SSI scenarios and concluded that informal reasoning is context-dependent. Furthermore, they concluded that learning in the context of SSI supports preservice teachers' informal reasoning practices and their ability to foster these practices among their students (Sadler et al., 2011).

SSI-based instruction also supports the development and utilization of informal and formal reasoning skills, which are crucial for scientific literacy. Students often use informal reasoning based on everyday experiences during discussions about these issues. However, they employ formal reasoning when they utilize scientific knowledge to justify their opinions through consistent logic (Sadler et al., 2011). Both types of reasoning are essential for achieving the complex learning outcomes that SSI instruction aims to promote. However, SSI context alone does not guarantee the development of argumentation skills. Evagorou and Osborne's (2013) case study on collaborative argumentation within SSI provides different perspectives on SSIs. By analyzing two pairs of 12- to 13-year-old students' conversations during participant observation on SSI instruction, researchers found that the SSI context did not guarantee that students to engage in argumentation. Instead, a sense of ownership was needed to engage students in the socioscientific argument. Thus, engagement is not necessarily more likely in a socioscientific context.

SSR

Research on SSI has shown that students benefit from SSI-based instruction in terms of developing science content knowledge, understanding NOS, reasoning and argumentation skills, and global citizenship. However, no specific construct described the broad set of practices essential to negotiating SSI. Socioscientific reasoning (SSR) was introduced to address this gap (Sadler et al., 2007). Sadler and his colleagues first proposed SSR as a theoretical construct associated with negotiating SSI. It subsumes four components:

(1) recognizing the inherent complexity and multifaceted nature of SSI

(2) analyzing issues from multiple perspectives

(3) appreciating the need for ongoing inquiry related to SSI

(4) employing skepticism in reviewing the information presented by parties with vested interests. (Sadler et al., 2007)

To further examine SSR as a construct in teaching and research, Sadler et al. (2011) examined SSR as a tool for conceptualizing students' practices related to negotiating SSI. They clarified the construct by understanding students' responses and practice baseline through interviews and hypothesized that SSR is not limited to one specific context. When learners become aware of and better prepared to respond to the diverse aspects of SSI, they can also practice negotiating SSI, as developed in other SSI contexts.

Research shows that SSR patterns differ across SSI contexts. Comparing high school students' SSR for two SSIs, Cian (Cian, 2020) found differences between complexity, perspective, and skepticism in different topics. Cian found that the SSR aspect of perspective could be better understood in an environmental SSI than in a genetics SSI, and it strongly correlated with the level of skepticism. Additionally, students were more inclined to recognize different perspectives on environmental issues, which resulted in less skepticism. On the contrary, for genetics topics, students were more likely to critique the inquiry process and showed less perspective-taking. The different levels of complexity were suggested to be the result of the mastery of content knowledge as a prerequisite for reasoning through SSIs. However, for inquiry, students' understanding of the need for additional investigation is limited, regardless of the topic. This study indicated that the SSR is not directly transferable between SSI topics.

The SSR construct has been used to examine scientific literacy gains among students from middle school to college in SSI instruction. Study designs vary from semester-long field-based classes to short-term interventions. For example, Kinslow and his colleagues (2019) modified an existing field-based ecology course over two consecutive summers for high school students around a local environmental SSI. They examined students' SSR competencies and environmental literacy changes throughout the course. They found evidence supporting the effectiveness of the field-based environmental SSI course in promoting student growth in SSR. More importantly, their findings responded to the previous research on short-term intervention around SSI that resulted in limited improvement of student SSR and encouraged them to devote more time and energy to field-based instruction to assess the long-term effects. They also mention explicit instruction's importance in developing a sense of skepticism, especially the need for specific instructional tools for promoting skepticism. Owen (2021) critiqued the traditional analysis of SSR as not illuminating the breadth of knowledge domains and indicated that content knowledge is insufficient for functional scientific literacy. He explored the domains being drawn while engaging in SSR, including economics, ethics, politics, psychology, science, and sociology.

Although studies on SSR have been an emerging issue in science education, it should be noted that there is still no consensus on what SSR is, and this discussion has been ongoing. Some researchers have used the term but do not see it as a construct. Instead, they use it interchangeably with multiple reasoning modes in SSIs, such as socioscientific problem-solving, informal reasoning, and ethical and economic reasoning (Glazewski & Ertmer, 2010). Based on an exploration of secondary school students' SSR, Karahan and Roehrig (2017) recommended adding three additional aspects to the SSR construct: identification of social domains affecting the SSI, (2) using cost and benefit analysis for evaluation of claims, and (2) understanding that SSIs, and the scientific studies around them, are context-based. Kahn and Zeidler (2019) conducted a conceptual analysis of perspective-taking in SSI contexts, one component of SSR. They admitted the complexity of perspective-taking and identified a more precise independent construct: socioscientific perspective-taking (SSPT), which requires engagement with others or their circumstances, an etic/emic shift in one's viewpoint, and a moral context guided by conscience.

The lack of consensus on the construct of SSR also leads to the assessment of SSR. Sakschewski et al. (2014) developed an instrument for SSR and socioscientific decision-making on energy-related issues. With the acknowledgment of Sadler's work on SSR to describe students' ability to reason through SSI, Sakschewski did not adopt the four components of SSR proposed by Sadler. Instead, he developed the items based on the different aspects of the topic and checked their validity and reliability. Instead of a measurement instrument to assess students' SSR across contexts, he tailored this instrument to energy-related issues.

On the other hand, studies on the four components of SSR have continued, as have their measurement. Romine et al. (2017) developed the Quantitative Assessment of Socioscientific Reasoning (QuASSR) to assess students' SSR gains through SSI-based instruction. The ten polytomous, two-tiered items of two scenarios are designed around the topics in the intervention. By analyzing the responses from participating students, they confirmed the instrument's validity and reliability and re-examined the SSR construct's dimensionality. Like Sakschewski et al.'s (2014) study, the instrument developed in this study was designed specifically for the intervention topics. It provides less information on the effectiveness of assessing SSR across contexts. However, in their follow-up study, two additional scenarios were added to the instrument to test the SSR consistency across SSI contexts. This assessment showed that SSR could transfer from learning opportunities related to one SSI to those of another. However, the transfer may vary regarding the issues' relevance to students' interests. This finding is significant for both SSI instruction and SSR measurement. Since SSR gained in one SSI instruction is transferable to other contexts, the SSR instruments using contexts that differ from the issues explored in instruction should still be able to detect any change in students' SSR.

The QuASSR is a valuable measurement instrument in the field and expands the approaches in relevant research. Most early studies of SSR used qualitative data, like student work, class discussions, and interviews, to understand students' SSR (Karahan & Roehrig, 2016; Sadler et al., 2011). However, recent research has incorporated more diverse approaches to assess the effectiveness of SSI-based instruction in promoting students' SSR. In a mixed methods study, Kinslow et al. (2019) used QuASSR scenario assessment to evaluate students' SSR before class, upon the conclusion of class, and six months later. They also used qualitative data, including students' learning logs throughout the class and summative position papers upon the conclusion of the class. Large-scale assessment and comparison are also possible with QuASSR. Cian (2020) used QuASSR and added additional items about the course topic to compare students' reasoning patterns across the SSI contexts of 16 classrooms in 3 schools. In this study, we adopted Romine et al.'s (2017) QuASSR instrument for a quantitative understanding of students' development of SSR through the intervention, aligned with qualitative evidence that provides a detailed picture of the SSR pattern.

Photovoice as an Instructional Tool

Photovoice was first introduced by Wang and Burris (1994) as a tool for participatory action research that provides people an opportunity to identify, present, and enhance their communities and enables researchers and readers to understand how people in the community understand their realities. People who participated were assigned a camera and took photos that they think to represent their life, and later talked about the stories behind the photo. It is a way for people to document and discuss their life and community. The photos taken and the stories told by the participants provided researchers with a more comprehensive and profound understanding of the community, and it showed the potential of photovoice as a research method.

Since Wang and Burris's (1994) use of photovoice as a participatory action research, this method has been widely used in public health education and community development. Wang (2006) also promoted that photovoice could be a tool for youth participation in community-based teaching and learning. In science education, the use of photovoice has been adopted by many researchers and educators to let students take photos to describe their understanding or concerns about science and describe the photos with others (Cook & Buck, 2010; Derr & Simons, 2020; Whitfield & Meyer, 2005). Specifically, in environmental science, in which the science topics are usually complex and local issues that involve different stakeholders, photovoice was used to achieve various learning goals. Past studies on the use of photovoice in environmental science have shown the benefits to science teaching and learning from different perspectives.

Cook and Buck (2010) introduced photovoice as a community-based socioscientific pedagogical tool to address the community's complex issues from their point of view and create a critical dialog between the scientific aspects of the issue and the social aspects of the community. They then examined pre-service elementary teachers' experience in a community of practice through a place-based inquiry through the use of photos taken by students (Cook & Buck, 2014). Cook and Quigley (2013) further indicated that the use of photovoice as a pedagogical tool benefits students in building their connections to science in their daily life and to the community.

Derr and Simons (2020) reviewed past studies to learn how and in what ways photovoice was being used in environmental science learning contexts and how photovoice was adapted in these settings. They concluded four pedagogical approaches with photovoice. First, photovoice could be a tool to explore a physical place to learn about environmental topics (Cook, 2014), like sustainability (Cole & Altenburger, 2019), environmental justice (Bellino &

Adams, 2017), and related science content knowledge. Photovoice is also being used as a conservation or sustainability tool, particularly in Indigenous or rural communities adjacent to protected areas and engagement in climate adaptation, resilience, and disaster planning. In STEM teaching, photovoice in an environmental science context leads students to identify and solve environmental problems by documenting the problems in their communities (Cook, 2014; Cook & Buck, 2010). Lastly, photovoice could be a decolonizing or de-settling method for nondominant groups to bring Indigenous pedagogies into science or environmental education (McMahon et al., 2019).

Studies on photovoice as an instructional tool have shown various benefits to science teaching and learning, especially in environmental science. However, as photovoice is being employed in the instruction of these complex issues, which are usually SSIs, we do not how it is influencing learners' SSR. In this study, photovoice was adopted as an instructional tool in a water quality unit of a scientific inquiry course to examine its effectiveness in promoting preservice teachers' SSR.

Methods

Methodological Approach and Research Questions

An action research design was selected considering the focus on intervention. Action research offers an approach to bridging the gap between educational research and teaching practices in science education (Laudonia et al., 2018). It is a clinical tool practitioners use to improve the rationality and justice of their practice. A typical self-reflective action research cycle includes planning, action, observation, and reflection (Carr & Kemmis, 2009). In action research, researchers are both a practitioner and a primary participant. They plan and conduct action in classrooms to solve an identified problem. The critical reflection on the action will further improve classroom practice and contribute to the researchers' professional knowledge. This study emerged from a problem identified during the authors' teaching practice: students demonstrated relatively low levels of reasoning during inquiry-based activities. The action taken in this study was using photovoice to foster SSR skills in the context of SSIs. With this action, we attempted to promote undergraduates' SSR ability and explore the effectiveness of photovoice in improving the four dimensions of SSR (Sadler et al., 2007). The following research questions guided the action research process:

(1) How does the use of photovoice affect preservice teachers' SSR? At which level (complexity, perspectives, ongoing inquiry, and skepticism)?

(2) Which aspects of the process work well? In what ways can we improve the use of photovoice in SSIs instruction to promote SSR?

Context and Participants

This study was conducted in an inquiry-based environmental science course for preservice teachers at a public university in the United States. The course was designed to provide preservice teachers with an understanding of the nature of science, insights into the careers and practices of environmental scientists, hands-on experience with environmental scientific inquiries through inquiry-based interactions, and the opportunity to develop and refine laboratory skills. Additionally, the course aimed to promote an understanding of scientific inquiry and the application of scientific principles through the theme of environmental science, as well as to improve the ability to make relevant life decisions based on evaluating credible scientific evidence. The class was held for 16 weeks, with the first two weeks focusing on the nature of science and the scientific inquiry process. The remaining weeks were divided into five modules, each covering a range of topics in the field of environmental science. Each of the modules emphasizes on some procedures of scientific inquiry. For example, the Climate Change module focused specifically on students' reasoning using provided evidence. The Water Quality module was selected for this study. In it, students are required to collect and analyze data to decide the water quality of the local stream flows across the campus. This module was conducted and took six classes to complete.

The lead author of this study served as the instructor for the course. Sixteen out of the twenty students enrolled in the course agreed to participate in the study, and 13 attended all the classes during the research. All participants were white, and 11 of them were female. These individuals are all in the initial phase of their higher education journey, being first-semester undergraduate students in a teacher preparation program, specifically focusing on elementary education. Their participation in the course was driven by the requirements to fulfill the science content segment of their program.

Intervention

This study focused on inquiring into water quality. The module began with readings and lectures to provide background knowledge, followed by videos on measuring and assessing the quality of water in different areas. During class discussions, students shared their observations and thoughts on the quality of water bodies they encountered. They also participated in a hands-on activity that simulated ocean currents, which demonstrated the connection between local and global water quality and the importance of monitoring local water bodies. With all this pre-inquiry information, the instructor brought out the question "how is the water quality of the campus river based on different indicators?" and introduced two indicators of water quality: macroinvertebrate and erosion. Each group of students (consisting of three-four individuals) was asked to design and conduct scientific investigations to determine the quality of the local stream. They were also required to include at least two additional indicators based on their previous readings and class discussions. The instructor encouraged students to consider the reasons behind their choices and to connect their content knowledge to the inquiry activity. By the end of the first week, each group had designed its inquiry process and was ready to collect at least data. Each group of students went outside to collect their data in the first class of the second week of the module. The instructor prepared the equipment according to the student’s design. The students' data collection included quantitative data such as PH value, types and extent of pollutants, temperature, water flow rate, and biodiversity; as well as qualitative data including odor, clarity, and signs of erosion.

The photovoice intervention includes 3 phases. First, during the data collection, students were asked to take photos that could best represent the status of the ecological system of the stream. Second, after collecting the data, they work as groups in the classroom to analyze the different pieces of evidence and create a visual representation where they could organize all the evidence on the photos. A dynamic discussion within the group about how the evidence indicates the water quality and how they came to their claim with all the pieces of evidence taken into consideration. The instructor provided prompts for the conversation to build the link between the photo and the data, and consider possible explanations and solutions, including: How does this show overall quality? How do the various indicators interact? What does the picture show that any one piece of data cannot? Is there any data contradicting with other evidence? Which aspect of water quality does the indicator show? Lastly, each group presented their photovoice product to the whole class and explain each piece of their evidence and how they indicate the different aspects of water quality and the overall water quality together. By the end of the unit, students were tasked with writing a scientific explanation of the driving question, using the photovoice activity and other evidence as a guide. In addition, they presented their findings in a poster session open to the school, featuring the photos they had taken, labeled with data and results, to share their conclusions about the water quality of the campus river.

Data Collection and Analysis

A convergent parallel mixed methods approach (Creswell, 2014) was adopted in this study to get a comprehensive understanding of the effectiveness of the intervention through quantitative and qualitative data collection and analysis. The subsequent sections describe the collection of quantitative data, followed by the qualitative data collection and the convergence of both data sets for analysis.

Quantitative Data Collection and Analysis

This study adopted the two scenarios (fracking and Branville bay) from the Quantitative Assessment of Socioscientific Reasoning scenarios (QuASSR) to assess students' SSR from the four competencies: complexity, perspective taking, inquiry, and skepticism (Romine et al., 2017). Each student completed one scenario before the module and one after the module. All 13 students that attend the whole classes of all 3 weeks had completed the test. We made the decision based on Romine et al.'s recommendation that the use of a single scenario is sufficient for measuring students' SSR and these two scenarios were relevant to the topic of water quality in this module (Romine et al., 2017). The pre-test scenario of fracking in Wyoming is related to a land and water management SSI with implications for water quality, economics, and the benefits of multiple stakeholders. The post-test scenario of Branville bay is related to port policy on the two different groups to protect the ecosystem health and biodiversity of the bay. Students learned the content knowledge of both scenarios in the readings before the module.

Following Romine et al.'s (2017) study, we adopted the partial credit model to score students' responses based on the three-level ordinal scale (0=low, 1=moderate, 2=high). We used a non-parametric statistical analysis because of the small sample size and the ordinal scores of the QuASSR questionnaire. Before comparing pre and post data, the nonparametric Wilcoxon matched pairs test was employed to determine the validity of the two scenarios at measuring students’ socioscientific reasoning equally.

Qualitative Data Collection and Analysis

Both students' work and class audio recordings were collected in addition to the QuASSR quantitative data. Students' work includes in-class lab sheets of in-class activity, groups' photovoice products, and their scientific explanations. Audio recording includes the discussion of in-class activity during the second phase and photovoice poster presentation in the third phase, to capture the informal reasoning during the natural conversations.

Qualitative data were analyzed following the qualitative typological approach (Hatch, 2002). The four SSR competencies: complexity, perspective taking, inquiry, and skepticism, are the priori typologies. We employed open-coding to explore ideas that emerged directly from the qualitative data to find the patterns and themes of SSR within each competence, and then check for additional evidence in the class conversation (Strauss & Corbin, 1990; Miles et al., 2014). The first author served as the primary analyst for the data analysis, and second author engaged in repeated peer debriefing throughout the coding process for trustworthiness of the coding and interpretation.

Convergence of quantitative and qualitative data

The study employed a convergent parallel mixed-method approach as outlined by Creswell (2014), wherein quantitative and qualitative data were simultaneously collected and analyzed. The QuASSR result provided metrics for assessing students' SSR before and after the intervention. Concurrently, qualitative scrutiny of student work and class recordings yielded insights into the development and demonstration of SSR during the course. In addition, we compared the pattern of students' SSR as shown in QuASSR results and the qualitative results to allow for triangulation and a more sophisticated understanding the development of students' SSR through the study. Collectively, this convergent analysis offers a multifaceted perspective that not only aids in interpreting the results but also bolsters the trustworthiness of the findings discussed in the subsequent section.

Results

Research Question 1: How Does the Use of Photovoice Affect Preservice Teachers' SSR? At Which Level (Complexity, Perspectives, Ongoing inquiry, and Skepticism)?

Quantitative Findings

The Wilcoxon matched pairs test indicated no significant differences between the two scenarios in measuring the four SSR competencies at pre and post survey. This corresponds with results from Romine et at.'s (2017) result that the scenarios performed equally at measuring student SSR. After establishing the validity of the two scenarios, we proceeded with a non-parametric Wilcoxon signed rank test for each of the four competencies at pre and post. Table 1 presents the results of the Wilcoxon signed rank test.

Table 1

Means and Standard Deviations of Pre and Post QuASSR result

Measure	Pre		Post	
	M	*SD*	*M*	*SD*
Complexity	1.50	0.65	1.31	0.73
Perspective-taking	1.00	1.02	1.46	0.91
Inquiry	1.27	0.93	1.5	0.91
skepticism	0.89	0.88	1.23	0.91

The Wilcoxon signed rank test reveals a statistically significant increase from pre to post result at the dimension of reasoning about perspective-taking, the need for ongoing inquiry, and skepticism. The means of these competencies of SSR all improved from the pre- to post-assessment. Students' understanding of the complexity of the issue did now show any improvement. However, it is the highest one of the four competencies from the beginning. The mean score on the 0-2 scale was 1.50 on the pre-test, and 1.31 on the post test. The gain of perspective-taking is specifically high, from 1.00 to 1.46.

Qualitative Findings

The results of the qualitative analysis show the general trend in the students' self-regulated learning (SSR) during the study and offer insight into the evolution of SSR in the various activities. The following is a summary of how the students applied the four SSR skills in their lab reports, class discussions, and scientific explanation papers. To maintain confidentiality, pseudonyms have been used for the students' names, as well as the names of the institution and location.

Complexity. The water quality unit was designed with multiple indicators from different perspectives that might contradict each other. During class activities, the students frequently discussed the complexity of water quality, human health, and economic development. All of the students participated in the Photovoice activity, in which they assembled evidence and reasoning to arrive at an overall claim. However, when analyzing the data and generating claims from the evidence, different patterns emerged in terms of recognizing the complexity of the issue.

Most of the students were able to refer to all the evidence but acknowledged the divergences differently. Many students referred to all the evidence and did address the pieces that did not support their claim. They justified why the contradictory evidence was not reliable or considered it insignificant in light of the supporting evidence. For example, one student stated that:

> Unfortunately, the levels of erosion are high, which does not support our hypothesis. However, these can easily be explained by the large population of people living on campus that walk near or engage with the river daily.

Several students were able to not only reason through the complexity of the issue and address the divergence within the evidence, but also perceive the issue as a complex one that needs to be discussed from different viewpoints. However, some students listed all of the evidence but only mentioned the evidence that supported their claim and ignored the evidence that did not. The students' emotions towards the water quality and different indicators were the main force behind some students' reasoning process, regardless of the evidence.

> Pollution is the only area in which we are looking for, therefore the other factors are irrelevant to testing the actual water quality of the rivers, plus these macroinvertebrates evolve and adapt overtime to the point where these other factors wouldn't be an issue in determining whether their presence is there due to the bad water quality.

The written work revealed that a few students only listed evidence that supported their claim and ignored evidence that contradicted it. For example, one student based their claim that the water quality was good solely on the pH value and macroinvertebrate data, but did not address the other two indicators, even though these were challenged in the group discussion by the instructor and acknowledged as contradictory.

Overall, the photovoice activity helped students to relate all the evidence together and make comprehensive claims, but the lack of addressing complexity indicated a missing link between the activity and how it was transformed into a scientific explanation.

Perspective-taking. Sophisticated perspective-taking involves the ability to analyze an issue and potential solutions from diverse viewpoints. The lab report did not show the evidence of perspective-taking, as it is designed for recognizing the importance of monitoring local water quality and the complexity of the issue. The class discussion also did not provide much evidence of it. However, in the scientific explanation, many students were able to consider the water quality issue from multiple perspectives, including those of students, campus management, and residents.

> Some ways residents/governments/institutions can help are to properly dispose of hazardous products, put up signs, use and dispose of harmful materials properly, Join in a beach, stream or wetland cleanup and prepare a presentation about your watershed for a school or civic organization.
>
> Residents in this area can continue to take care of this river and not litter or worsen the erosion around the river. The institution of the University can set in place mandatory and frequent monitoring systems to make sure the water in the campus river stays in excellent condition.

Approximately one-third of the students demonstrated low perspective-taking ability. Some of them did not provide any solutions, while others were only able to offer potential solutions from their own perspective.

> By monitoring water quality, we were able to see the issues of the water and determine how we can fix it for the future. For instance, by acting on the eroding area now, we can avoid clogging of the creak and keep from the decline of organisms in the area.

There is another one that analyzes the issue from the perspective of water's ability to fulfill the action of drinking, fishing, swimming, nourishing the environment and recommending In order to keep water, clean we need to focus mainly on pollution. That is the easiest things civilians can do to help the issue on a day to day basis. This student's highly emotional approach to reasoning through the evidence also led to a lower recognition of the complexity of the issue, as mentioned in the complexity part.

The results of the qualitative data indicate that while perspective-taking competency was not prominently displayed in-class activities, many students demonstrated an awareness of the fact that different stakeholders may have different perspectives on a complex SSI and could act accordingly to improve the condition in their writings.

Inquiry. Scientific investigation and SSIs are naturally open to further inquiry and enhancement of our understanding. Advancing inquiry competency of SSR requires students to be able to identify the possible questions for further inquiry around the social and scientific aspects of the issue. Analysis of qualitative data shows a lower level of recognizing the need for further inquiry. The water quality unit itself is not perfectly designed and was subject to be challenged and refined. Besides, it's an ongoing issue that needs continuous attention. However, most students didn't exhibit this competency in their lab reports, class discussions, or scientific explanations. Only One student considered soil Ph in the future:

> One recommendation for future research that my group decided upon, was testing the soil PH next to the river itself. We feel that this data would further support our claim and would provide more relevant ecological information.

Another one mentioned the longitude of the study:

> For the future I think we could take samples from the same stream but over the course of multiple days that way we can see how things change and how the water progresses. This would make our evidence more reliable since it would be based off multiple different samples and not just one.

Lab reports and class discussions didn't provide evidence of students' inquiry competency either. The photovoice activity aided the students in organizing the existing evidence in a way that allowed them to connect all the information and provide a framework for considering the evidence from various perspectives. However, there is a lack of evidence in the qualitative data indicating that the activity promoted the students' ability to view the inquiry project on socioscientific issues as ongoing rather than as a question to be answered and then completed.

Skepticism. Scientific skepticism is a significant scientific habit of mind that refers to the reflective process of critically examining the potential bias of existing evidence or claims. For this water quality unit, students' skepticism competencies are mostly shown by their examination of the evidence they collected and the claims they made based on the evidence.

Most students were found to be able to identify potential sources of bias that may influence their decision about the water quality, in both class discussions and their scientific explanations. Lab reports before the project design didn't reveal this competency. The critiques are mostly about project design, data collection, and data analysis. Typical critiques involve not enough indicators, single-location samples, lack of repeats, one-time data collection, errors in reading data, and miscommunication within groups. One example was:

> What we concluded was that it mostly depended on the area where you collect data. Some other groups had vast differences in their findings, but this was mostly due to the vast difference in the area they were researching. Next time, findings may be more similar if groups looked in similar areas of the creek.

It is noticed that besides the common critiques on designing and conducting the inquiry project, some critiques arise from the contradiction of evidence in the photovoice activity:

> This is the only conflicting evidence from the data collected but it is still not a bad pH, the rest of the data makes up for the lower pH level. This is inconclusive to the data collected and I think retesting would be a good idea.

To conclude, students generally showed skepticism competency of SSR toward the end of the unit. The skepticism is mostly towards the critique of their own practice and recognizing potential bias of their evidence.

Research Question 2: Which Aspects of the Process Work Well? In What Ways Can We Improve the Use of Photovoice in SSIs Instruction to Promote SSR?

The goal of the intervention is to enhance preservice teachers' socioscientific reasoning skills through an inquiry project that includes a photovoice activity. The focus is on improving their ability to recognize the complexity of an issue and consider it from multiple perspectives. We also aim to improve their competencies in inquiry and skepticism, if possible. Our analysis of the data collected at different stages shows that the intervention was effective in promoting preservice teachers' development of each competency at different phases.

As the core of the intervention, the photovoice activity helped learners recognize the complexity of the issue and perspective-taking. It also pushed students to be skeptical on their evidence through the contradiction they faced during the activity. The photovoice activity helped many students recognize the complexity of the issue and address the divergence between different types of evidence. The lab report and class discussion helped students understand the complexity of the issue. However, some were unable to address the contradiction between the evidence despite being challenged by the instructor. This suggests a need to further emphasize the complexity of the issue and link informal reasoning in discussion to the development of formal scientific explanations. By doing so, preservice teachers can achieve a higher level of SSR in terms of complexity.

Through creating the photovoice in group discussion and sharing their photovoice with other groups, learners can recognize potential bias that existed in the inquiry process and how to fix it. This also leads to a small improvement on the inquiry competency of SSR. However, it needs to be noticed that based on the quantitative data, the inquiry is overall a lower aspect of students' SSR, and it matches with the qualitative result. The results revealed a lack of emphasis on ongoing inquiry. Future action should involve discussions on the further information needed, as well as the ways in which that information could be generated. Students showed their ability of perspective taking in scientific explanation after the photovoice. But the lab report and discussion showed no evidence of it. More discussion on the social aspects needs to be discussed after their finding of the issue in class to further improve their understanding of the topic.

Besides the development of socioscientific reasoning, students are able to list their evidence together and come up with the claim through reasoning on all the evidence. The activity helped students to develop a better scientific argument. It helps fulfill the goal of the course and should be kept in the future.

To conclude, the photovoice activity was effective in promoting the four competencies of SSR to a different extent, especially in terms of complexity. More efforts to organize discussions on perspective-taking and skepticism could further help students strengthen their reasoning process and transform it into a formal scientific argument. The ongoing inquiry competency needs specific attention, as students had a relatively lower level of this aspect and there was less evidence showing its growth throughout the intervention.

Discussions

Past empirical studies on SSR have shown mixed results on the pedagogical skills that foster greater levels of reasoning during SSI-based instruction (Bächtold et al., n.d.; Kinslow et al., 2019; Leung, 2022; Leung & Cheng, 2023). This study deepens our understanding of how to foster preservice teachers' SSR skills. Specifically, the findings demonstrate the potential of using photovoice as a vehicle to support the development of SSR and provide a possible instructional strategy for teaching and learning. Current reform efforts in science education research strive to equip students with the ability to cope with real-world issues, where social and cultural factors intersect with scientific phenomena so that students can engage in these socioscientific conversations (Hodson, 2003). And teachers are highly affecting students' learning process. Photovoice in this study shows the potential of achieving such goals in preparing preservice teachers through the opportunities of encountering them with facts from a diverse perspective.

The present study highlights the complex relationship between emotion and evidence-based reasoning in the context of preservice teachers' scientific sense-making. Sadler and Zeidler (2005) distinguish between rationalistic informal reasoning, which is based on reason-based considerations, and emotive informal reasoning, which is based on care-based considerations. The findings of this study suggest that for those who adopt different perspectives and rely on evidence-based reasoning, emotive reasoning is less likely to influence their reasoning process. Conversely, learners who demonstrated a high level of emotional engagement with the issue at hand were more likely to engage in emotive reasoning, but did not exhibit the same level of scientific evidence-based reasoning as other students. Further research on how to incorporate learners' emotions into the design of SSI-based instruction that promotes SSR could be beneficial in helping students to both engage with the issues that matter to them and improve their reasoning skills.

This study also fostered more questions that provide a direction for future research regarding SSI, SSR, and photovoice. Past studies on SSI also show a lack of diversity in the SSI topics. Across the studies with different focuses on SSIs, the topics selected for intervention are similar. Climate change (Klosterman & Sadler, 2010; Sadler et al., 2011), gene-modified technology (Dawson & Venville, 2010; Lee et al., 2013), and ecology (Herman et al., 2020) are the most common SSI contexts for the studies. The reasons behind this are worth considering. For example, the teacher in Dawson and Venville's (2010) study used two SSIs in a genetics context—cystic fibrosis, and genetically modified tomatoes—to promote 10th-grade students' argumentation skills because they best suited the course's genetics content. The topics were selected by both the teacher and researchers to ensure students had enough background knowledge to engage in argumentation. Also, they chose the topic because of previous successful implementations with students of similar ages. This study designed the intervention on water quality issues, which involves the perspectives of different groups and science from different perspectives.

Conclusion

With the challenge of developing students' functional scientific literacy to neogiate with the complex SSIs in daily life, it is important to preparing science teachers with adqueate SSR to promote such learning among students. This study reported the use of photovoice to promote preservice teachers' SSR in an inquiry about local water quality. The results provide insights on the development of the four dimensions of SSR, complexity, perspective-taking, inquiry, and skepticism, and analyzed the effectiveness of each step in the process of the intervention. The development of these dimensions did not occur at the same level. It is acknowledged that photovoice was used as a tool to analyze and present findings within a small community in this study. Future trials involving photovoice in broader, community-based teaching and learning contexts, with the participation of diverse stakeholders, may yield greater benefits.

The findings suggest that photovoice can be a powerful tool to help preservice teachers navigate the intersection of emotion, evidence-based reasoning, and socioscientific issues. However, the results are context-specific and limited to the authors' practice as action research. Further research involving additional trials of photovoice in SSI-based instruction, as well as comparisons with lessons that do not use it, would provide broader insights into its effectiveness and offer clearer guidelines for implementing it to develop students' SSR.

The study also indicates that emotion, while valuable for engaging students, can sometimes detract from evidence-based reasoning if not carefully integrated into instructional design. Future research should explore how to effectively balance emotional engagement and scientific reasoning in SSI-based instruction. Furthermore, the diverse perspectives brought forward through photovoice can help address the lack of diversity in SSI topics by encouraging the exploration of local, real-world issues that resonate with learners' lives.

Ultimately, the study provides a promising framework for future research and practice in both preservice teacher education and SSI-based instruction. By leveraging tools like photovoice and encouraging critical reasoning across diverse contexts, science educators can better equip teachers and students SSR to tackle the complex, real-world challenges they will face.

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Corresponding Author Contact Information:

Author name: Conghui Liu

Department: Curriculum and Instruction

University, Country: Indiana University Bloomington, USA

Email: congliu@iu.edu

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