Investigating Pre-service Science Teachers' Argumentation Skills Through Place-Based SSI Instruction in Mining Environment

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Abstract

The aim of this study was twofold: First, we aimed to explore the effectiveness of place-based SSI instruction on pre-service science teachers' argumentation skills. Second, we aimed to explore how their initial ideas about constructing and operating a gold mine changed after participating in a five-week place-based SSI instruction including a gold mine field trip. The study was designed as a quasi-experimental one-group pretest-posttest design. The participants were 15 senior pre-service science teachers. The data were collected from students' written reports about their decisions in constructing and operating a gold mine. Semi-structured interviews were conducted with five participants to get more in-depth insight into their written reports. The results revealed that the number of participants who disapproved of constructing and operating a gold mine where they live significantly increased after the instruction. Moreover, their reasoning quality including counterarguments and rebuttals was increased prominently. Place-based SSI instruction has the potential to develop participants' argumentation skills as well as their sensitivity to environmental socioscientific issues.

Keywords: local issues, place-based environmental education, pre-service science teachers, socioscientific issues

Introduction

In the past 20 years, socioscientific issues (SSI) have become more apparent in science education. While issues like genetic engineering, cloning, renewable energy, genetically modified foods, and climate change have traditionally been a context for SSI (Sadler, 2004; Sadler & Zeidler, 2005), the COVID-19 pandemic introduced new directions for SSI. For instance, individuals faced to make informed decisions about many issues covered in the SSI context such as vaccination, using a face mask, or plastic pollution created by disposable gloves or masks. These issues involve scientific aspects while also including controversy in their nature (Sadler, 2004). Thus, individuals need to make informed decisions by considering their own values, and experiences as well as different stakeholders' perspectives (Chang Rundgren & Rundgren, 2010). However, informed decision-making skills do not develop on their own. There should be consistent and deliberate instruction to nurture individuals' decision-making skills.

Some of the issues covered in SSI are closely related to the environment (Herman, 2018). While making informed decisions on environmental issues, individuals need to contemplate varying viewpoints, environmental considerations, and nature itself (Herman, 2018; Herman, Zeidler & Newton, 2020). Traditionally, most SSI research and instruction has been conducted solely in formal learning environments, such as classrooms, and through student participation in hypothetical situations and decision-making (Zeidler, Herman, & Sadler, 2019). For instance, Sadler and Zeidler (2005) used hypothetical scenarios on genetic engineering to explore college students' informal reasoning. However, Herman (2018) argued that students' lived experiences should be part of SSI instruction to understand how individuals react when faced with an SSI as a component of their everyday lives. Indeed, practical sessions or field-based learning were reported to provide authentic and active learning experiences for students (Andrews, van Lieshout, & Kaudal, 2023; Chapple et al., 2022). To do so, more recent efforts integrated place-based science education with SSI-based instruction (Herman, 2018; Herman, Owens, Oertli, Zangori, & Newton, 2019, Herman et al. 2020). Consequently, place-based SSI instruction has been introduced to enhance students' sense of place and attachment to the real "others" (people and the environment) who suffer from SSI and their resolution (Herman et al., 2020).

Place-based Science Education

Teaching concepts across the curriculum in language, arts, math, science, social studies, and other subjects by utilizing the local community and environment as an integrating framework for learning at all levels lies at the core of place-based education (Sobel, 2004). Place-based education has a long history in science education(Lim & Barton, 2010; Semken, Ward, Moosavi, & Chinn , 2017). Semken et al. (2017) indicated that some groups – indigenous (e.g., Native Americans, Native Alaskans), rural, and underrepresented groups (e.g., African Americans or other ethnicities) – are forced to relocate from the places that are most meaningful to them. So, they argue that place-based science education creates an authentic context to develop their sense of place. The literature reported that place-base science education enhanced students' scientific understanding and knowledge of science content (van Eijck & Roth, 2007); improved scientific ways of thinking (Lim & Barton, 2006); enhanced active participation in the community (van Eijck & Roth, 2007); and utilized of place attachment and sense of place (Lim & Barton, 2006; van Eijck & Roth, 2007).

Place-based SSI Instruction

In their review of new directions in SSI research, Zeidler et al. (2019) pointed out that place-based SSI instruction has the potential to create a suitable context where students' sense of place and attachment to real others (people and the environment) that are impacted by SSI could be enhanced (Herman et al., 2018). Students engage directly with people and the environment that are impacted by environmental SSI through place-based SSI instruction (Herman et al., 2020). Herman and his colleagues used place-based SSI instruction by using various local issues held in the Great Yellowstone area (Herman et al., 2018, 2019, 2020), or Missouri River (Herman, Poor, Oertli, & Schulte, 2023). The authors explored the developments in participants' nature of science (NOS) understanding as well as emotive reasoning competence. In a similar manner, several attempts in global contexts explored the effectiveness of place-based SSI instruction (Avsar Erumit, Namdar, & Oğuz Namdar, 2023; Kim, Ko, & Lee, 2020; Powell, 2021). The results indicated important outcomes for participants: it enhanced much more nuanced NOS views (Avsar Erumit et al., 2023; Herman et al., 2019; 2023), increased content knowledge (Herman, 2018), and developed of a high sense of emotive reasoning and deep compassion for nature and people who experience difficulties as a result of environmental SSI (Herman et al., 2020). Moreover, place-based SSI instruction enhanced socioscientific reasoning and environmental literacy (Kinslow et al., 2019), and evidence-based reasoning (Powell, 2021) and character development as global citizens (Avsar Erumit et al., 2023; Kim et al., 2020). One important aspect that is common in all the above-mentioned studies is that the issues selected were local which makes it easier for participants to attach the place.

Mining: An authentic setting for place-based SSI instruction

For over a decade, mining has been used as an authentic and local issue in SSI-based instruction. In an earlier study, by taking sixth-grade students to a science centre exhibition about mining that included four parts—drilling the ore, blasting the surface, environmental effects of mining on wildlife, and mining and daily life interaction—Pedretti (1999) investigated how Canadian sixth-grade students interpret and make a decision on a controversial mining topic. The findings showed that taking students to a mining exhibition fostered their informed decision-making and improved critical thinking skills. Students also developed stronger motivation and an emotional attachment after they were asked to justify and provide evidence for their decisions to construct a mine in the town. Moreover, they were able to consider different stakeholders' views and developed emotional attachments to those who were involved in the issue. Pedretti (2004) also explored participants' understanding of science by using two exhibitions (Mine Games and A Question of Truth) for over 10 years. She revealed that these kinds of exhibitions improved learning by personalizing subject matter, evoking emotions, and promoting dialogue and debate. In a more recent study, Gutiérrez (2018) explored Colombian high school students' decision-making on extracting oil in a local territory of Colombia and exporting it for economic gain. The results revealed that participants showed a limited number of argumentation schemes. Most students tended to approve of founding an oil company by considering economic gains. In another study, Gao et al. (2021) prepared an SSI-based teaching unit for enhancing 10th-grade students' emotional competence by using Coltan mining as a local case. The authors revealed that SSI-based units focusing on environmental local dilemmas can be used to promote the emotional competence of participants. The literature summarized above speaks about how the mining issue can be used as a local case in SSI instruction. Thus, the researcher chose gold mining as a compelling and authentic setting for place-based SSI instruction.

SSI and Argumentation

Promoting students' argumentation skills has been subject to both policy documents (such as NRC, 2012) and available research (Dawson & Carson, 2020; Sadler, 2004; Zohar & Nemet, 2002). Argumentation focuses on how individuals present and justify their claims and conclusions (Zohar & Nemet, 2002). As SSI focuses on ill-structured, open-ended, and debatable issues (Sadler, 2004), it is closely related to argumentation. SSI framework uses discourse practices such as argumentation, debate, discussion, and other types of discourse to engage participants being involved in thinking and reasoning processes (Zeidler et al., 2019). While dealing with SSI, students often get involved in argumentation and decision-making on this issue (Wu & Tsai, 2007). Consequently, argumentation has been a central theme in SSI education (Dawson & Carson, 2020; Sadler, 2004; Sadler & Donnelly, 2006; Wu & Tsai, 2007; Zeidler et al., 2019).

Constructing an argument is an essential part of argumentation. An argument includes a claim with data and evidence; and could be expressed in written, oral, or thought forms (Dawson & Carson, 2020). Toulmin (2003) created the most well-known and used structured framework to evaluate the quality of arguments as well as the development of argumentation generation skills. Toulmin's Argumentation Pattern (known as TAP) has been successfully used to assess the quantity and quality of students' arguments in science education (e.g.,Erduran, Simon, & Osborne, 2004). The TAP components include a claim (an assertion), data (relevant evidence), warrant (a linking of claim and data), qualifier (conditions under which claim or data is supported), rebuttals (conditions where the claim or data is not supported), and backing (underlying theory or assumptions to support data/warrants) (Toulmin, 2003).

As mentioned above, due to the ill-structured and open-ended nature of SSI, the development of students' argumentation skills has been explored in various SSI contexts (e.g., Dawson &

Carson, 2020; Garrecht, Reiss, & Harms, 2021; Sadler & Donnelly, 2006; Zohar & Nemet, 2002). While the studies reported that the context itself played a significant role in enhancing the argumentation quality (Garrecht et al., 2021; Sadler & Donnelly, 2006), students' written argumentations and argumentation quality improved after carefully designed SSI-based instruction (Atabey & Arslan, 2020; Aziz & Johari, 2023; Dawson & Carson, 2020; Garrecht et al., 2021; Zohar & Nemet, 2002). Thus, there is a need for designing SSI-based instruction to develop students' argumentation skills which directed the current study.

A wide range of issues has been employed in SSI research to investigate students' argumentation skills. These issues range from genetic engineering (Sadler & Donnelly, 2006; Zohar & Nemet, 2002), climate change (Dawson & Carson, 2020), animal testing (Garrecht et al., 2021), nuclear energy (Atabey & Arslan, 2020), plastic pollution (Aziz & Johari, 2023), and other issues such as artificial lakes, chicken coops, leather tanneries, base stations, and hydroelectric power plants (Capkinoglu, Yilmaz, & Leblebicioglu, 2020). Lately, Gutiérrez (2018) used mining as a local case to investigate high school and undergraduate students' argumentative schemes. However, no intervention study used mining as a local case like used in this study.

Research Aims

Different authentic settings were used in place-based SSI instruction such as wolf reintroduction (Herman et al., 2019) or hydroelectric power plants (Avsar Erumit et al., 2023). In addition, the researchers investigated the effectiveness of place-based SSI instruction on different traits including nature of science (NOS) views (Avsar Erumit et al., 2023; Herman et al., 2019, 2023) or emotive reasoning competence (Herman et al., 2020). However, the researcher did not encounter any studies exploring the effects of place-based SSI instruction on participants' argumentation quality. Thus, this study aimed to explore how pre-service science teachers' (PSSTs) argumentation skills were enhanced after participating in a place-based SSI instruction about gold mining. Specifically, this study aimed to answer the following research questions:

1. How did participants' decisions on the construction and operation of a gold mine change after participating in a place-based SSI instruction?
2. How did participants' reasoning quality change after participating in a place-based SSI instruction focusing on gold mining?
3. How did place-based SSI instruction affect PSSTs' argumentation quality?

Method

Research design

The present research employed a quasi-experimental one-group pretest-posttest design to investigate the development of PSSTs' argumentation quality over place-based SSI instruction. It is not possible to randomly assign participants to groups in quasi-experimental designs (Price, Chiang, & Jhangiani, 2018). In a quasi-experimental one-group pretest-posttest design, the researcher does not have a control group, instead, the researcher measures the same dependent variable before (pretest) and after (posttest) the intervention (Privitera & Delzell, 2019). In this study, a quasi-experiment one-group pretest-posttest design was intentionally selected due to the small sample size (constraints brought by university policies – if the group included less than 30, it was not possible to open a second course under the same name). The graphical illustration of the one-group pretest-posttest design is presented in Figure 1:

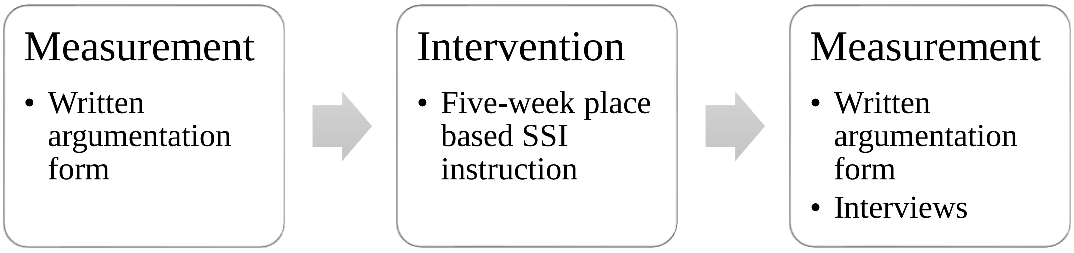

Figure 1. Graphical illustration of quasi-experimental one-group pretest-posttest design

Participants
The study involved 15 PSSTs from a mid-sized public university in the Western Anatolia region of Türkiye. The participants were senior pre-service science teachers who were enrolled in an elective course entitled "Problems Related to Science and Technology". The course was offered during the seventh semester of a science teacher education program. All of the PSSTs came from socioeconomically middle-class backgrounds. They were between 21 and 23 years old.

The intervention
The place-based SSI instruction was part of an SSI-oriented elective course called 'Problems Related to Science and Technology'. This course included the definition of SSI, the characteristics of SSI, the role of considering multiple perspectives during negotiating SSI, and the role of informed decision-making and reasoning. A five-week place-based SSI instruction focusing on gold mining was implemented as part of this course. This implementation included three phases: (1) pre-departure instruction, (2) field experience, and (3) post-field instruction. In the *pre-departure stage,* the participants need to get familiar with the context and the controversial issue which will be discussed in the following weeks (Herman et al., 2018, 2020). Two weeks were spent on this phase. During these two weeks, participants had a chance to get familiar with the context. The *field experience* included a presentation by the experts in the mine. Then, the participants visited the open-pit and leaching areas to understand how the gold was extracted from the ore. The visit helped participants to get immersed in how the area was changed. The participants were encouraged to ask multiple questions to the experts about the gold extraction and cyanidation processes. *Post-field instruction* lasted for two weeks: After getting first-hand experience with the gold mining process, the Turkish Foundation for Combating Soil Erosion (TEMA) reports were discussed. TEMA is a major environmental organization that held protests and ongoing legal cases against mines in Türkiye. In addition, some interview transcripts held with local villagers living near the gold mine were discussed. Details of the intervention were presented in Supplementary Material-1.

Data collection tools
Data were collected utilizing a written argumentation form and semi-structured interviews based on the questions on the argumentation form. The study was approved by the University's Science and Engineering Ethical Committee with issue number E.98353. At the beginning of the study, each participant signed an informed consent form and was made aware that they could withdraw at any moment. Every participant received an ID number, ranging from 1 to 15. For example, PSST-1 for the first participant of the study.

Written argumentation form
To assess participants' ability to construct arguments, counter-arguments, rebuttals, and justifications, participants' written responses were collected as pre- and post-tests before and

after place-based SSI instruction. The form included questions to reveal participants' opinions of the establishment of a gold mine. The questions were aligned with the literature exploring participants' written argumentation quality (Atabey & Arslan, 2020; Aziz & Johari, 2023; Zohar & Nemet, 2002). The questions are presented below:

1. Do you want a gold mine to be built and operated where you live? Please explain the reasons for your decision.
2. If you had a friend who disagreed with you about building a gold mine where you live, what reasons would s/he have?
3. How would you convince your friend? Please, explain.

While the first question was asked to elicit participants' ability to make a claim and provide supportive evidence, the second question was asked to determine participants' ability to construct counterargument(s). The last question was asked to determine participants' ability to rebuttal construction.

Interviews

To get more information about their opinions on constructing a gold mine, five participants were invited to the interview session. The same questions in written forms were used to delve into participants' ideas. The interviews were conducted online with each participant after the course was completed as the Higher Education Council postponed face-to-face courses in higher education institutions due to major earthquakes that happened in Kahramanmaras, Türkiye in 2023. Each interview was audio-recorded and transcribed to support the written documents of the participants.

Data analysis

A total of 30 written argumentation forms were collected and analysed by the researcher. If the participant's response only included a claim (e.g., 'I think a gold mining company could be established' or 'I believe it should not be established'), it was not considered an argument but a claim. For a response to be considered as an argument, it should include at least one justification. Students' written responses were first qualitatively analysed and then transferred to numerical form to explore the differences between before and after place-based SSI instruction.

To create an agreement in the coding rubric (see Supplementary Material-2) developed by the researcher, a second researcher who has extensive expertise in SSI and argumentation was invited to the study. She examined the coding rubric prepared by the researcher and approved that it could be used for coding the written responses of participants. One-third of the total documents (10 documents in this case) were independently coded. Then two researchers came together to discuss the documents independently coded. A %100 agreement was ensured between the researchers. Subsequently, the rest of the reports were coded by the researcher.

Ethical considerations

The data were collected in a classroom where the author was both the instructor and the researcher. To overcome researcher/authoritative bias, the author took a series of precautions (some also were used for addressing self-evaluation/self-serving bias): The first precaution was not grading the participants' written reports collected before and after the intervention. This allowed the participants to express themselves without being worried about grading. The second measure was the interviewing of the selected participants after the course was completed. The interviews were conducted online due to the compulsory online education transition as a result of the major earthquakes that happened in 2023. There was again no pressure because the assignments of the course were already completed. Khatun and Haque (2024) also indicated that conducting in-depth interviews with participants can minimize researcher bias. Prolonged involvement and thick description were other measures used for confirming the credibility and validity of the study. The researcher stayed at the research site before and after the intervention to ensure prolonged involvement. Pre-service teachers' written reports and interview transcripts helped to create a rich and thick description of the study for the readers. One last measure was creating a rubric to analyse the written responses of participants by reviewing the previous rubrics (Aziz & Johari, 2023; Sadler & Donnelly, 2006). This rubric was sent to a science education researcher who has expertise in SSI and argumentation and she coded one-third of documents independently by using this rubric. A percentage agreement (inter-coder agreement) was calculated by dividing the number of agreements by the total agreements and disagreements. The analysis rubric was presented as Supplementary Material-2.

To prevent self-evaluation/self-serving bias, several measures were used (conducting in-depth interviews with voluntary participants, inviting an expert to analyse the rubric developed, and calculating inter-coder reliability between the researcher and the science education expert during the analysis).

Findings

The first research question explored how participants' decisions changed after participating in a place-based SSI instruction. Figure 2 shows the frequency of decisions before and after place-based SSI instruction. While eight participants agreed on the idea of constructing and operating a gold mine before instruction, four participants consistently approved its construction and operation. The number of participants who disagreed on its construction and operation was increased (n=4 for pre-instruction and n=11 for post-instruction). Three participants were hesitant about its establishment and operation before instruction. This number was decreased and we did not observe any participant who was hesitant about the establishment of a gold mine after place-based SSI instruction (n=0). These results altogether showed that the place-based SSI instruction notably influenced participants' ideas about the construction and operation of a gold mine where they live. While most approved the idea before place-based SSI instruction, their ideas were mainly changed after the instruction. However, few participants still supported the idea (n=4).

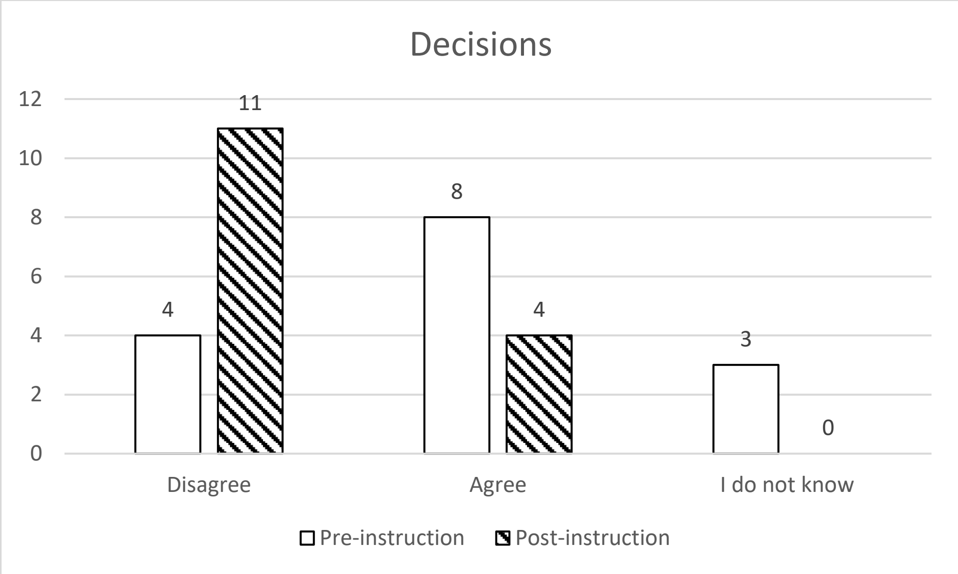

Figure 2. Frequency of participants' responses about the establishment of a gold mine nearby

Encountering different stakeholders (the mining company, TEMA reports, local voices) in place-based SSI instruction helped participants consider different perspectives and even change their decisions after instruction. For instance, PSST-1 was hesitant before instruction. She explained how her decision changed after the instruction:

> *I don't want a gold mine to be established in the city where I live. I knew that cyanide was a harmful substance in the first lesson. Then I thought about how valuable gold is for countries and I was undecided. When I went on the mine field trip, I was very convinced about the establishment of a gold mine after hearing geological engineer's talk about mining. In fact, I thought in my heart, why not extract a mine that contributes so much to the country? I was very surprised to hear that only 8% of cyanide is used in mining and the remaining 92% is used in other areas. I did not think that it was very harmful because of the low percentage. However, when I thought about it later, if cyanide is used in mining, it is easier for it to mix with the soil and get into the groundwater.*

She continued:

> *Again, they told us that they used rainwater and did not use groundwater. I was convinced that they did not consume any extra water resources. When I heard about its contribution to our country and daily income, I wanted a gold mine to be established in my city. I thought positively until I read the TEMA reports, watched interviews with locals, and discussed them with my classmates in the last lessons. I learned about the irreparable consequences of possible accidents, the trees cut down for drilling and roads, the amount of water used... I realized that mines do not leave us any water and that they deplete our water. I learned that not only rainwater is used in mining. Water is essential in our lives. Without water, there is no us, no living, no life.*

This sentiment shows how her ideas about constructing and running a gold mine shifted after place-based SSI instruction. Another participant (PSST-14) explained how his idea was changed after the instruction:

> *I was in favor of establishing a gold mine in the first lesson. Then, when I went to the gold mine. When I saw the work there, the functioning of the mine, and listened what the geological engineer's talk, I supported the establishment of a gold mine more. The reasons why I wanted this are that there are jobs for the people there, it contributes to the country's economy, and the schools, wedding halls, and even our faculty were all established with the money invested by the mining company. However, in the following weeks, I researched this issue thoroughly. I read the reports published by the TEMA foundation, watched videos, looked at the BBC reports, and changed my mind. I decided that if the mining operation would leave such permanent damage and if it would harm people and natural life, I did not want it to be established.*

After exploring the main tendency of establishing a gold mine, our second research question explored how their reasoning quality was changed after place-based SSI instruction. Figure 3 shows how reasoning changed before and after place-based SSI instruction. While participants' responses were coded either level 1 (n=4) or level 2 (n=7) for reasoning quality, only a few instances (n=4) were found for higher levels of reasoning quality. We only saw one participant who was labeled as Level 4 (who provided a rebuttal along with counterarguments and supportive arguments) before place-based SSI instruction. The post-test scores were promising: While most of the responses were coded either level 1 (n=4, 26.7%) or level 2 (n=7, 46.7%) before instruction, we did not detect any level 1 or level 2 types of reasoning in participants' responses after place-based SSI instruction. Figure 3 shows how their reasoning quality changed before and after instruction:

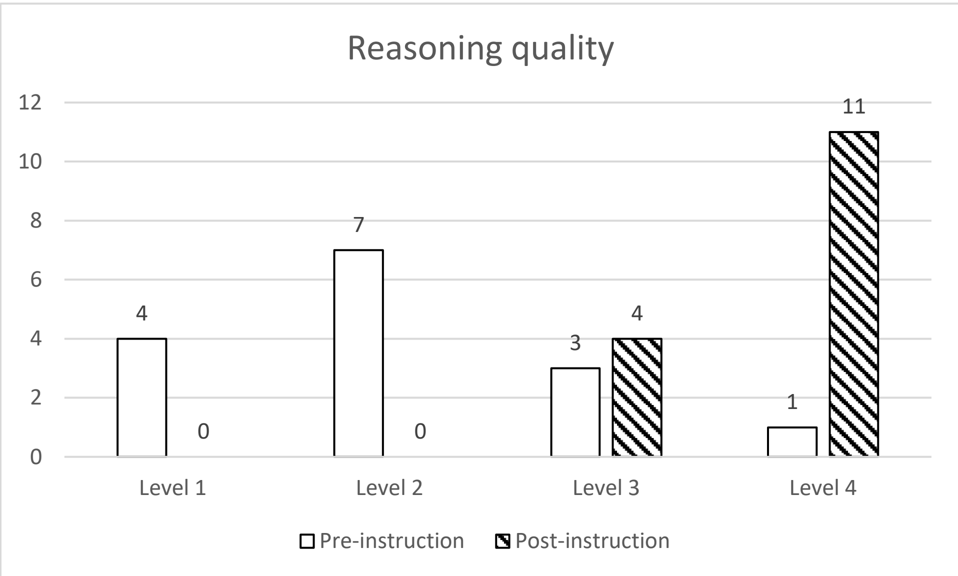

Figure 3. Frequency of the participants' reasoning quality level

With respect to our third research question about argumentation quality, high-level reasoning (levels 3 and 4) was increased after place-based SSI instruction. Four participants were labelled as Level 3 (26.7%) and 11 participants were labelled Level 4 (76.3%) indicating higher reasoning quality. We, then, searched the traces of supportive arguments, counterarguments, rebuttals, and arguments in the participants' responses. The frequency of supportive arguments, counterarguments, rebuttals, and the total number of arguments construed before and after the instruction were summarized in Table 1.

Table 1. The frequency of claims, supportive arguments, counterarguments, rebuttals, and the total number of arguments construed before and after the instruction

Type of argument	Pre-instruction	Post-instruction
Supportive argument	15	37
Counterargument	7	19
Rebuttal	1	11
Total number of arguments	23	67

Table 1 shows how the number of pre-service science teachers' supportive arguments, counterarguments, and rebuttals increased after place-based SSI instruction. Indeed, we observed their supportive arguments including pieces of evidence for supporting their claims were found in both groups who agreed and disagreed about establishing a gold mine.

In a similar vein, we explored how the number of counterarguments and rebuttals changed after place-based SSI instruction. As seen in Table 2, both the number of counterarguments and rebuttals were increased after the instruction. While there was only one participant (PSST-15) who was able to provide a rebuttal for her argument before place-based SSI instruction (labelled as Level 4), there were 11 participants who provided a rebuttal for their arguments after place-based SSI instruction. PSST-15 was an exception since she was part of a project exploring local middle school students' perceptions of gold mining in Usak city. So, she was aware of the many consequences of gold mining even before the place-based SSI instruction.

The effect of place-based SSI instruction became more evident in the individual progression of participants. Both groups (agree and disagree) developed more nuanced supportive arguments along with counterarguments and rebuttals after place-based SSI instruction. Experiencing different stakeholders' views and perspectives (e.g., the villagers, the experts in the mining company, and different reports about gold mining) helped participants to construe more supportive arguments, counterarguments, and rebuttals. Experiencing different stakeholders' views and perspectives (e.g., the villagers, the experts in the mining company, the representative of an environmental protection organization, and different reports about gold mining) helped participants construe more supportive arguments, counter-arguments, and rebuttals.

Discussion, Conclusions, and Suggestions

This study explored how PSSTs' decisions and their reasoning about the construction and operation of a gold mine changed after participating in a place-based SSI instruction. The results revealed that most of the participants (n=11) were against constructing and operating a gold mine after the course. Most of them only had considered the benefits and economic contribution of constructing a gold mine before the course. Participating in the course helped participants to experience different stakeholders' perspectives and this helped them to change their initial views. This finding is compatible with available research reporting that participants changed their initial views after participating in SSI-based instruction. For instance, Atabey and Arslan (2020) reported pre-service teachers' initial thoughts about constructing a nuclear power plant changed after the course. While there was no research directly exploring the change in participants' responses after participating in a place-based SSI instruction, there was evidence showing that participants developed much more nuanced forms of emotive reasoning (e.g., moderated concern and empathetic dissonance) towards the people and environment affected by environmental SSI (Herman et al., 2020). Feeling more empathy towards the people and the environment affected by the SSI could be the main reason why the participants changed their initial views. Indeed, students developed a sense of belonging that helped them to immerse themselves in the environment after participating in an on-campus field-based education (Chapple et al., 2022). Moreover, increased conceptual understanding and informed decision-making skills, greater retention and engagement, and authentic skill development were reported as benefits of these kind of interventions (Chapple et al., 2022; Pedretti, 1999).

The change in participants' opinions about constructing and operating a gold mine in a relatively short time frame (a five-week place-based SSI instruction) might be related to the different types of reflection that PSSTs possess. They might align their responses with their own learning (known as inward focusing) after the course while it was also possible for them to align their reasoning based on the curriculum materials covered during the course (known as outward focusing) as Lebedev and Sharma (2019) indicated. Participants in this study mostly changed their initial views based on the course material provided (outward focusing). Indeed, the sentiment provided by PSST-14 showed how she initially changed her ideas based on the course material. Supporting this finding, Lebedev, Lindstrøm, & Sharma (2020) reported that students modified their answers after watching two physics videos and answering a series of questions regarding videos based on what is covered in the course.

Another significant finding was that participants' argumentation quality was enhanced after participating in the place-based SSI instruction. They were able to generate more supportive arguments for their decisions, counter-arguments, and rebuttals after the course. This finding further was supported by the literature reporting that SSI-based instruction enhanced participants' argumentation quality (Atabey & Arslan, 2020; Aziz & Johari, 2023; Garrecht et al., 2021). Studies (e.g., Garrecht et al., 2021) showed that a carefully designed SSI-based course could assist students in broadening their arguments. Moreover, this course could be beneficial in helping students understand the need to justify their decisions with scientific evidence as stated by Dawson and Carson (2020). Indeed, Dawson and Carson (2020) reported that introducing argumentation in environmental SSI can help improve students' argumentation quality. In some cases, we still observed that participants had difficulty producing counter-arguments and rebuttals. This finding is in line with the literature reporting that producing counter-arguments and rebuttals is cognitively demanding (Aziz & Johari, 2023; Erduran et al., 2004). Still, we did observe an increase in the number of participants who were able to produce counter-arguments and rebuttals after the course. While there was only one participant who was able to construct a rebuttal before the course (she was an exception since she already had been part of a project exploring local middle school students' attitudes towards gold mining), there were eleven participants who were able to present rebuttal for their decisions. Of course, exploring writing expressions as an indicator of the quality of argumentation might be criticized as written expressions might limit participants' real discussion schemes in classes (Nielsen, 2013). In his review, Nielsen (2013) pointed out that Toulmin's (2003) model may have difficulty revealing students' dialogic argumentation characteristics, which are operationalized when students are actively engaged in group discussions by making arguments and critically analysing the arguments made by others. Supporting this, Jafari and Meisert (2021) indicated that the group-based negotiation process activates the use of relative argumentative resources.

Perhaps, a future motive may be analysing the group discussions held during the course for supporting students' written reports. In addition, analysing the components of arguments (i.e., argument, supportive evidence, counter-argument, and rebuttal) during the group negotiation process may be another move to get more in-depth information about the development of participants' argumentation quality.

Limitations of the study and future research

The current study has some limitations that can be addressed in future research: First of all, participants only visited a gold mine and read some policy reports prepared by TEMA in addition to watching interviews with villagers who opposed and supported gold mining during a TV show. While designing future studies, more stakeholders such as representatives of an ecological organization and villagers might be invited to the course or there might be more intensive field trips to the villages near the mine and different stakeholders could also be invited to the course. Even though the visual and written reports were helpful as stated by participants to understand different stakeholders' perspectives, as a researcher I expected a much deeper emotional attachment to the place by the participants. In line with this, the development of participants' emotive reasoning competence and their sense of place can be investigated in future research as Herman et al. (2020) did. Moreover, other aspects such as the development of NOS views (e.g., Avsar Erumit et al., 2023; Herman, 2018; Herman et al., 2023) might be investigated in future research.

Secondly, only participants' written reports were analysed in this study. As discussed in the last part of the discussion, analysing the group discussions might be useful to understand how their reasoning quality changed over the course. Analysing group negotiation while dealing with complex and ill-structured issues like SSI is proposed as an effective way to enhance students' higher-order practices such as critical thinking (Murphy et al., 2018) and quality of reasoning (Jafari & Meisert, 2021).

As a teacher educator, it was also a self-teaching process for myself as well. Designing a place-based SSI instruction including a field trip to a gold mine was kind of challenging as it required different kinds of arrangements by many organizations and many official permissions were needed before conducting such a field trip. Moreover, as the mine was far away from the city, the transportation and organization needed additional attention and care. Still, it was also self-rewarding to experience the place (i.e., to see how the mine changed the place completely and to hear how the experts defended that the mining company will preserve the fertile soil stripped from the surface and how it will be put back when the gold mine is closed 20 years later). Consequently, I am convinced to use mining as a local and intriguing context in my SSI-based teaching.

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