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Promoting preservice teachers' global citizenship and contextualised NOS views through role-play activities integrated into place-based SSI instruction on climate issues

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ABSTRACT

This mixed-methods study explored changes in preservice teachers' (PSTs) understanding of the nature of science (NOS) and their values as global citizens after a place-based intervention augmented with role-play activities concerning climate change. The study further probed how these values manifested during role-play improvisations, where participants adopted the roles of global citizens. Conducted in Turkey with 20 PSTs, it integrated local field trips and role-play scenarios focused on climate change. We led PSTs on excursions to locales such as hydroelectric power plants, enabling interactions with the environment and local individuals, and facilitating role-play on climate-related issues. Within these scenarios, we employed a contextualized NOS approach to foster a comprehensive grasp of the NOS. Data was collected using the 'Character and Values as Global Citizens Assessment' scale, interviews, and video-recorded role-plays. Results indicated that the place-based SSI intervention enhanced PSTs' perspectives on NOS and cultivated their global citizen values. The values demonstrated in role-play improvisations shifted based on the scenarios. Consequent to these findings, the study recommends purposefully designing role-play scenarios targeting specific value domains for enhancement. It recommends involving students in local issues and using NOS-enriched role-play scenarios to bolster their values, and NOS understanding and diversify their argumentative perspectives.

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Introduction

Enhancing learners' functional scientific literacy has long been a goal for science educators and policymakers (Herman, 2018; Herman et al., 2022; Roberts, 2007). To that end, science educators have emphasised the importance of immersing students in an authentic sociocultural context and providing them with avenues to respond to real-world dilemmas pertaining to science, society, and culture (e.g. Zeidler et al., 2019). These educational approaches and their outcomes align closely with the characteristics of the

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Vision II science literacy framework defined by Roberts (2007) and Roberts and Bybee (2014). In recent years, several scholars have proposed the idea of Vision III science literacy, emphasising critical global citizenship, philosophical values, and sustainability (Aikenhead et al., 2007; Rudolph & Horibe, 2016; Sjöström & Eilks, 2018).

Other researchers have emphasised the importance of socio-political engagement in science education (Hodson, 2003), responsible action towards promoting science-based citizenship (Sperling & Bencze, 2010), and collaboration in responding to issues (Roth & Lee, 2004). Community-related activities and contextual relationships with people and locations are vital in fostering students' sense of civic responsibility and authentic learning (Kim et al., 2020).

Furthermore, students may require guidance in assuming others' perspectives when dealing with SSIs (Lee et al., 2013). Moreover, individuals with little or no connection to local places may remain oblivious to these locations' aesthetic, cultural, and political significance, potentially accepting environmental or social degradation (Semken & Freeman, 2008). The context or place is crucial for learners to address and resolve SSIs effectively (Zeidler et al., 2019). Place-based learning experiences can help students feel part of society and inspire them to act for its benefit (Gruenewald, 2003).

Place-based pedagogical approaches, which focus on SSI, can effectively promote students' sense of place and people, enhance their character and values as citizens, and increase their functional scientific literacy (Herman, 2018; Herman et al., 2022; Kim et al., 2020). This pedagogy's roots stretch far, with contextual and culturally relevant teaching being common practices among indigenous peoples. However, science education research has only vocalised this approach within the last two decades (Semken et al., 2017). Only a limited number of studies have examined students' responses when exposed to and taught about SSIs within a real-world, localised context where they interact with individuals directly confronted with these issues (Herman et al., 2021).

Place-based SSI instruction can help students develop a holistic and contextualised understanding of the Nature of Science [NOS] (Herman, 2018). However, few studies have focused on promoting students' NOS views via place-based SSI instruction. Previous research, primarily centred on interventions aimed at improving the NOS views, has mainly utilised decontextualised assessment items, as indicated by Herman (2018). The contexts presented in these assessment items often do not directly correlate with SSI. Like Herman, other researchers have also expressed concerns regarding using decontextualised items for NOS assessments (e.g. Allchin, 2011; Allchin et al., 2014; Hodson, 2009). They argue that decontextualised questions often need more clarity for students and may lead to confusion or misunderstandings. On the other hand, context-embedded questions require specific domain knowledge (Herman, 2018). The same questions in different SSI contexts may elicit varying student responses (Hodson, 2009).

Moreover, explicit connections to more complex dimensions of SSI, such as the contemplation of multiple perspectives, are limited in science education efforts (Herman et al., 2021). When students engage in argumentation, they become receptive to various perspectives based on evidence (Khishfe, 2012) and craft and refine their understanding (Berland & McNeill, 2010). The cognitive activities of forming and reshaping their knowledge might reflect their understanding of scientific knowledge's properties and construction process (Khishfe, 2022). Therefore, promoting argumentation skills is vital to enhancing students' understanding of the NOS. However, as

Capkinoglu et al. (2020) pointed out, experiences with SSI in local places may not be sufficient to create high-quality arguments and make logical judgments about the cases and people. Educators must provide students with tangible experiences in nature and with community members. They must deconstruct these experiences with effective pedagogies afterward to promote their understanding of real-world issues and their connection to science and other disciplines (Herman et al., 2021). We used role-playing for preservice teachers' [PSTs'] engagement with the place, the local issue, and the people to enhance students' reasoning to incorporate multiple perspectives in their arguments (Sagmeister et al., 2021; Mun et al., 2022). Role-play is an effective pedagogical tool to engage students in rich argumentation and reasoning about SSI (Archila, 2017; Belova et al., 2015; Simonneaux, 2001).

Role-playing, one of the drama techniques, allows individuals to act as another person and imagine the perspective of that person in a specific role (Craciun, 2010). Therefore, role-playing can be used in SSI instruction to develop students' understanding of the multiple perspectives of different parties on SSI and their development of values as global citizens (Namdar & Oğuz Namdar, 2021). To our knowledge, no study has used place-based SSI instruction that utilises role-play activities to promote students' NOS understandings, and values as global citizens until today.

This study investigated the changes in the preservice teachers' understanding of the NOS views and their values as global citizens after engaging in place-based instruction regarding local climate issues', their values. We aimed to immerse PSTs in local climate issues with field trips to several places and use role-playing to have PSTs explicitly think of other people's perspectives and then transfer their understanding of local issues to global climate issues. We also explicitly used contextualised NOS in role-playing scenarios to promote PSTs' holistic and contextualised understanding of NOS. In line with these purposes, the research questions of this study are;

1. How are the values of preservice teachers, as global citizens**,** changed through place-based SSI instruction that utilises role-play activities related to local climate issues?
2. How are the contextualised NOS views of preservice teachers changed through place-based SSI instruction that utilises role-play activities related to local climate issues?
3. How frequently do PSTs enact values during their weekly role-plays?

Literature review

SSI as a context for NOS instruction

The definition of NOS has been a subject of contention in science education literature (Herman et al., 2013). For example, Lederman (2007) proposed NOS tenets applicable across various scientific disciplines. Others have argued for a 'family resemblance approach' to NOS, which emphasises variations while considering commonalities among disciplines (Irzik & Nola, 2011; Erduran & Dagher, 2014). Meanwhile, some have argued that a rigid notion of NOS is futile, as science is highly nuanced and context-dependent (Rudolph, 2000).

Different contexts have been employed for NOS integration, including historical and contemporary scientific examples (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2014;

Akerson et al., 2019a, 2019b, 2019c; Avsar Erumit & Akerson, 2022; García-Carmona & Acevedo-Díaz, 2017), inquiry-based activities (e.g. Avsar Erumit et al., 2019; Khishfe & Abd-El-Khalick, 2002), and socio-scientific issues (Avsar Erumit & Yuksel, 2023; Eastwood et al., 2012; Khishfe, 2022).

The SSI instruction has been promoted as a suitable context to improve students' conceptualizations of NOS as these topics are connected to science and society, illuminating the values, presumptions, and notions emphasised by NOS (Herman et al., 2019; Khishfe & Lederman, 2006). Several studies have investigated the impact of SSI instruction on enhancing students' NOS understanding. Sadler et al. (2004) investigated the relationship between students' conceptualizations of NOS and their positions on global warming. They found a relationship between the students' appraisal of the social embeddedness of science and their decision on the issue. Eastwood et al. (2012) compared the effects of explicit NOS education given in SSI- and content-driven contexts on secondary students' views of NOS. Despite considerable NOS understanding improvements in both groups, those exposed to the SSI environment utilised examples to describe social and cultural NOS components. Khishfe (2022) investigated the impact of explicit NOS instruction in the SSI versus the scientific context and found that students' NOS understanding and argumentation skills improved more in the SSI context than in the scientific context.

Place-based SSI as a context for NOS instruction. Utilising SSI as a context for teaching NOS is a widespread approach that demonstrates efficacy for enhancing students' NOS understanding to some extent. However, the existing literature is limited to fully engaging students in authentic SSI experiences and needs more contextual alignment between SSI and NOS (Herman, 2018). One potential approach that may promote such a connection is the place-based approach.

Only a few studies have examined the benefits of place-based SSI instruction on developing students' understanding of NOS. Herman (2018) showed that place-based SSI instruction focusing on the wolf reintroduction in Yellowstone National Park improved secondary students' views on contextualised NOS aspects, including the role of science and technology in solving environmental issues and cultural influences on environmental science. Herman et al. (2019) found that students' descriptions of the trophic cascade became more complex and accurate due to place-based SSI instruction in another study on the same SSI. The results also showed a relationship between students' contextualised NOS opinions and the depth of their post-explanations on the trophic cascade.

Character and values as global citizens in the context of SSI

Character and values are promoted as the essential factors that support an individual's decision-making about action and responsibility towards global SSIs (Lee et al., 2012), fostering responsible citizenship. Researchers pay specific attention to character and values in the context of SSI, as the decisions about these issues affect the well-being of society (Karpudewan & Chan, 2020). Three elements of character and values – ecological worldview, social and moral compassion, and socioscientific accountability – serve as focal point to cultivate the decision-making skills of responsible global citizens.

Ecological worldview refers to understanding and beliefs that humans are an integral part of the ecosystem and that all entities in nature are interconnected (Bowers, 1999;

Choi et al., 2011). Being conscious about their place in the ecosystem, students can value, care about, and take responsibility for the environment (Lee et al., 2012). This understanding can also prompt them reflect on their actions and their potential effects on the environment and others. In addition to the interconnectedness of the environmental components, ecological worldview also refers to the understanding of coexistence with others for a sustainable future.

Social and moral compassion includes three sub-dimensions: ethical concerns, perspective taking, and moral and ethical sensitivity. Developing character and values towards socioscientific issues requires individuals to empathise with others (Ruiz & Vallejos, 1999). Those with high values respect and have empathic concerns towards others who are affected by the issues throughout the world, by sympathising with them (Choi et al., 2011; Lee et al., 2012; Wilson, 2011). Social and moral compassion also includes consideration of different and competing perspectives on the issue through debate or discussion (Fowler et al., 2009) Furthermore, in order to take moral decisions, individuals should possess moral and ethical sensitivity. This sensitivity helps individuals be aware of the moral and ethical aspects and consequences associated with the issues when making decisions (Bebeau et al., 1999; Clarkeburn, 2002).

Socioscientific accountability refers to the individuals' sense of personal responsibility regarding SSIs (Lee et al., 2013). People who feel responsible about the issues may also feel personal connections with the issues and could act towards making an impact and solving them (Hudson, 1999). Individuals should also consider how their responsible decision could have an impact on the society regarding SSIs (Powell et al., 2021). Furthermore, socioscientific accountability also refers to individuals' willingness to act on issues. researchers promote community-based socio-political action as a means to solve these issues (Roth, 2003; Roth & Lee, 2004).

The role of SSI in promoting character and values

To foster pro-environmental behaviours, it is vital to engage students in authentic learning environments, thereby developing a sense of place and an attachment to nature (Brehm et al., 2006; Kurdyavtsev et al., 2012; Scannell & Gifford, 2010). People form personal and emotional attachments to places (Manzo & Devine-Wright, 2013), making a sense of place crucial for connecting human relationships with their environments (Semken & Freeman, 2008). In science education, connecting local and global contexts for meaningful learning is still a topic of debate. Some researchers argue that while learning global issues, the local underpinnings should not be overlooked, as this can cause students to feel disconnected from the topics (Montgomery & Fernández-Cárdenas, 2018). As climate change affects humans at both local and global scales and accountability can be the first step towards developing pro-environmental behaviour, enhancing the sense of place through role-play activities in the local context can be leveraged to inform decision-making in a global context.

A handful of previous empirical studies have reported conflicting results across different age groups regarding character and values. For instance, Lee et al. (2013) found that SSI-based instruction increased social and moral compassion among high school students. Yet, these students struggled to demonstrate empathy towards others and be willing to act on the issues. Similarly, Kim et al. (2020) demonstrated that

community-based SSI programmes significantly influenced the character and values of fifth-grade students. On the other hand, Powell et al. (2021) observed that teaching about animal cloning significantly affected middle school students' social and moral compassion and socio-scientific accountability but had less impact on their ecological worldview. Several studies have also been conducted with Turkish PSTs. In a study involving 201 PSTs, Öztürk (2019) reported that the participants scored highest on the empathic concerns dimension and lowest on the responsibility dimension of the CVGCA questionnaire. Conversely, Uzel (2020) found that SSI-based teaching improved the character and values of Turkish pre-service biology teachers across all dimensions.

SSI and role-play

Drama techniques in science education are commonly called 'role-plays' (Dorion, 2009). Unlike presentational drama, which primarily focuses on communicating the ideas and processes of scientific phenomena or concepts, experiential drama emphasises the importance of immersive experience and the engagement of affective domains such as attitudes, values, character traits, and emotions (Ødegaard, 2003). This experiential drama can be integrated into science classrooms through role-playing activities. Role-playing offers several benefits, including enhanced conceptual understanding (Maharaj-Sharma, 2008), improved critical thinking (Phillips, 2013), and the promotion of discourse and critique through argumentation (Agell et al., 2015; Simonneaux, 2001).

As a drama technique, role-play provides opportunities for students to enact roles in real-life situations, engaging their affective domains (Agell et al., 2015). In addition, role-playing increases the likelihood of students understanding others' perspectives and encourages multifaceted considerations (Kolstø, 2006). Such skills are crucial for decision-making, identity exploration, and empathy development (Dorion, 2009; Duveen & Solomon, 1994; Ødegaard, 2003).

Through role-playing, students can learn about SSI's moral and ethical principles and their place in the world (McSharry & Jones, 2000). Studies in the context of SSI often incorporate role-playing into debates (e.g. Agell et al., 2015; Bosser & Lindahl, 2020). However, different instructional techniques are also incorporated in role-plays when dealing with an SSI, such as employing role cards without engaging students in impersonation (Agell et al., 2015), simulating court trials (Duveen & Solomon, 1994), and reenacting scenes from a play (Archila, 2017). In particular, in the context of teaching climate change, role-plays help students explore and learn about the NOS (Baskerville & Anderson, 2021), build a sense of urgency to mitigate the effects of greenhouse gas emissions (Hensel et al., 2022), and improve their argumentation skills (Dawson & Carson, 2020).

In this study, we structured role-playing into three stages, reflecting the drama instruction methodology proposed by Adıgüzel (2015): preparation (or warming up), improvisation, and evaluation. PSTs were cognitively prepared for role-play during the first step through short lectures, discussions, and interactions with experts and community members. The second step was dedicated to enacting the role-plays, employing various techniques such as dyads, whole-group role-plays, and small-group role-plays. The final step involved evaluation and reflection, during which students reflected upon the roles and arguments initiated within their groups and assessed the impact of place-based learning opportunities on their reasoning about climate change.

For example, we organised a field trip to a hydroelectric power plant station (HEPP) in the fifth week. At the station, engineers and specialists outlined the energy production process and discussed the technologies they employed. They also detailed their measures to minimise the impact on fish populations and riverside plant life. Following this, a specialist escorted us to a higher elevation, where the water collection began. Students had the opportunity to interact with workers and engineers at the station, asking various questions. Afterward, we divided the students into two large groups. We presented them with a scenario: one group would argue for hydroelectric power plants, while the other would argue against them. Each group incorporated several roles that mirrored those of local stakeholders. Some students represented locals concerned about the regional economy; one role-played an energy engineer, while another was a minister of energy and natural resources, providing a political perspective. Other roles included an activist from a non-governmental environmental organisation, a village headman offering a cultural viewpoint, and a resident suffering health issues related to the power plant. One participant focused on the impact on animal life, evaluating the situation from moral and ethical perspectives. The scenarios from other weeks are presented in Appendix A.

Design and methods

We used a quasi-experimental convergent mixed methods design (Creswell & Plano Clark, 2018) to investigate the aforementioned research questions. Using qualitative and quantitative tools and combining the two, we sought to understand PSTs' values as global citizens on local and global climate issues. The purpose of using mixed methods is to compile multiple ways of knowing to better understand the phenomenon of preservice teachers' enactment of values about local and global socioscientific issues. This approach allowed us to capture different facets of the phenomenon; including the change in their values, enactment of values during role-plays, and their contextualised NOS views in pre- and post-intervention stages (Greene, 2007; Greene et al., 2001).

Context and participants

This study was conducted at a mid-sized public university in Rize, a city in the northeastern region of Turkey. Rize, characterised by a subtropical climate, is a coastal city nestled amidst the Kackar Mountains and accompanied by a steep hillside that trails along the coastal strip. The city boasts a high tourism profile, owing mainly to its picturesque highlands and plateaus, and is renowned for tea farming. Several locally SSIs in the region, including hydroelectric power plants, organic tea production, a sea embankment for the new international airport, and the Greenway project – which seeks to connect many plateaus in the Black Sea region through highway construction – attract substantial national attention.

In Turkey, all middle school science teacher education programmes adhere to a standardised curriculum prescribed by the Higher Education Research Council of Turkey. This curriculum includes specific courses, overall course content, and credit allocations. Notably, the curriculum does not require climate change education or drama courses. While climate change is frequently taught as part of an earth science course, drama is only offered as an elective. In contrast, a course on the nature of science, is a required

component in the final semester of the programme. Furthermore, at the eighth-grade level, a mere 8 h are devoted to climate change topics within the national middle school science curriculum.

The participants of this study consisted of 20 pre-service middle school science teachers – two males and 18 females. This gender distribution is typical for Turkish science education programmes. These participants, who were sophomores, juniors, and seniors, were enrolled in an elective course about applying science in technology. One student was an international attendee from Central Asia, while the rest hailed from different regions of Turkey, with a majority from the Northeast Black Sea region. None of the students have previously taken the nature of science course. The first author was the course instructor. The second author was a science educator who participated in developing data collection tools and the data analysis process. The third author, an elementary educator specialising in drama in education, contributed to the study by developing role-play scenarios.

Data collection

We used the 'Character and Values as Global Citizens Assessment' [CVGCA] scale as the quantitative data source, first developed and validated by Lee et al. (2013) and adopted by Karışan and Yılmaz-Tüzün (2017) in Turkish. The Cronbach alpha of the Turkish scale was calculated as .832. The scale was developed to measure three sub-dimensions of values as global citizens on SSIs that include ecological worldview (inter-connectedness and sustainable development), social and moral compassion (moral and ethical sensitivity, perspective-taking, empathic concerns), and socioscientific accountability (feeling of responsibility and willingness to act). The CVGCA consisted of 20 items with a 5-point Likert-type scale. (e.g. If human beings manipulate and change nature (or life) for their benefits, it might cause devastating results), empathic concern (e.g. I feel sorry for those who are suffering (ex: from famine or incurable diseases) without enjoying benefits of life science technology), moral and ethical sensitivity (e.g. I can predict the social, ethical and moral impacts that the development in life science might cause), and willingness to act (e.g. I believe global cooperation and supports from various nations are required to solve social issues related to life science). This is a widely accepted and used approach to identify character and values both in the international and Turkish contexts (Gürleyen & Öztürk, 2022; Öztürk, 2019; Uzel, 2020).

The adopted version of the CVGCA consisted of 13 items and four factors, including sustainable development. During the validation process for the Turkish version of the test, the authors removed Item 1, Item 2, Item 9, Item 10, Item 12, Item 15, and Item 20 after factor analysis because these items did not load onto any factor. Initially, items 1, 2, and 3 were employed to assess the 'interconnectedness' sub-dimension within the ecological worldview component, yet only item 3 was successful in this regard. Likewise, the 'perspective-taking' factor, initially examined using items 9 and 10, failed to associate these items with any factor. Item 15 also did not load onto any factor. Consequently, the Turkish version does not include the sub-dimensions of interconnectedness, perspective-taking, and a sense of responsibility.

As the qualitative portion of the study, we conducted pre- and post-one-on-one semi-structured interviews to understand; (1) PSTs' contextualised understanding of NOS on

climate issues and (2) their feelings of responsibility and willingness to act on local and global climate issues. The first and second authors developed the interview questions, sent them to two other science educators, and revised them based on their recommendations.

The contextualised NOS aspects included; the tentativeness of scientists' explanations of climate issues, empirical evidence used to explain climate change, scientists' subjectivity in their explanations of climate change, imagination and creativity used to develop models and explain climate issues, scientific methods used for climate issues, general structure and aim of experiments in science, and social and cultural impacts on scientists' explanations about climate issues. Sample questions included such as 'How sure science can be that the Earth is warming to dangerously high levels?', 'What do scientist use when they explain climate issues orally or in a written form' (if the student says 'experiment results' to the previous question) 'Is manipulated experiments always necessary for the advancement of science?' and 'Do climate scientist do experiments?' 'What do scientists use when they develop a model to represent climate issues?', 'How sure do you think scientists are about climate change that they predict would happen in the future?', 'How likely do you think these predictions will take place?' 'Do you think all scientists agree that our globe is warming and human impacts on the environment expedite that warming?', '(if answered No to the previous question) Why do you think scientists can come up with different explanations even when they look at the same data?', 'Do you think their explanation can change based on their culture?'

In the second portion of the interview, we developed questions to measure students' feelings of responsibility and willingness to act to help tackle climate issues. The questions included;

> Do you personally help to tackle the climate issues? How much would you rate your contribution if you were to rate it out of 10? What would be the similarities or differences in the impacts of individuals living in different parts of the world? What responsibilities do you think people might have individually to tackle the impacts of climate issues? What responsibilities do you think people might have locally/globally to mitigate climate-issue impacts? If there was an action to help tackle climate issues, would you support this action even when you compromise your comfort? Would you prefer to use clean energy sources even when using it increases the amount you pay for your energy bills?,
>
> How do you think we may reduce our carbon footprint? Have you been doing anything to reduce your carbon footprint?, How willing do you feel to change your daily habits and act individually to reduce the impacts of the climate crisis? How much would you rate your willingness if you were to rate out of 10? How willing do you feel to act locally in your local area to reduce the impacts of the climate crisis?,
>
> How much would you rate your willingness to act locally if you were to rate out of 10? What would you say if you were to write a letter to local authorities about local environmental issues in the Eastern Black Sea region? How willing do you feel to act globally to reduce the impacts of climate change?,
>
> How much would you rate your willingness to act globally if you were to rate out of 10? What would you say if you were to write a letter to international authorities, such as the United Nations, with global environmental issues that cause climate change? If you were to start a social action to fight against the climate crisis, what would you do?

Individual interviews lasted around 45 min each. We audio and video recorded students' weekly role-play improvisations to analyze value statements utilised by students.

Our recording started when the first student initiated the role play and continued until the group decided on the issue.

Place-based intervention

The initial seven weeks of the course were conducted on the university campus, during which students were immersed in various SSIs. This was followed by the place-based experience segment, which spanned the next six weeks. Each week, we organised field trips to various locations within and surrounding the town, except for the first intervention week, which took place on the university campus. Figure 1 below illustrates the programme's progression, detailing the approach followed for each place-based event.

As depicted in Figure 1, our first undertaking was a field trip to the designated location. Aside from our trips to the beach and university campus, we organised visits to various institutions where PSTs engaged in spontaneous discussions with experts, employees, and other community members. We handed out informational materials containing scientific details about the subject matter discussed during these field visits. Following this, we assigned the PSTs a role-play scenario and allowed ample time for preparation. PSTs then enacted their roles using the available facilities and supplies. Subsequently, we discussed the issue at hand, during which PSTs shared their perspectives. Additionally, we deliberated on how the issue might be interpreted in various ways, depending on the viewpoint. Table 1 below outlines the place-based role-play events. For further information on the coverage of weekly place-based activities, please refer to Appendix A.

Data analysis

We used Paired Samples t-test and Wilcoxon Rank to analyze pre- and post-CVGCA scores before and after the place-based SSI intervention. Also, we used Cohen's d to show the effect size.

The first and the second authors analysed the interviews separately. For the contextualised NOS portions of the interview, we utilised Lederman et al. (2002) categorisation of 'naïve', 'adequate', and 'informed'. Before the analysis, we have determined illustrative examples of how PSTs with such views could respond to a particular question. For example, when we analysed PSTs' views on 'Empirical evidence used to explain climate issues', we used questions like 'How sure science can be that the Earth is warming to dangerously high levels?' PSTs with an informed view on this aspect could respond, 'Scientists collect various data such as the temperature and precipitation records in the atmosphere. They collect such evidence daily, monthly, and annually and compare the results to the past. Based on all evidence they collect and their observations, they make inferences that climate change is happening. Based on the trend that their graphical results show, they can make predictions', whereas a student with a more naïve view could respond, 'They may explain based on the experiments they make'.

For the PSTs' socioscientific accountability on climate issues portions of the interview, we compared and showed graphs of PSTs' answers on pre- and post-interviews that involved numeric. An example of such a question is, '*How much would you rate your willingness to act to solve issues in your local region if you were to rate out of 10?*' For the rest of

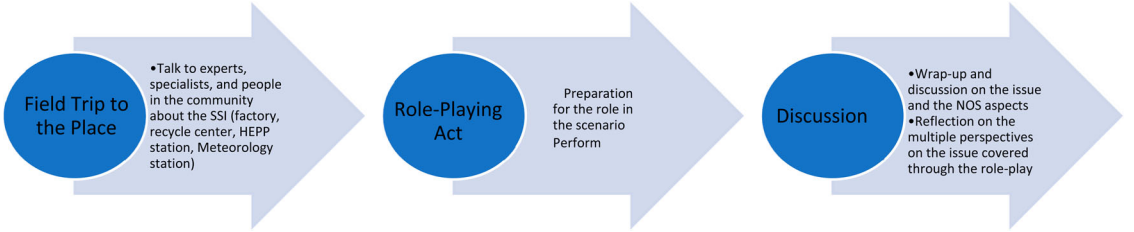


Figure 1. Place-based event progression.

Table 1. Place-based role-play SSI events.

Place	Topic	Role-play scenario
University Campus	Our daily habits and carbon footprints	Students at eco-friendly vs. non-eco-friendly campuses
Tea factory	Industrial wastes	Do we need another factory in our region?
Beach	Plastics in seas and oceans	Municipal president's decision to close beach trails for hikers and visitors
Recycling centre	Recycling process	Whether to recycle or not?
HEPP station	Renewable energies (hydroelectric)	Is HEPP really clean energy? -support or not to support HEPP in local region
Meteorology station	Do we trust scientists' future predictions about global warming	Is global warming happening?

the questions, we compared each PST's pre- and post-response and coded the themes they commonly used regarding feeling responsibility and willingness to act.

We calculated the frequency of value statements PSTs used during the role-play acts to answer the third research question. First, the first and second authors read the transcripts and highlighted 'turns' separately in which PSTs used value statements. Some turns included more than one value statement, and we reported multiple value domains in the reporting. Then, we came together in a meeting and compared the selected three video recordings. As the discrepancies were calculated to be less than 5%, the rest of the group role-play data were split between the first and second authors to identify the relevant turns.

Results

1. Changes in Preservice Teachers' Values concerning Climate Change Issues through Place-Based SSI Instruction

The quantitative results from the statistical analysis confirmed that place-based SSI instruction, complemented with role-play activities, significantly enhanced PSTs' values as global citizens. The Shapiro–Wilk test was used to determine whether the data were normally distributed, as illustrated in Table 2 below. Specifically, PSTs demonstrated statistically significant improvements in the overall CVGCA score ($t = 3.774$; $p < .05$), 'sustainable development' ($t = 2.454$; $p < .05$), and 'willingness to act ($t = 2.398$; p .05), as presented in Table 3 below. However, there was no statistically significant improvement in the dimensions of 'social and moral compassion' ($t = -0.384$; $p = 0.705$) and 'empathic concern' ($t = 1.453$; $p = 0.163$).

Echoing the findings from the CVGCA scale, the responses from PSTs during interviews questions also indicated a significant shift in their values as global citizens. Notably,

Table 2. Normality test (Shapiro-Wilk).

		W	*p*
Sustainable development pretest	Sustainable development posttest	0.858	0.007
Social and moral compassion pretest	Social and moral compassion posttest	0.850	0.005
Emphatic concerns pretest	Emphatic concerns posttest	0.957	0.495
Willingness to act pretest	Willingness to act posttest	0.926	0.128
Character and values as global citizens pretest	Character and values as global citizens posttest	0.954	0.424

Note. A low *p*-value suggests a violation of the assumption of normality.

Table 3. Paired-sample t-test (two-tailed) and descriptive statistics for the CVGCA scale.

		Mean	SD	SEM	*t*	*p*	Cohen's d
Overall CVGCA	Post	55.35	3.313	0.741	3.774	0.001	0.8439
	Pre	52.60	4.031	0.901			
Sustainable development	Post	18.60	0.940	0.210	2.454	0.024	0.5487
	Pre	17.65	1.872	0.418			
Social and moral compassion	Post	7.50	1.192	0.267	−0,384	0.705	−0.0858
	Pre	7.60	0.883	0.197			
Empathic concern	Post	12.90	1.483	0.332	1.453	0.163	0.3249
	Pre	12.30	1.559	0.349			
Willingness to act	Post	16.50	2.306	0.516	2.398	0.027	0.5362
	Pre	15.05	2.544	0.569			

when we asked about their personal contributions in addressing climate change, The PSTs' numerical ratings demonstrated a significant increase post-intervention, as indicated in Figure 2 below.

In the initial interview, 13 PSTs reported feeling responsible and contributing to mitigating the impacts of climate change. However, this number rose to 19 in the follow-up interview, signifying a heightened sense of personal accountability. Moreover, there was a marked increase in the PSTs' willingness to take action on climate change, both individually and collectively.

Figures 3–5 showcase the comparative pre- and post-intervention ratings of their willingness to take action at the individual, local, and global levels. As the tables indicate, there was a general trend of increased initiative among the PSTs at all three levels. On an individual scale, the mean score rose from 6.9 (pre-intervention) to 8.5 (post-intervention). Similarly, on a local level, the mean score increased from 7.3 to 8.3, while the global action willingness score rose modestly from 7.1 to 7.6.

The verbal responses from PSTs provided further evidence of the intervention's impact on their sense of responsibility. In the initial interview, half the PSTs could not define 'carbon footprint'. However, in the follow-up interview, all PSTs could define it and provide concrete examples of how they had personally reduced their carbon

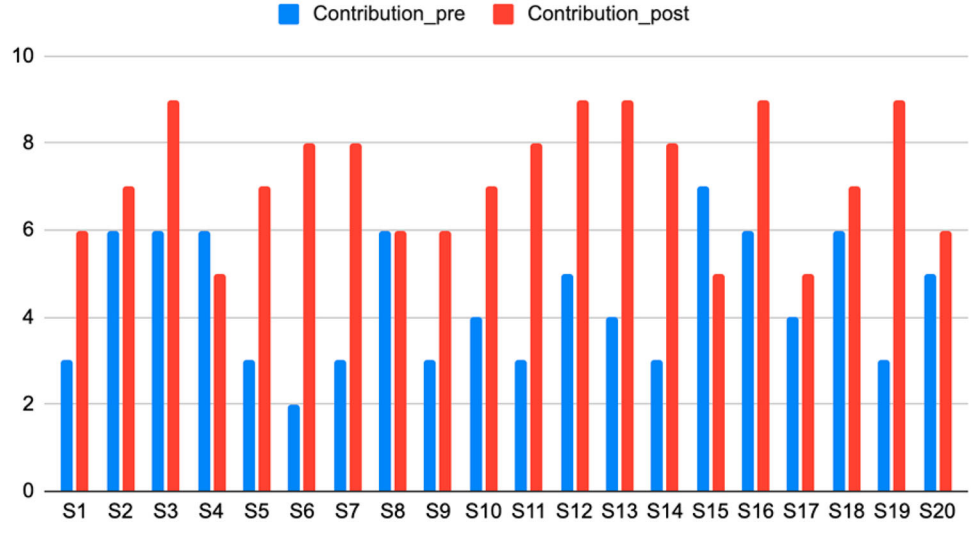


Figure 2. Personal contribution in combating climate change.

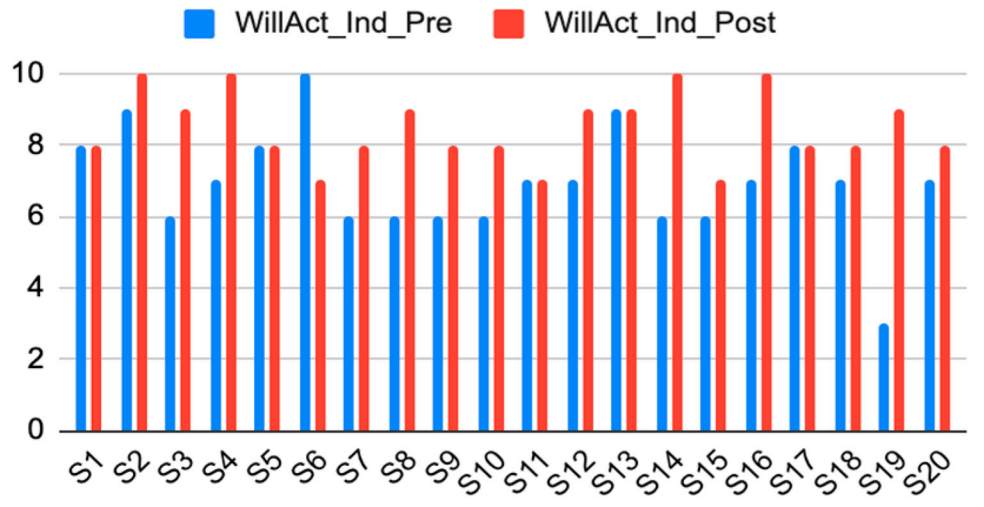


Figure 3. Willingness to take action at individual level.

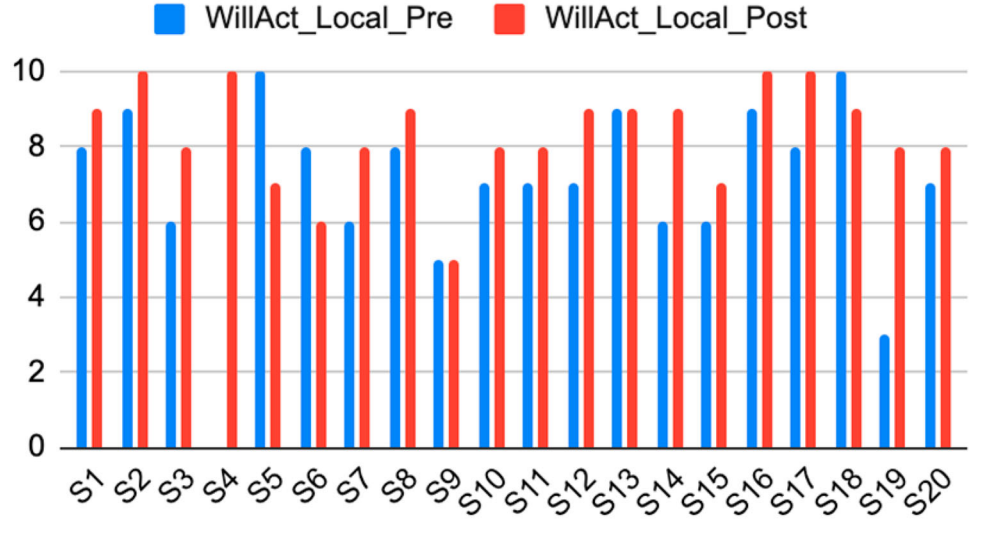


Figure 4. Willingness to take action at local level.

footprints. In response to a question about their contributions to mitigating climate change, the PSTs' initial answers were rather general. They included stereotypical responses such as 'I do not use much perfume, and I use public transportation' (S2, pre-interview) or 'I do not contribute' (P3, pre-interview). However, their post-interview responses revealed a noticeable evolution in their understanding and actions. They were able to articulate specific examples demonstrating their contributions to reducing the impact of climate change.

> 'After taking your class, I felt more responsible and contributed more. I try to recycle, stop using disposables, walk small distances, and carry my water in reusable glass bottles (P2, post-interview)'.

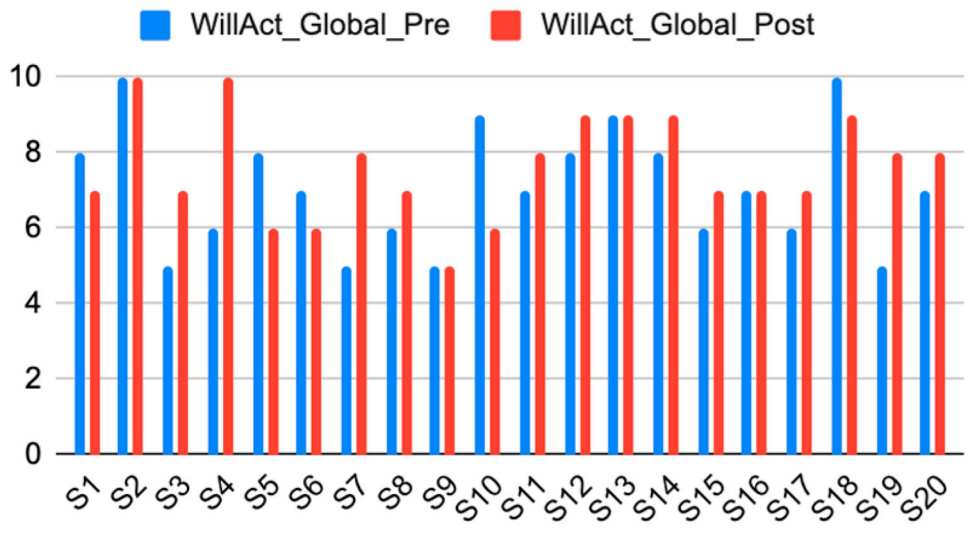


Figure 5. Willingness to take action at global level.

> 'I realized that many things we are doing impact climate change. Now, I turn off the lights when I do not need them; I am careful about water consumption. Almost everything in the supermarket is packaged in glass or plastic. I buy local foods and consume less food in packages. I buy in glass and do not throw them away to store dry foods or use them to make jams. I donate the clothes I do not need anymore' (P3, post-interview).

During the initial interview, many PSTs needed further education on how individuals worldwide could differently impact climate issues. In the post-interview, however, they exhibited greater awareness of how cultural habits, geographical conditions, and countries' economies can have varying impacts on the climate. For example, S1 did not provide a specific example in the initial interview. However, in the post-interview, she used more concrete examples, as illustrated in the following excerpt:

> 'Using technology or fossil fuels might be similar anywhere. However, the economic conditions in different countries might change whether to use public transportation or individual cars, and the intensity of emissions might change. For example, we are not a developed country, so public transportation is shared here. People in more developed countries have cars. However, they may recycle more while we recycle less' (P1, post-interview).

One international PST, who had firsthand experience with the contextual differences in various parts of the world, was able to provide more concrete examples from multiple countries. Her responses evolved from the initial to the final interview. For instance, in the initial interview, she stated:

> 'People use fewer technological devices in some villages like mine. However, I overuse electronic devices here' (P7, pre-interview).

> 'People's impacts may depend on socio-economic conditions. We use natural gas for heating in my hometown. Because we have natural gas reserves, we pay small amounts once or twice a year. Since we do not pay for it, we overuse it. We open the windows in winter while the heater is on. I now see how energy is vital for us. When I visit my family, I tell them how valuable energy is. My family lives in a village where they consume less. However, I order

> food online here. So, in terms of living conditions, people consume a lot here. Before taking this class, I used to buy coffee from famous coffee shops and thought I was cool when I carried this disposable cup. However, I now try to consume less (P7, post-interview)'.

The PSTs' responses to the questions gauging their willingness to act differed depending on the phrasing. When we asked, 'If there was an action to reduce climate change, would you support this action even when you compromised your comfort?' eighteen out of 20 PSTs responded affirmatively in the initial and follow-up interviews. However, when we asked, 'Would you prefer to use clean energy sources even when using them increases the amount you pay for your energy bills?' the affirmative responses were fewer. In the initial interview, eleven PSTs said 'yes'. This number increased to fifteen in the follow-up interview. Those who responded negatively cited economic conditions as the reason. For example, the stated:

> 'I would support it if the economic conditions were better in our country. Right now, even 250 Turkish liras for the bills are so expensive. So, it depends on the financial condition' (P19, post-interview).

The evolution in the pre-service teachers' (PSTs) responses was also evident in the content of the letters they were asked to write to local and international authorities. For instance, P20's initial response was generic: 'I would talk about the environmental problems' (pre-interview). However, her response in the post-interview was more detailed, as she elaborated:

> I would tell them to increase the number of HEPP stations to increase the production of renewable energy and contribute to the region's economy (P20, post-interview).

In the initial interview, a PST's response to what she would include in a letter to the United Nations was quite uncertain: 'I would talk about such problems, but I do not know what to write' (P3, pre-interview). However, in the final interview, her response evolved, and she articulated:

> 'I would compile data about extreme weather events happening recently around the globe, such as floods and forest fires because of climate change, and talk about how people's habits in one region influence other people elsewhere'. I would suggest they do a project that people from around the world can contribute (P3, post-interview)'.

1. Changes in Preservice Teachers' Contextualised NOS Views through Place-Based SSI Instruction

PSTs' responses to pre- and post-interview questions concerning aspects of the NOS demonstrated improvements in each aspect we concentrated on in our study. As depicted in Table 4 below, PSTs' comprehension saw the most significant advancements in 'Tentativeness of scientists' explanations of and climate issues', 'Empirical evidence used to explain climate issues', and 'Scientists' subjectivity in their explanations of climate change'. There was a modest improvement in PSTs' understanding of the 'General structure and aim of experiments in science'. However, some PSTs maintained in their post-interview responses that experiments in are necessary in all fields of science.

An example of an improvement in a PST's ability to use evidence to explain issues can be seen in the responses of PST 4. During the pre-interview, when asked 'How sure

Table 4. PSTs' contextualised NOS understandings.

	Naive		Adequate		Informed	
Contextualised NOS aspects and climate issues	Pre test	Post test	Pre test	Post test	Pre test	Post test
Tentativeness of scientists' explanations of climate change	7	0	13	0	0	20
Empirical evidence used to explain climate change	1	0	18	0	1	20
Scientists' subjectivity in their explanations of climate change	8	0	11	1	1	19
Imagination and creativity used to develop models and explain climate change	10	0	7	5	3	15
Scientific methods used for climate issues (do we need manipulated experiments to explain climate change?)	17	0	3	9	0	11
General structure and aim of experiments in science	19	3	1	8	0	9
Social and cultural impacts on scientists' explanations about climate change	10	0	7	1	3	19

scientists can be that the Earth is warming to dangerously high levels?' she responded, 'Based on experiments they make'. In the post-interview, however, her understanding seemed more nuanced:

> We observed at the meteorology station that scientists have the technology to record momentary data on temperature and humidity. They record all of this data. Upon comparing recent data to historical data, they realized that the warming was accelerating (P4, post-interview).

We asked, 'What do scientists use when they develop a model to represent climate change?' In the pre-interview, *only* three PSTs showed an informed view, whereas 15 PSTs did so post-interview. Furthermore, some PSTs drew on their place-based experiences as examples, stating that scientists used data, as well as their creativity and imagination, to develop models and explain climate change. One such response was,

> 'When we collected waste from the beach, we weighed it and displayed the results in a bar graph. Scientists gather similar data types, analyze them, and use symbolic models to make them more concrete. They can use a graphical model, like we did, and use their imagination to best visualize the phenomenon' (P17, post-interview).

We asked the following questions to assess PST' views on the scientific method: 'What do scientists use when they explain climate issues orally or in written form?' (If the student said 'experiment results'), 'Are manipulated experiments always necessary for the advancement of science?' and 'Do climate scientists do experiments?'. We observed minimal improvement in this aspect; nevertheless, there was still some progress. Nine PSTs exhibited an informed view in the post-interview, which was a significant improvement considering that none were at this level during the pre-interview. For instance, one PST stated, 'I think climate scientists do experiments and explain climate change' (P18, pre-interview).

> 'Manipulated experiments are not always sufficient in science'. Observable phenomena provide insights into the processes of nature and evolution, and we cannot manipulate such events in a laboratory setting. 'Experiments are necessary in science; however, climate scientists typically collect data through observations and use tools like satellites for data analysis' (P18, post-interview).

Depending on the role-play topic, PSTs could more successfully incorporate NOS aspects in some weeks than others. In the first five weeks, PSTs' remarks leaned more toward

value statements than NOS in the initial five weeks. However, in the meteorology station, PSTs had the opportunity to observe a variety of scientific tools that recorded instantaneous data. This experience led them to articulate various NOS aspects during role-play more frequently than in previous weeks. The following excerpt serves as an example of NOS statements utilised by PSTs at the meteorology station. Underlined in the dialogue are the NOS aspects, including the use of empirical evidence to explain climate change, the tentativeness of scientists' explanations of climate change, the role of imagination and creativity in developing models and describing climate change, and the scientific methods used to address climate issues;

> Student 1: The weather forecast showed it would be rainy today, so I wore a warm coat this morning. But now, it is sunny. How can I trust these weather forecasts?
>
> Student 2: Who creates the weather forecasts?
>
> Student 3: It's the meteorology station, but their predictions may not be successful.
>
> Student 4: Then, should we rely on something other than scientific information?
>
> Student 5: If you rely on it, you might avoid getting caught in the rain. They provide us with advanced notice. Thanks to science, we can predict the weather.
>
> Student 1: But their predictions and explanations change. If they change, then it isn't science.
>
> Student 3: In that case, let's not go to the doctor. It is the same thing.
>
> Student 4: The doctor provides us results from experiments.
>
> Student 6: The meteorology station conducts observational studies, a type of scientific study. They record instant data and predict the weather by analyzing this information. When scientists talk about global warming, they explain the changes that will occur in the future by comparing current data with data from past years.
>
> Student 2: How can we trust their predictions when even their forecasts about the daily weather do not come true?
>
> Student 7: There is changeability in science.
>
> Student 4: If meteorology forecasts are subject to change, how can I believe in the accuracy of that information and act accordingly?
>
> Student 8: Their estimates may not always be accurate, but they are highly reliable because they are based on evidence. (Meteorology Station).

Preservice teachers' value statements in role-play improvisations

The PSTs' improvisation was evaluated with respect to their expression of values. The domains of these values varied according to the scenarios. Socioscientific accountability was highest during the recycling scenario and lowest during the hydroelectric power plant scenario. The HEPP scenario evoked the highest social and moral compassion, whereas the beach scenario elicited the least. Table 5 presents the instances in which PSTs' declared their values each week. Please refer to Appendix B for the sample excerpts from each value domain.

Table 5. The frequency of value declarations utilised in weekly role-play improvisations.

Activity	Ecological Worldview (f)	Social and Moral compassion (f)	Socioscientific accountability (f)
1 Campus	Interconnectedness: 15 Sustainable development: 3 Total: 18	Moral and ethical sensitivity: 2 Empathic concern: 1 Perspective taking: 3 Total: 6	Feeling of responsibility: 23 Willingness to act:10 Total: 33
2 Factory	Interconnectedness: 24 Sustainable development:14 Total: 38	Empathic concern: 5 Perspective taking: 8 Total: 13	Feeling of responsibility: 7 Willingness to act: 4 Total: 11
3 Beach	Interconnectedness: 9 Sustainable development:1 Total: 10	Moral and ethical sensitivity:2 Empathic concern: 1 Perspective taking: 1 Total: 4	Feeling of responsibility: 17 Willingness to act: 15 Total: 32
4 Recycling	Interconnectedness: 13 Sustainable development:8 Total: 21	Empathic concern: 6 Perspective taking: 4 Total: 10	Feeling of responsibility: 28 Willingness to act: 34 Total: 62
5 HEPP	Interconnectedness: 9 Sustainable development: 11 Total: 20	Moral and ethical sensitivity: 13 Empathic concern: 5 Perspective taking: 6 Total: 24	Feeling of responsibility: 1 Willingness ton act: 1 Total: 2
6 Meteorology	Interconnectedness:3 Sustainable development: 1 Total: 4	Moral and ethical sensitivity: 1 Empathic concern: 3 Total: 4	Feeling of responsibility: 12 willingness to act: 10 Total: 22

Discussion

In today's society, when each individual holds responsibility for addressing global concerns such as climate change, one of the critical objectives of science education is to cultivate students' values as global citizens and to enhance their functional scientific literacy. To achieve this goal, we designed and implemented a place-based SSI intervention involving role-play activities centred around local climate issues to foster PSTs' understanding of contextualised NOS views and their values as global citizens. We organised field trips to locations pertinent to specific topics related to climate change or prevention actions, and we developed role-play scenarios linked to those places and topics. These scenarios incorporated several NOS aspects and the complexity of multiple perspectives on the issues. PSTs improvised role-plays on site, leveraging the locale's resources and their experiences from the visits.

Place-based learning approaches provide first-hand experiences for students to have direct contact with the local environment (Alagona & Simon, 2010). Students' self-reflection and moral and empathetic reasoning are fostered through place-based SSI activities (Goralnik & Nelson, 2017). Furthermore, it has been argued in previous studies that role-play is an essential medium for developing students' values regarding environmental issues (Namdar & Oğuz Namdar, 2021). Our results further indicated that place-based learning fostered students' values as global citizens at the individual, local, and global levels when coupled with role-play activities.

Previous studies have yielded conflicting results regarding PSTs' demonstrated accountability values and global perspectives (e.g. Lee et al., 2012; Uzel, 2020) when

dealing with SSIs, even after instruction. Our findings suggests that PSTs' socioscientific accountability has improved across various personal, local, and global contexts. Although PSTs' willingness to act increased at personal, local, and global levels, they hesitated more when the mitigating activities required substantial personal sacrifice, such as paying more for energy bills. They attributed their reluctance to factors like the country's economic condition or their status as students with limited income. These findings mirror those of Herman (2015), who found that students' readiness to combat global warming declined as the required personal sacrifice rose. However, the study also identified certain factors, such as students' NOS views, that influenced their willingness to act. Similarly, Herman (2018) demonstrated that students willing to donate to an environmental organisation exhibited more informed and contextualised NOS views. Our study showed improvements in students' contextualised NOS views and willingness to take action, suggesting reciprocal growth in these areas.

Character and values are manifested in and linked with moral reasoning, a process where ill-structured problems are evaluated by considering alternative perspectives and additional data (Berkowitz & Simmons, 2003; Lee et al., 2012; Perkins et al., 1991). The literature suggests that moral reasoning is context-dependent (Topcu et al., 2010). In a review study, Van Der Leij et al. (2022) reported that the content and context (regarding the emotional charge associated with the topic) impact students' moral sensitivity. Further supporting this, our results suggest that PSTs feel a heightened sense of accountabiliy for mitigating climate change when the associated factors are more personal, such as personal consumption and recycling habits, and protecting sea habitats by reducing beach pollution.

In contrast, during the HEPP and tea factory visits, PSTs primarily utilised value statements linked to the ecological worldview and social and moral compassion regarding issues that necessitated more political and governmental actions. Such scenarios are considered practical tools compile multiple ways of knowing to better understand the in environmental education to engage students in decision-making, and making most decisions involves blending evidence, personal values, and experiences, and using role-playing can clearly illustrate this distinction (Carlomagno et al., 2014; Stoeth & Carter, 2022).

Despite a general upward trend in CVGCA results, our study highlighted less significant progress in the social and moral compassion domains. Concurrently, during the six weeks of role-play improvisations, PSTs made fewer value statements compared to the ecological worldview and socioscientific accountability domains. This discrepancy might be due to the Turkish version of the scale, which omits some items found in the original one. Alternatively, PSTs' understanding of their role as part of nature, their sense of responsibility, and their willingness to act developed faster than their moral and ethical sensitivity, empathic concern, and perspective-taking abilities. This finding suggests that these latter aspects may need more time to mature fully.

Our findings align with those of Lee et al. (2013), who observed that students exhibited substantial improvements across all domains according to the CVGCA results; their classroom observations and in-class reflections revealed struggles in embracing diverse perspectives and empathising with individuals experiencing genuine hardship. These observations underscore the inherent difficulties of cultivating a comprehensive and empathetic worldview. Consequently, this further emphasises the importance of

fostering these qualities over time, allowing for a more nuanced understanding and empathy to emerge organically.

Our findings extend previous research demonstrating that place-based instruction focused on SSIs enhances students' NOS views' accuracy and contextual nature (Herman, 2018). For students to improve their reflexive and contextual use of NOS, they need to be engaged in authentic situations and observe the work of scientists (Herman et al., 2019). Alongside place-based instruction, identifying and acting out various perspectives through role-play can boost students' sociocultural awareness based on the contextual features of the SSI encountered because role-play effectively cultivates multiple perspectives (Howes & Cruz, 2009). Role-playing shows promise as a pedagogical approach that fosters the use of and reflection on NOS aspects. However, role-playing still needs to garner the recognition it deserves in science education. Increasing the use of these activities will necessitate innovation in science teacher preparation. Methods related to role-play and research findings should be incorporated in science teacher preparation programmes (Belova et al., 2015).

Limitations and concluding remarks

The methodology and participants in this study presented several limitations that warrant discussion. First, there was considerable variability in the time PSTs spent on role-plays. Some PSTs took more time during role plays than others, a factor that could have influenced the patterns observed in the va domains reflected during the improvisations. This variability can be partly attributed to the personality traits of PSTs, as these traits have been found to impact decision-making processes related to energy issues (Busic-Sontic et al., 2017).

A second limitation arose from the instructional decision not to provide PSTs with structured roles for the role-plays. This lack of defined roles likely affected how PSTs prepared for the role plays and the duration of time they spent during role-playing. Future implementations may consider assigning structured roles to the participants. This approach could reduce variability in preparation and execution, promote a more uniform duration of role-play across participants, and potentially result in more consistent findings across the value domains under examination. Furthermore, the value domains used in the role-play improvisation varied according to the scenarios. The results recommend deliberately utilising role-play scenarios based on the value domain targeted for improvement (Namdar & Oğuz Namdar, 2022).

Another methodological limitation was the difference in the number of items between the original version and the Turkish version of the CVGCA scale. During the validation process, some items had to be removed, resulting in the Turkish version lacking the subdimensions of interconnectedness, perspective-taking, and a sense of responsibility. However, we accounted for each domain the PSTs used in role-play improvisations. We also posed many open-ended questions, primarily related to the sense of responsibility and willingness to act, in pre- and post-interviews, and we noted the changes in responses. Future studies could employ the scale in its original language if the participants have the proficiency to understand and respond to the questions in English.

Certain limitations emerged due to the poor audio quality during outdoor place-based activities, particularly the beach session. As a result, there may have been an

underrepresentation in the total number of value statements that were not accurately captured. Therefore, future research efforts should consider employing higher-quality sound recording technologies to ensure more accurate data collection.

Despite these limitations, the results of the study were insightful. They revealed that a rich place-based SSI intervention, supplemented with role-play activities, effectively enhanced PSTs' contextualised NOS views. Moreover, developed their value systems, fostering a sense of responsibility and cultivating a willingness to act as global citizens.

Despite these limitations, the results of the study were insightful. They revealed that a rich place-based SSI intervention, supplemented with role-play activities, effectively enhanced PSTs' contextualised NOS views. Moreover, the intervention developed their value systems, fostering a sense of responsibility and cultivating willingness to act as global citizens. This study will contribute to science education by introducing a place-based pedagogical approach enhanced with role-play scenarios.

This study contributes to science education by introducing a place-based pedagogical approach, enriched with role-play scenarios, to enhance learners' understanding of NOS and their values as global citizens. However, due to the multifaceted nature of the instruction, it becomes challenging to isolate which components contributed most significantly to the observed learning outcomes.

Overall, interpretations of the results must be carefully examined as there was no control group in the study to conclude whether the significant increases occurred based on the intervention or can be attributed to other factors (Bernard, 2013). For example, as the participants were from different cohorts, their previous training on explicit or contextual NOS, might affect their NOS understandings as observed in previous studies (Bell et al., 2011).

For a more nuanced understanding, future research designs could benefit from incorporating control groups to validate the effects. For instance, one study might examine the impact of SSI instruction enhanced with role-play activities. Subsequently, a place-based experience could be added to the experimental group in addition to the role-play SSI instruction that the control group receives. This setup would allow for a comparison to determine if the inclusion of place-based instruction offers additional developmental benefits. Another study could integrate the place-based component with the control and experimental groups while introducing role-play scenarios to the experimental group. This approach highlights the specific impact of role-play on students' NOS views and any consequent changes in their values as global citizens.

Prior studies asserted that place-based SSI interventions have the potential to promote students' sense of place, understanding of people, and their values as citizens, thereby bolstering their functional scientific literacy (Herman, 2018; Herman et al., 2021; Herman et al., 2022; Kim et al., 2020). Enhancing learners' functional scientific literacy is a long-standing objective in science education. Therefore, educators persistently explore pedagogical approaches to improve students' functional literacy. Given the findings and implications of this study, it will undoubtedly attract the attention of a diverse range of science educators, offering a novel and practical approach to achieving this long-standing educational goal.

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Appendix A

Place-based activities and the content of weekly role-play scenario

University Campus	The first week of the place-based instruction started at the university campus, where students role-played their daily habits on different campuses, including eco-friendly and non-eco-friendly campuses. Before the role-playing act, they calculated their carbon footprints and discussed their daily routines and their impact on the environment. Then, we divided them into three groups and provided them with different scenarios. In the first scenario, students acted as students who studied at a non-eco-friendly campus, ate fast food, consumed disposable cups, and drove the campus with their vehicles. The second group acted as students who studied at a non-eco-friendly campus but were less consuming than the first group. They were taking public transportation but still eating packaged food and recycling. The third group acted as students who studied at an eco-friendly campus where they ate local food, including vegetables and fish, used bicycles between buildings, and refilled water bottles from fountains in the buildings.
Tea factory	The following week, we went to a tea factory, where a specialist explained the black tea extraction process. He introduced the technology they used and their precautions for the environment. He also showed the reports of an environmental engineer who worked for the factory. Then, students chatted with several other workers and asked their questions. Then, when we were still at the factory, we divided the PSTs into four groups and gave them their scenarios. The scenario was about whether or not building a new factory is necessary for the region. Students acted as; the factory's principal, a local tea manufacturer who supported the idea, an elderly local person who suffered from air pollution and therefore did not support the idea of building a new tea factory, and the factory's environmental engineer who explained their solutions to reduce the industrial pollution and greenhouse gasses. We told them they could add other characters to the scenario. They performed in the principal's office and utilized the factory's supplies.
Beach	In the third week, we had a field trip to the beach, where we had our trash bags and collected waste. Then, PSTs grouped the wastes based on materials such as plastic bottles, metals, papers, fishing nets, and natural wastes like tree branches. They weighed wastes and showed the results as a pie graph and found that plastic wastes outweighed all the other groups and had the most prominent piece in the pie graph. After that, we gave them a scenario about the municipal president's decision to close beaches to visitors for a while because of increasing plastic pollution in the sea. Two students in each group acted as municipal security that closed the beach trails for hikers and visitors. A few students acted like young friends, eating at the beach and throwing trash there. A few students acted as environment activists explaining to young people how their actions harm the sea, surroundings, and living organisms. A few students acted as tourists who

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	came to the town and were miserable about the municipal decision. In the end, we discussed as a whole group how plastic wastes in the seas and oceans impact fish lives and how greenhouse gas emissions increase with the production of plastics.
Recycling center	In the fourth week, we had a field trip to a recycling center where the company's manager and specialist explained the recycling process—this week's scenario was whether to recycle. While we were still at the recycling center- the big hall where all recycling items are classified and piled up, PSTs acted as supporters or deniers of recycling based on their reasoning. We did not previously divide PSTs into groups this week. Instead, the instructor randomly touched on two PSTs each time, and they started a conversation with the other person on the scene. The scenario continued until all PSTs acted.
HEPP station	In the fifth week, we had a field trip to a hydroelectric power plant station [HEPP], where the engineers and specialists explained the energy production process and introduced the technologies, they used during energy production. Also, they mentioned the precautions they are taking to minimize the impact on fish populations and plants on the river shore. Then, the specialist accompanied us to the upper hill, where they started collecting water. Students talked with workers and engineers at the station and asked their questions. Then, we divided students into two big groups and gave students a scenario. One group supported hydroelectric power plants, while the other group was against them. In each group, there were a few local people evaluated from the region's economy, one energy engineer, a minister of energy and natural resources evaluated from a political perspective, an activist volunteering for a non-governmental environmental organization, the headmen of the village who evaluated it from the cultural aspect, and a local sick person and evaluated the issue from the health aspect. This local person focused more on the animal lives and evaluated from the moral and ethical aspects.
Meteorology station	In the sixth week, we had a field trip to a meteorology station, where a specialist introduced the technology, they used to collect data for weather and precipitation predictions. While we were at the station, we gave students their scenarios. We divided students into two groups in the first round of the role-play act. One group supported global warming, while the other acted as deniers. They acted like people who met in a resort area chatting about the weather. The deniers pretended to be people who did not believe what the scientists said about global warming by using some reasoning, such as how the earth had glacial areas in the past and then warmed up and then cooled down again. In the scenario, a sudden rain started when the deniers complained that meteorologists' predictions never came true. They also said that because meteorologists did not use manipulated experiments, their predictions were untrustworthy. They also stated how they would believe scientists' predictions about global warming and the earth's future even when their predictions did not come true within the same day. The other group supported that global warming was happening. They emphasized that scientists made observations, collected and compared data with past data, and made inferences about global warming. They mentioned how extreme weather events, such as the fires in Europe or floods, were caused by global warming. In the second round of the role-play act, they acted like they came together with the same groups of people 60 years later. The earth had warmed then, and the area's climate had changed. They began to remember the weather 60 years ago and their current thinking about global warming. The third round was the role-play about each student's small talk/reflection as an older adult who confronted climate change and what they wanted to say to their young version.

Appendix B

Sample excerpts for each character and value domain

Character and Value Dimensions	**Examples of Value Statement**	**Place-based Activities**
Interconnectedness	The factories release greenhouse gases that harm the environment and increase global warming. Factory construction destroys forests, and our region will experience more landslides as the number of trees declines.	**Tea Factory**
Sustainable development	I would like you to realize how constantly this was with us in the past when we did not even have a glass of water to drink when we look around us now. Life is beautiful, so we should know the value of the future.	**Meteorology Station**

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Moral and ethical sensitivity	Most marine animals die from plastic waste. How would you dispose of your garbage if you knew this was happening?	**Beach**
Empathic concern	How do you explain the extreme drought? We see it in the news. Don't you see the African children? X: Yes, I see and feel sorry for them, but what can I do?	**University Campus**
Perspective-taking	I work in a factory. How would I bring bread to my kids when the factory is closed?	**Tea Factory**
Feeling of responsibility	I try to make my food and have less waste. If I use packaged food, then I go and recycle.	**Recycle Center**
Willingness to act	I want to tell the Minister of Energy and Natural Resources that the people living and farming around these HEPP stations cannot use water.	**HEPP Station**