Science & Education
https://doi.org/10.1007/s11191-024-00512-4

ARTICLE

# Impact of Argument-Driven Inquiry Activities on Pre-service Science Teachers' Views of the Nature of Scientific Inquiry in the Context of Climate Change Education

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Accepted: 26 February 2024


**Abstract**
This study aimed to investigate how argument-driven inquiry (ADI) activities impact pre-service teachers' views of the nature of scientific inquiry (NOSI), with a specific focus on climate change. To this end, an ADI approach was used to teach climate change, where the aspects of NOSI were explicitly taught. A sample of 24 pre-service teachers participated in a science project which included ADI sessions addressing climate change topics. The pre-service teachers participated in four ADI activities related to rising sea levels, clean water resources, extreme weather events, and zero energy building. The sessions involved explicit instruction on NOSI to enhance pre-service teachers' understanding. A view of scientific inquiry (VOSI) questionnaire was used to investigate pre-service teachers' views of scientific inquiry before and after the instruction. The results of the study showed that the pre-service teachers improved in all six aspects of NOSI, but higher improvements were observed in the aspects "multiple methods of scientific investigations" and "distinctions between data and evidence."

## 1 Introduction

As the problem of climate change becomes more important and urgent (NASA, 2023; NOAA, 2023), new generations who are just born and have not even started primary school will feel the burden of climate change on their shoulders in the future, and they will both seek solutions to climate change and adapt to living with global warming. Regarding the vital significance of climate change, research on climate change education has also expanded (Henderson & Drewes, 2020). However, climate change is not just a scientific concept. Various influential aspects of climate change make it difficult to teach this subject.

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Published online: 15 April 2024

Among these influential factors are worldview (Zummo et al., 2021), values (Aksit et al., 2018), epistemic cognition (Quarderer et al., 2021), emotions (Hufnagel, 2015), and political identity (Walsh & Tsurusaki, 2018). Due to this challenge of the complexity of climate change, there is no broad consensus on which educational strategies are most effective (Monroe et al., 2017).

In learning about climate change, it is necessary to grasp the empirical nature of science as a way of knowing the context and conceptual knowledge of climate change, as well as through the development of tentative explanations of evidence-based cause-and-effect relationships (Bell & Lederman, 2003; Bell et al., 2011). By arguing that Bell et al. (2011) and Bell and Lederman (2003) underscore the importance of two key aspects in learning about climate change. Firstly, it emphasizes the necessity of understanding the empirical nature of science. This means recognizing the significance of empirical evidence—observations and data derived from real-world experiences—as a fundamental way of knowing and comprehending the context and conceptual knowledge surrounding climate change. Secondly, the argument suggests that learning about climate change also involves developing tentative explanations. These explanations are based on evidence-supported cause-and-effect relationships. In other words, students or learners are encouraged to construct preliminary interpretations of the data and evidence they encounter, keeping in mind the established relationships between different factors influencing climate change. This process of developing explanations adds a layer of critical thinking and analysis to the learning process, enhancing the depth of understanding beyond mere factual knowledge.

This multifaceted and complex nature of climate change requires both knowledge building by using different educational strategies and understanding the epistemology of science in education. In order to comprehend the epistemology of science, it is essential to grasp the nature of science (NOS) and the nature of scientific inquiry (NOSI). The "consensus view" has given rise to a significant corpus of empirical research focused on how students and teachers understand the nature of science (NOS) within science education, as highlighted by Ackerson and Donnelly (2008) and Abd-El-Khalick and Lederman (2000). This body of work has subsequently led to numerous debates and discussions within the community of science educators. A particular point of contention in this debate involves Lederman's (2007) position, which suggests that despite the connection between the nature of science (NOS) and scientific inquiry, it is important to distinguish between the two. He argues that "inquiry" should be defined as the methodologies and techniques used in science, whereas the NOS is more focused on the epistemological aspects of how scientific knowledge and processes are understood. Grandy and Duschl (2008) have challenged these assertions by suggesting that they oversimplify the essence of observation and theory and largely disregard the significance of models in shaping the conceptual framework of science. Actually, although a general consensus on the NOS has not been reached and discussions continue, this topic falls outside the scope of this research.

Although NOS and NOSI are related, NOS is more about scientific knowledge, which is the product of scientific research, whereas NOSI is more about the scientific research process (Leblebicioglu et al., 2017). The aspects of NOSI that are accessible and relevant to students have been defined by Schwartz et al. (2008) to include six aspects: scientific questions guide investigations, multiple research methods, multiple research objectives, justification of scientific knowledge, distinctions between data and evidence, and community of practice. Students' understanding of NOSI has an important place in science education. Schwartz (2012) suggested that students should understand the nature of the development and processes of science to assess how scientific knowledge is evaluated and to assess the validity of scientific claims, even when they are conducting their own scientific research. Understanding NOSI requires understanding the role of scientific inquiry in science and what scientific knowledge is. NOSI has eight aspects: (1) "scientific investigations all begin with a question and do not necessarily test a hypothesis"; (2) "there is no single set of steps followed in all investigations (no single scientific method)"; (3) "inquiry procedures are guided by the question asked"; (4) "all scientists performing the same procedures may not get the same results"; (5) "inquiry procedures can influence results"; (6) "research conclusions must be consistent with the data collected"; (7) "scientific data are not the same as scientific evidence"; (8) "explanations are developed from a combination of collected data and what is already known" (Lederman et al., 2014). Moreover, Perkins and Blythe (1994) defined understanding as "the understanding is being able to perform in various thought-demanding ways with the topic—to explain, muster evidence, find examples, generalize, apply concepts, analogize, and represent in a new way" (Perkins & Blythe, 1994). Thus, when we use enhancing and measuring PSTs' views of NOSI, we mean PSTs' understanding of NOSI.

Many studies report that engaging students in scientific practices with NOSI instruction can enable them to improve their NOSI aspects (Leblebicioglu et al., 2017; Cetin, 2021). Also, Cetin (2021) showed that when students are engaged in argumentation and scientific practices such as inquiry together, their NOSI views can be improved properly. Besides scientific practices, argumentation can also potentially improve students' NOSI views. This is because, as Duschl (2008) presented, argumentation includes the epistemological and conceptual aspects of science learning by combining these aspects of what it means to "do science" to support a deep understanding of the nature of scientific knowledge and practices. Moreover, research showed that integrating the explicit nature of science and argumentation instruction in a science content course improves learners' nature of science (Bell & Linn, 2000; Yerrick, 2000; Ogunniyi, 2006; McDonald, 2010; Kutluca & Aydın, 2017). Also, Eymur (2019) presented that the ADI model gives an opportunity for students to ''do science'' to provide a deep understanding of the nature of scientific knowledge and practices.

As some studies (Leblebicioglu et al., 2017; Metin Peten, 2022) have shown that argumentation and inquiry methods allow students to understand NOSI better, we implemented the argument-driven inquiry (ADI) method in the concept of climate change to improve students' views of NOSI. We take the concept of climate change as a tool by which students' epistemology of science can be investigated. Some researchers have suggested that controversial socio-scientific issues like climate change can provide a distinctive context for students to enhance their epistemic structures (Bell et al., 2011; Karl et al., 2009; Matkins & Bell, 2007).

Therefore, the present study engaged students in scientific practices in the concept of climate change to improve their views of NOSI. Thus, the study aimed to improve students' views of NOSI within the context of climate change by using the ADI method. As some researchers have supported, we believe that some of the controversial issues about climate change arise from confusion about how science works at a basic level and lack of understanding of epistemology of science (Sinatra et al., 2014). We hypothesize that engaging students in argumentation and inquiry, for example, using the ADI method in this study, to understand the science content behind climate change may improve their views of NOSI. The main purpose of the study was to explore the effectiveness of ADI in the context of climate change in improving the pre-service teachers' (PSTs') views of NOSI by addressing the following question:

1. How do PSTs' views of NOSI change after participating in ADI activities in which they deal with climate change problems and experience explicit teaching of NOSI?

## 2 Theoretical Framework

### 2.1 Argument-Driven Inquiry (ADI)

ADI is a novel instructional method that includes argumentation and scientific inquiry practices. ADI has eight iterative steps to implement. The steps and purposes are presented in Table 1 (Sampson & Walker, 2012).

ADI is founded on social constructivist theory, which includes social and personal educational processes. The social process means that the construction of knowledge takes place through interaction with others, while the personal process involves the individual building of knowledge and understanding. This framework of theory ensures two important issues in instructional method. One of them is that students should experience scientific practices to learn with others and from their experiences. Another is that scientific practices should ensure students' individual gains in the construction of their scientific knowledge and norms. Students get the opportunity to develop skills in scientific literacy and scientific norms when engaging in authentic scientific practices. There have been many studies investigating the effectiveness of ADI in developing various aspects, such as scientific writing and argumentation skills (Sampson & Walker, 2012; Sampson et al., 2013; Walker & Sampson, 2013), scientific literacy (Strimaitis et al., 2017; Walker et al., 2012), and conceptual understanding and presentation skills (Çetin & Eymur, 2017; Çetin et al.,

**Table 1** The steps of the ADI instructional model and purposes

| Step | Purpose |
|---|---|
| Identification of the task and the research question | Attract students' attention<br>Activate students' previous knowledge |
| Developing a method; collecting and analyzing data | Give students a chance to design and practice an investigation<br>Provide an opportunity for students to decide what type of data they need and how they collect them |
| Generation of a tentative argument | Give students the opportunity to develop a tentative argument that includes claim, evidence, and justification of evidence |
| Argumentation session | Make students discuss and share their ideas<br>Give students a chance to get feedback about their argument |
| Open and reflective discussion | Make students share the knowledge and experiences they have gained from sharing with their friends in other groups |
| Writing an investigation report | Make students learn how to craft a written argument |
| Double-blind group peer review | Give students a chance to understand a good quality investigation report<br>Provide an opportunity for students to get feedback from their peers |
| Revising the investigation report | Make students revise and improve their writing |

2018). Furthermore, ADI is also reported to improve students' views of NOS and NOSI (Cetin, 2021; Eymur, 2019; Metin Peten, 2022). It is noted that the integration of deliberate discussions about NOSI and NOS into ADI instruction improves students' views of NOS and NOSI. This improvement is grounded in providing opportunities for students to "do science" in ADI when engaging in scientific practices. "Doing science" also enables students to gain a deep understanding of the nature of scientific knowledge, norms, and inquiry.

"Doing science" means laboratory activities that allow students to engage in science practices, such as designing their own investigations and developing and criticizing their arguments in science laboratories. Unfortunately, throughout history, science laboratories have traditionally served a limited purpose, mainly allowing students to experimentally verify concepts presented in lectures and gain some practical laboratory skills (Cooper & Kerns, 2006). The majority of laboratory curricula have been structured to ensure that students produce the "correct" outcomes and draw the "expected" conclusions. While these verification or "cookbook" labs efficiently cover various topics within a semester, they often lack substantial opportunities for meaningful learning (Domin, 1999; Hofstein & Lunetta, 2004). For this reason, students have not known how to do science and behave like scientists in the laboratory. However, in ADI, development of tentative argument requires students to construct an argument that includes an explanation substantiated by evidence and a justification for the selection of that evidence. This phase of the model underscores the significance of argumentation in the field of science. It underscores the idea that students should recognize the necessity for scientists to substantiate their explanations, conclusions, or claims with suitable evidence and reasoning, as scientific knowledge is not based on dogma (Hodson, 2008).

In summary, the ADI instructional model is structured as a comprehensive instructional unit that aims to stimulate students' participation in a series of activities, including inquiry, argumentation, writing, and peer review. These activities are strategically designed to help students do science and behave like scientists.

## 2.2 Climate Change

Climate change has become a pressing global issue that requires urgent attention and action. As such, it is essential to integrate climate change into science education at all levels. Science education provides a crucial platform to educate students about the causes, impacts, and mitigation strategies of climate change (Dawson et al., 2022). Through science education, students can develop an understanding of the fundamental scientific concepts that underpin climate change, including the greenhouse effect, carbon cycle, and melting icecaps (Shepardson et al., 2012). Furthermore, science education plays a role in fostering students' critical thinking skills and their ability to effectively manage information which implies not only acquire knowledge about climate change but also develop the skills to handle, evaluate, and apply that information in a thoughtful and effective manner related to climate change issues (Matkins & Bell, 2007). This may involve assessing the reliability of sources, understanding different perspectives, and making informed decisions based on the available information. If aligned with learning objectives, NOSI can be considered an appropriate framework for comprehending climate change and its impacts (Kumar et al., 2023). According to Cantell et al. (2019), by incorporating climate change into education, future generations can be equipped with the necessary knowledge and skills to address climate change issues and contribute to a more sustainable future. These educational interventions not only aim to enhance students' knowledge and thinking abilities related to the subject but also have the potential to create future scenarios regarding climate change and effectively inspire students to take meaningful action. By including climate change in science education, we can equip future generations with the knowledge and skills necessary to address the challenges of climate change and contribute to a more sustainable future. Climate change is a complex and multifaceted issue that requires a comprehensive understanding of NOSI, which provides an excellent framework for understanding climate change and its impacts. According to the National Research Council, "scientific inquiry is the process by which scientists ask questions, develop explanations, and test those explanations against evidence" (National Research Council, 2012). Scientific inquiry requires a critical evaluation of evidence and the use of empirical data to develop arguments and claims. In the context of climate change, we hypothesize that helping students construct an understanding of the science content behind climate change involves supporting them in the epistemology of science, for example teaching them how to differentiate scientific evidence from scientific data, as well as recognizing that there is no single scientific method. Therefore, understanding NOSI is critical in addressing climate change and developing effective solutions to mitigate its impacts.

### 2.3 Nature of Scientific Inquiry (NOSI)

The idea of NOSI has existed for decades, but different names and definitions have been suggested for it. The concept of "knowledge about inquiry" was evident in the National Science Education Standards (NRC, 1996) and related documents in the USA, but these recommendations had multiple definitions of "inquiry." This situation has led to different interpretations of what inquiry means and what students should know and be able to do regarding inquiry. As a result, the term "nature of scientific inquiry" has frequently appeared in the literature, although it has often been conflated with NOS (nature of science) and inquiry skills. Some researchers, such as Schwartz (2004) and Neumann et al. (2011), have made conscious efforts to differentiate between NOS and NOSI, as well as inquiry skills. Other scholars, however, have argued for an overarching concept of NOS that incorporates skills, the nature of scientific knowledge, and NOSI (e.g., Irzik & Nola, 2011). Still, others maintain that NOS, NOSI, and inquiry skills are overlapping but distinct conceptual frameworks (e.g., Lederman & Lederman, 2014; Schwartz et al., 2012).

For this study, we adopt the latter framework, where NOSI is considered distinct from but related to NOS. Our intervention, data collection, and analysis are based on this conceptualization of NOSI. Previously, the views of scientific inquiry (VOSI) questionnaire, developed by Schwartz et al. (2008), were utilized to investigate students' perspectives on NOSI. Schwartz (2004) employed Views of Nature of Science Questionnaire (VNOS-Sci) and Views of Scientific Inquiry Questionnaire (VOSI-Sci) on scientists from various disciplines to study scientists' views on NOS and NOSI (Appendix). Although there was no apparent correlation between the science field and NOS perspectives, as reported by Schwartz and Lederman in 2008, Schwartz discovered that scientists' views regarding NOSI could vary depending on their investigative methodology.

Aydeniz et al. (2011) examined high school students who participated in scientific laboratory work to analyze the changes in their views of NOS and NOSI. The researchers discovered that the students learned about the process of inquiry but did not grasp the implicit aspects of NOSI. To address this, they recommended that the implicit aspects of NOSI be made more explicit. Some studies argue that it is important to address it explicitly in science instruction. This means that educators should provide learners with deliberate and reflective learning experiences that help them to develop a deeper understanding of NOSI (Aydeniz et al., 2011; Burgin & Sadler, 2016; Cetin, 2021). Lederman et al. (2014) recommend that learners should have explicit instruction in NOSI to develop more accurate and nuanced conceptions of scientific inquiry. Similarly, Osborne (2014) argues that inquiry activities should have explicit epistemic goals, or goals related to the nature of scientific knowledge, for learners to develop a deeper understanding of the content.

Without explicit instruction or goals related to NOSI, learners may only develop surface-level knowledge of scientific content without understanding the underlying principles and processes that drive scientific inquiry. Therefore, it is important for educators to incorporate explicit instruction and reflective learning experiences related to NOSI into their science instruction. When we talk about explicit and reflective learning experiences for NOSI, we do not mean a direct or didactic approach where declarative statements are made about NOSI. Instead, explicit and reflective learning experiences involve the purposeful teaching of NOSI aspects in conjunction with climate change. This can be achieved through ADI activities. The aim is to draw learners' attention to relevant NOSI aspects through discussion and reflective questioning. Lederman and Lederman (2014) suggest that educators intentionally help learners to recognize and understand the NOSI aspects that are inherent in scientific inquiry through reflective questioning, discussion, and analysis. By doing so, learners can develop a deeper and more nuanced understanding of scientific inquiry and the nature of science rather than simply acquiring superficial knowledge of scientific facts. So, we provided PSTs with explicit and reflective educational experiences on aspects of the NOSI, encompassing inquiry-based activities such as experiments and investigations, facilitated through discussions and reflective questioning, as suggested by Lederman and Lederman (2014). Furthermore, the aspects of NOSI were evaluated using a questionnaire (Zion et al., 2020), which included seven open-ended questions designed to gather participants' insights on the six aspects of NOSI.

## 3 Method

### 3.1 Participants

The study group for this research comprised 24 PSTs studying in the department of science teaching. The announcement of the project was communicated through various channels in order to receive the applications of PSTs who wanted to participate in the project. After receiving the applications, maximum diversity sampling criteria (Patton, 2015) were considered in selecting the final participants. To ensure maximum diversity, attention was paid to assure that the PSTs were from different universities, from different regions of Turkey, and had different academic achievement levels. The study group consisted of PSTs from 12 different universities in various regions of Turkey. Moreover, the participants' cumulative grade point averages (CGPAs) that is a measure of a student's academic performance, representing the average of all the grade points they have earned, ranged from 2.0 to 3.8 on a system with the highest grade of 4. Out of the participants, 19 were female, and 5 were male, with gender distribution proportional to the number of pre-service teachers who applied to participate in the project. The courses taken by the participants at the undergraduate level were very similar because the Council of Higher Education regulates undergraduate teaching programs in Turkey and ensures that all universities follow a standard program.

## 3.2 Context of the Study

The project in this study is supported by the Scientific and Technological Research Council of Türkiye (TÜBİTAK) within the scope of the Grant Program for Scientific Training. These projects aim to bring together students from different universities to receive expert training on various current topics. The main aim of this project was to improve PSTs' understanding of NOSI by using ADI activities in the context of climate change. The project lasted five days (Table 2) and included activities and training sessions provided by field experts on argumentation, ADI, socio-scientific issues, and NOS. The activities included in the project were designed using the ADI approach to address the issue of climate change. Because of the complex and multifaceted nature of climate change, it involved several scientific disciplines, such as physics, chemistry, and biology. Therefore, climate change can be thought a suitable context for students to engage in scientific inquiry.

Throughout the project, the participants were engaged in four ADI activities: rising sea levels, clean water resources, extreme weather events, and zero energy building. The researchers assigned the PSTs into six groups with four students in each group. As seen in Table 3, each ADI activity dealt with different guiding questions and highlighted different aspects of NOSI.

Apart from the ADI activities, the PSTs attended sessions on argumentation, socio-scientific issues, the theoretical part of ADI, NOSI, and twenty-first-century skills in science education. In the argumentation session, PSTs were told what an argument is, its basic components (such as claim, data, justification, supporting, and rebuttal), and the characteristics of a quality argument. In addition, after the PSTs were asked to construct a valid argument for a given issue, they were shown examples of high-quality and poor-quality arguments. In the session about socio-scientific issues, the characteristics of socio-scientific issues were introduced to the PSTs. Moreover, socio-scientific subject examples were presented to them, and a discussion was carried out on one of those subjects. With that discussion, it was tried to show the PSTs that socio-scientific issues offer a suitable environment for teaching NOSI. In the theoretical course about ADI, the steps of ADI were introduced to the PSTs one by one. In addition, an exemplary ADI activity on the concept of density was conducted with the PSTs before moving on to the actual ADI practices related to climate change. In the session on NOSI, the dimensions of NOSI and its importance in science education were explained. Finally, what the twenty-first-century skills are and how these skills can be gained through ADI activities were discussed with the PSTs. For a better understanding of how we conducted the ADI activities, "Zero Energy Building Activity," one of the ADI activities in the project, is explained in detail below.

### 3.2.1 Zero Energy Building Activity

**Stage 1-Task (Identification of the Task)** The investigation began by introducing a phenomenon related to greenhouse gases produced in buildings. For this purpose, the researchers distributed handouts including information about the role of greenhouse gas emissions in climate change, the impact of building emissions resulting from urbanization, and why reducing building emissions is essential for climate adaptation action. The handout effectively engaged the PSTs' attention and stimulated their prior knowledge in relation to the

**Table 2** Project program

| | 1st day | 2nd day | 3rd day | 4th day | 5th day |
|---|---|---|---|---|---|
| Morning sessions | Opening ceremony | **What is argument-driven inquiry (ADI)?** | **Nature of science inquiry in science education** | **21st-century skills in science education** | **Extreme weather-floods—ADI activity (task, ideas, and plan stages)** |
| 08:45–10:15 | Pretest: VOSI 270 questionnaire | Introducing ADI and its steps | Introducing the dimensions of the nature of scientific inquiry and explaining their place in science education | This course emphasizes the intersection of science education and climate change, focusing on 21st-century skills such as problem-solving, creative thinking, and analytical thinking. Participants were informed of these skills to address climate challenges effectively | Reading handouts on the impact of increased extreme rainfall due to global warming on flooding, identifying the research problem, and creating a research plan to obtain data on the problem |
| 10:30–12:00 | Icebreaker activities | **What is argument-driven inquiry (ADI)?** An example ADI activity for understanding the method | **Zero energy building—ADI activity (task, ideas, and plan stages)** Reading handouts on the impact of buildings/urbanization on greenhouse gas emissions to identify a research problem and creating research plans to obtain data related to the problem | **Wastewater treatment—ADI activity (task, ideas, and plan stages)** Reading handouts on the pollution and depletion of water resources due to climate change and human impact, identifying research problems, and creating research plans to obtain data for the problem | **Extreme weather-floods—ADI activity (do and share stages)** Groups collect data, analyze them, and prepare their arguments by creating a presentation poster based on their designed research plan. Argumentation session, in which groups defend their findings and conclusions based on the collected and analyzed evidence |
| Afternoon sessions | **Argumentation and science education** | **Sea-level rise—ADI activity (task, ideas, and plan stages)** | **Zero energy building—ADI activity (do and share stages)** | **Wastewater treatment—ADI activity (do and share stages)** | **Extreme weather-floods—ADI activity (reflect and report stages)** |

**Table 2** (continued)

| | 1st day | 2nd day | 3rd day | 4th day | 5th day |
|---|---|---|---|---|---|
| 13:00–14:30 | Introduction of argumentation and demonstration of its applications in science education based on actual cases | Reading handouts on melting glaciers to identify the research problem, introducing climate action simulation to obtain data for the problem, and creating research plans for groups | Groups collect data, analyze them, and prepare their arguments by creating a presentation poster based on their designed research plan. Argumentation session, in which groups defend their findings and conclusions based on the collected and analyzed evidence | Groups collect data, analyze them, and prepare their arguments by creating a presentation poster based on their designed research plan. Argumentation session, in which groups defend their findings and conclusions based on the collected and analyzed evidence | Sharing the gained knowledge and experiences for evaluation in the class and writing reports on the research process |
| 14:45–16:15 | **Socio-scientific issues in science education**<br>Introduction to socio-scientific issues and their characteristics, the relationship between socio-scientific issues and the nature of science, and introduction of problems/solutions arising from climate change | **Sea-level rise—ADI activity (do and share stages)**<br>Groups collect data, analyze them, and prepare their arguments by creating a presentation poster based on their designed research plan. Argumentation session, in which groups defend their findings and conclusions based on the collected and analyzed evidence | **Zero energy building—ADI activity (reflect and report stages)**<br>Sharing the gained knowledge and experiences for evaluation in the class and writing reports on the research process | **Wastewater treatment—ADI activity (reflect and report stages)**<br>Sharing the gained knowledge and experiences for evaluation in the class and writing reports on the research process | Posttest: VOSI 270 questionnaire |

**Table 2** (continued)

| | 1st day | 2nd day | 3rd day | 4th day | 5th day |
|---|---|---|---|---|---|
| 16:30–18:00 | | **Sea-level rise—ADI activity (reflect and report stages)**<br>Sharing the gained knowledge and experiences for evaluation in the class and writing reports on the research process | | | |
| Evening session | **Welcome party** | Evening activities | Evening activities | Evening activities | |

**Table 3** Description of activities

| Activity | Guiding questions | Main NOSI aspects emphasized |
|---|---|---|
| Rising sea levels | Which solution suggestions do you think would have the greatest impact in reducing sea-level rise by preventing glacier melting? | Scientific questions guide investigations<br>Multiple methods of scientific investigations<br>Multiple purposes of scientific investigations<br>Recognition and handling of anomalous data |
| Clean water resources | How can the issue of access to clean water resources, which our country faces, be resolved? | Multiple purposes of scientific investigations<br>Distinctions between data and evidence<br>Justification of scientific knowledge |
| Extreme weather events | What criteria should a potential flood- or landslide-resistant house have? | Scientific questions guide investigations<br>Multiple purposes of scientific investigations<br>Recognition and handling of anomalous data |
| Zero energy building | What can you do to reduce greenhouse gas emissions in your school? | Multiple methods of scientific investigations<br>Justification of scientific knowledge<br>Distinctions between data and evidence |

guiding question. The participants' task for this activity was to identify what could be done to reduce greenhouse gas emissions in buildings. The PSTs were asked to take notes on what they noticed and what they wondered about. After that, the PSTs started to work with groups of four people. The whole class discussion resulted in the setting of the research problem as "How can greenhouse gas emissions be reduced in your school?" During the discussion, the researchers highlighted the role of scientific questions in guiding research. The participants then collaborated with their groupmates to generate ideas for the topic. For example, some groups discussed the role of cities and buildings in greenhouse gas emissions, while others examined the structure of their building and how it could affect greenhouse gas production. By noticing different strategies and perspectives, the participants gained a better understanding of the complex nature of the problem and the different ways to handle it. This gave researchers an opportunity to highlight the multiple purposes of scientific investigations in the context of NOSI.

**Stage 2-Plan (Developing a Method)** After the ideas stage, groups created and shared a plan for collecting and analyzing data. During the planning process, the researchers reminded the groups to select a proper research method for their identified research questions. Next, the researcher asked questions such as "What kind of data do you plan to collect?," "How do you plan to collect such data?," "Why do you want to collect in this way?," and "How do you plan to analyze the data collected in this way?" to make the group think that there is no single scientific method that must be followed in scientific research.

**Stage 3-Do (Collecting and Analyzing Data, Generation of a Tentative Argument)** Once the groups collected the data according to the research methods they had determined, they created a tentative argument by analyzing their data to answer their research questions. For example, in the said activity, some groups focused on insulation in buildings to reduce greenhouse gas emissions and conducted their research based on the data they obtained from their experimental setups. Other groups worked on the impact of different fuel types on greenhouse gas emissions by calculating the combustion reactions and analyzing how the fuel types used in buildings affect greenhouse gas emissions. Some other groups focused on photosynthesis and calculated how increasing green areas (such as green walls and roofs) in building designs could effectively reduce greenhouse gas emissions by creating models. At this stage, the researchers guided the groups to understand the difference between data and evidence. The argument was collaboratively developed on a whiteboard, which facilitated the visualization of group members' ideas and allowed for easy sharing among the group. The PSTs' arguments included a claim (an answer to the guiding question), evidence, and rationale. The participants did not have a great difficulty in determining what counts as a claim and what counts as an evidence, as they had attended the theoretical sessions in which the steps of ADI and the components of the argument were explained.

**Stage 4-Share (Argumentation Session)** During the argumentation session, one of the group members presented their arguments to other groups. The participants evaluated the presented arguments by criticizing them. At this stage, the participants often discussed the accuracy and reliability of the scientific data. For example, regarding the data collected by the groups investigating insulation for this activity, the reasons for some differences and inconsistencies in the data and what needs to be done in the scientific process to ensure the reliability of the dataset were discussed. While discussing different ways to answer the question, the participants also discussed the feasibility of the solutions. For instance, they found changing fuel types feasible and logical. However, they questioned its practicality, although they thought increasing green spaces in buildings (such as green walls and roofs) could effectively reduce greenhouse gas emissions. The NOSI aspect “justification of scientific knowledge” was prominent in the discussions conducted in this session.

**Stage 5-Reflect (Open and Reflective Discussion)** At this stage, the researchers asked the PSTs to reflect on what they had learned from their investigation. The researchers asked, “Which type of data did you collect?,” “How did your group’s data collection process differ from others?,” “Were there any similarities and differences in your research compared to other groups?,” and “Do you think there were any strengths and weaknesses in your research?.” By asking these questions, the researchers led the participants to discuss different research methods, data collection procedures, and the evidence they gathered to make the NOSI aspects more visible. The participants often highlighted the challenges of the complexity of scientific research related to climate change and how social needs and current events can impact scientific research and the work of scientists.

**Stage 6-Report (Writing an Investigation Report, Double-Blind Group Peer Review, Revising the Investigation Report)** The reporting stage includes three steps: (1) writing an investigation report, (2) double-blind group peer review, and (3) revising the investigation report. Therefore, each PST independently composed a written scientific argument in the form of an investigation report to address the guiding question, which they subsequently submitted to the researchers. The individually written reports underwent peer review, offering an additional opportunity for the refinement of the written scientific arguments. Meanwhile, the researchers emphasized how scientists share scientific research and how this way of working contributes to science.

### 3.3 Data Collection and Data Analysis

To analyze the PSTs’ views of NOSI before and after participating in the project, the VOSI 270 questionnaire was administered. VOSI 270 was applied as a pre-test, as a post-test, and as a retention test after two months. VOSI 270 highlights the NOSI aspects of questions, multiple methods, purposes, justification, anomalous data, and data and evidence (Zion et al., 2020). The questionnaire comprises seven open-ended questions to elicit responses from participants on the six aspects of NOSI. The PSTs completed the questionnaire individually in approximately 30 min. The rationale for using this questionnaire is twofold. First, the NOSI aspects targeted in this questionnaire are consistent with the NOSI aspects we expected to improve in our study. Second, as Schwartz et al. (2015) stated, this version of the questionnaire is suitable for our research participants, namely pre-service teachers. Two researchers worked together to code the data to ensure reliability in data analysis. Both researchers have previously participated in NOSI studies and conducted data analysis, so they can be considered experts in this field. The researchers, who initially coded the three questionnaires together, came to a common conclusion by discussing where they disagreed. Then, they independently coded 15 questionnaires, and the Cohen’s kappa for inter-rater agreement for this coding was calculated as 0.79. The rest of the questionnaires were coded by one of the authors of the research. The data were coded with respect to the categories explained in the work of Lederman et al. (2014). Considering the possibility of the pre-service teachers to present their views on NOSI in more than one question, a holistic analysis of the answers was carried out, as Lederman et al. (2014) suggested and explained in detail. The PSTs' responses were coded into three categories (i.e., naive, mixed, and informed) for the six aspects of NOSI. An informed view includes responses that reflect the accepted views, a mixed view includes partially accepted views, and a naive view includes unaccepted views. The coding scheme for the study is presented in Table 4.

## 4 Results

The views of the PSTs for each NOSI dimension were coded as naive, mixed, or informed, converted into percentages, and are presented in Table 5.

### 4.1 Scientific Questions Guide Investigations

At the beginning of the project, the PSTs mostly had naive views on this aspect (52%), six PSTs had mixed views (29%), and only four PSTs had informed views. In the post-test, 19% of the PSTs held naive views, 33% had mixed views, and 48% held informed views. Table 5 shows that the increase in the number of the PSTs with informed views could not be preserved in the retention test. However, those PSTs did not turn to naive views, and their answers showed that they developed some understanding but were not as knowledgeable as those with informed views. The following quotes from the PSTs show a naive view in the pre-test, an informed view in the post-test, and a mixed view in the retention test:

> Before starting a scientific research, a scientist requires a comprehensive research plan, which will serve as a guiding framework throughout the research process. During the implementation of this plan, the scientist will need an ample amount of content knowledge and procedural expertise to effectively carry out the research. (naïve, 4th question)

> Scientists try to understand nature. Scientists need a research question to decide what and how to research out of all the things to research in nature. This research question guides them in every step they take. (mixed, 1st question)

> Scientists need a research problem and hypothesis to guide them in their research. (informed, 4th question)

### 4.2 Multiple Methods of Scientific Investigations

At the beginning of the project, more than half of the PSTs had mixed views (57%), 33% had naive views, and just two had informed views (10%). In the post-test, the PSTs' views were more improved into informed views (81%). Nineteen percent had mixed views, and none of the PSTs held naive views. Sixty-seven percent of the students kept their informed views, while only 33% held mixed views in the retention test. Below is an example of an informed view, which reflects that scientists may follow different procedures, either experiment or observation, to address the same question:

> When looking for an answer to a question, scientists choose the method that suits them. For example, this design sometimes requires controlling and intervening vari-

**Table 4** Coding scheme: exemplary naive, mixed, and informed views of six NOSI aspects

| NOSI aspects | Questions | Naive | Mixed | Informed |
|---|---|---|---|---|
| Scientific questions guide investigations | 1, 4 | Scientists do not need to have a question to begin a scientific investigation | Scientists need a research question and a hypothesis before starting a scientific investigation | Scientists formulate a research problem about what to research before starting a scientific investigation |
| Multiple methods of scientific investigations | 1, 2, 4, 5, 6, 7 | The experimental method, in which we change some variables and control others, is the only scientific way of obtaining data | There are different ways of getting scientific data regardless of where you collect them or which instruments you use to collect them | Scientists may use experiment or observation, depending on the nature of the research problem |
| Multiple purposes of scientific investigations | 1, 4, 5, 7 | The purpose of science is to provide technological development | Science aims to contribute to both theoretical (theoretical physics) and applied (vaccine technology) fields | The conditions, budgets, interests, and imaginations of scientists determine what and why they will research |
| Justification of scientific knowledge | 2b, 3a, 4b, 5, 7 | Two scientists performing the same experiment under the same conditions must obtain the same results | Even if scientists perform the same procedure, they may get different results because it is impossible to create exactly the same conditions | Performing the same procedures might lead to different results, and negotiation and interpretation play a crucial role in science |
| Recognition and handling of anomalous data | 5 | When there is an anomaly in the data we have obtained, we must repeat the measurement to eliminate the error | Encountering anomalies in science does not indicate a mistake in what we do | Anomalous data is important because it can raise new research questions and give us an opportunity to rethink the existing theories |
| Distinctions between data and evidence | 3 | Data and evidence are the same. Data is the verbal form of evidence | When making a decision about your problem, you use the data you have collected and the evidence you have | Data and evidence are different from each other. Evidence is the interpretation of data in the light of the research problem |

**Table 5** Percentages of the participants across the seven NOSI aspects

| Aspects | Pre-test | | | Post-test | | | Retention-test | | |
|---|---|---|---|---|---|---|---|---|---|
| | % naive | % mixed | % informed | % naive | % mixed | % informed | % naive | % mixed | % informed |
| Question | 52 | 29 | 19 | 19 | 33 | 48 | 19 | 62 | 19 |
| Method | 33 | 57 | 10 | 0 | 19 | 81 | 0 | 33 | 67 |
| Purpose | 71 | 24 | 5 | 33 | 48 | 19 | 43 | 38 | 19 |
| Justification | 38 | 43 | 19 | 10 | 38 | 53 | 10 | 38 | 52 |
| Anomalous data | 67 | 24 | 10 | 38 | 29 | 33 | 38 | 43 | 19 |
| Data and evidence | 57 | 19 | 24 | 0 | 24 | 76 | 0 | 29 | 71 |

ables. However, sometimes the research topic may not be suitable for the experiment. In such cases, scientists can also collect data only through systematic observations. (informed, 2nd question)

Although the PSTs with mixed views generally admitted that scientists also use observation to collect data, they could not separate an observation from an experiment. Those PSTs often perceived observation as a step in the experimentation procedure. The excerpt below clearly demonstrates the perception of observation as a method used in carrying out an experiment, rather than the idea that collecting data by observing an event without intentionally intervening in the independent variable to create a change in the dependent variable is a scientific method itself:

In a study where we investigated the effect of temperature on the dissolution rate, we took water at different temperatures and added the same amount of salt to it. In that experiment, we observed the dissolution amount of salt directly with our eyes and recorded our data. In other words, we used both the observation and the experimental method in that experiment. (mixed, 2nd question)

A group of PSTs with mixed views, on the other hand, admitted that there are different methods for collecting data. However, they attributed the reason for this difference to the data collection tool or the place where data are collected. For example, a PST's response below represents the view that scientists working in different branches of science carry out research by using different tools in different types of laboratories due to the nature of the subjects, which shows that they use different methods:

A scientist working in a physics laboratory, a scientist working in a chemistry laboratory, and a biologist working in nature do different research. The environments in which they work and the materials, sources, and methods they use to collect data vary accordingly. (informed, 4th question)

### 4.3 Multiple Purposes of Scientific Investigations

A vast majority of the PSTs in the pre-test (71%), 33% of the PSTs in the post-test, and 43% of the PSTs in the retention test had naive views about multiple purposes of scientific investigations. The PSTs with naive views generally repeated the generic sentence they saw in their textbooks about the purpose of science. The following excerpt is representative of a naive view:

Scientists conduct controlled experiments to understand the nature in which they live. (naive, 1st question)

Twenty-four percent of the PSTs in the pre-test, 38% of the PSTs in the post-test, and 48% of the PSTs in the retention test held mixed views about the purpose of scientific research. Only one PST in the pre-test and four PSTs in the post-test and retention test admitted that science can serve many different purposes. A PST's response below represents an explanation of the multipurpose of science by emphasizing the factors determining the motivations of scientists about what they will research and what this research will serve:

When a scientist decides what to research, factors such as the conditions they are in, their field of expertise, and their budget limit them............ This research can

> offer a solution to an unsolved problem in the field, lead to technological development, or contribute to the development of a theory. (informed, 4th question)

### 4.4 Justification of Scientific Knowledge

At the beginning of the project, 38% of the PSTs had naive views on this NOSI aspect. However, this rate decreased to 10% at the end of the project, and it was also preserved in the retention test. The PSTs who had naive views on this aspect did not realize that scientists must corroborate their claims with argument-based evidence. Two students with naive views in the post-test and in the retention test had the idea that scientists would get the same conclusion if they followed the same procedure. Below is an example of this:

> In order for us to accept a claim made by a scientist as true, different scientists must reach the same conclusion under the same conditions. This is because two scientists performing the same experiment under the same conditions must obtain the same results. This same result shows us that the claim is scientific. (naive, 5th question)

The results of the study suggest that the PSTs have difficulty understanding how scientists asking similar questions and following similar procedures may validly draw different conclusions. Although those with mixed views admit that scientists asking the same question might get different results, the reasons they have indicated for their answers show that they do not have a mature and realistic idea on this subject. Forty-three percent of the pre-service teachers in the pre-test, 38% in the post-test, and 38% in the retention test held naive views. The following excerpt is representative of a mixed view:

> Two scientists performing the same experiment under the same conditions could obtain different results. This is because, in the environment created to collect data, everything may not be the same down to the last detail. Or the scientist may be tired and careless that day. (mixed, 2th question)

At the end of the project, the rate of the PSTs who had informed views on this aspect increased from 19 to 52%, which was also maintained in the retention test. The PSTs with informed views appreciated that performing the same procedures might lead to different results, and negotiation and interpretation play a crucial role in science, as can be seen in the following response:

> Scientists doing the same experiment may arrive at different conclusions. Their knowledge and expertise on the subject guide them in interpreting the data. When scientists come to different conclusions, they try to persuade each other to determine which is acceptable. For this, they write articles, participate in congresses, and prepare posters. (informed, 2th question)

### 4.5 Recognition and Handling of Anomalous Data

At the beginning of the project, 67% of the PSTs held naive views, 24% held mixed views, and 10% held informed views. At the end of the project, the percentage of students having informed views was 33%. The number of PSTs with mixed views remained almost the same from the pre-test to the post-test. The PSTs who had informed views in the post-test were confused again in the retention test and returned to their mixed views. In the retention test, 38% of the PSTs held naive views, 43% held mixed views, and 19% held informed views.

The PSTs with naive views generally stated that anomalies are experimental errors and can be corrected using different methods. Moreover, these students said that anomalies reduce the reliability of the experiment and must be removed, as it is evident in the following quote:

> When scientists encounter an anomaly, they must reconsider their experiment to understand the reason for their mistake. For this, they can repeat the experiment, if necessary, have a colleague check their work, or change the method and materials they use to collect data. If they cannot eliminate the anomalies, they cannot convince anyone that the results they have achieved are scientific. (naive, 7th question)

On the other hand, a few PSTs with informed views stated that they considered anomalies necessary for the development of science. These PSTs, who defined anomalies as data that do not match expectations, emphasized that scientists should look at this part of the data more carefully if they encounter an anomaly. The following excerpt is representative of an informed view:

> When scientists encounter an anomaly, it's a good opportunity for them. This is because anomalies imply to scientists that there is something out there that has not been noticed and explained before. This new situation may lead to the revision of a part of a theory or the birth of a new theory. (informed, 5th question)

Although the PSTs with mixed views on this aspect of NOSI accepted that anomalies are not mistakes, they did not have informed views of what to do when faced with anomalies. Although the idea that anomalies are very important for the development of science was formed by these PSTs, the answers they gave imply that they had no idea about how anomalies could achieve this, as can be seen in the following response:

> Anomalies play a crucial role in the advancement of science. Scientists, when encountering anomalies, should perceive this situation as an opportunity for their own progress. (mixed, 7th question)

## 4.6 Distinctions Between Data and Evidence

In the pre-test, more than half of the PSTs (57%) held the naive view that scientific data and evidence are the same. In the post-test and in the retention test, there were no PSTs who could not distinguish between data and evidence. Below is an example of a naive view, which reflects that there is no difference between evidence and data:

> We collect data to make a claim as a result of research. These data are numeric. If we express these numerical data in words, we will obtain evidence. (naive, 3rd question)

Nineteen percent of the PSTs had mixed views in the pre-test. This rate increased to 24% in the post-test and to 29% in the retention test. The students with mixed views stated that data and evidence are not the same thing, but they had difficulty explaining the difference between them. At the end of the project, 76% of the pre-service teachers (16 PSTs) had informed views, and one PST dropped back to a mixed view in the retention test. At the beginning of the project, the percentage of those who had informed views was 24%. The PSTs with informed views were aware that data and evidence have different functions and sources. While these PSTs defined data as observations, they emphasized the importance of interpreting the data in the light of the research question for evidence. In the "Zero Energy Building Activity," some PSTs focused on insulation in buildings to reduce greenhouse gas emissions on the data they obtained from their experimental setups and some of them also focused on photosynthesis and calculated how increasing green areas (such as green walls and roofs) in building designs. One data was not enough to provide evidence to support a claim, so PSTs needed to measure other data to develop further evidence. For example, PSTs were asked, "Can you support your claim with only this data or do you need more data to provide evidence?" The following discussion focused on the differences between data and evidence. Moreover, a sample quote is as follows:

> In the research we conduct, we collect data to reach a conclusion. These data could come from an experiment or observation we make. We interpret these data to answer our research question and obtain our evidence. So, I think data and evidence are not the same thing. (informed, 3th question)

## 5 Discussion

The objective of this research was to investigate how the use of ADI in the context of climate change contributes to enhancing PSTs' understanding on NOSI. For this purpose, various ADI activities related to climate change were developed. While conducting the activities, the PSTs engaged in scientific practices such as making claims, evaluating claims, collecting data, and designing methods to solve research problems. At the same time, they had the opportunity to enhance their understanding of NOSI during the activities. The science project demonstrated that it was highly effective in fostering the development of two aspects of NOSI: "multiple methods of scientific investigations" and "distinctions between data and evidence." At the end of the project, most PSTs (81% and 76%, respectively) demonstrated well-informed perspectives on these aspects. It is worth noting that these PSTs maintained their improved performance during the retention test, and it is essential to highlight that most PSTs initially held naive or mixed views regarding these aspects. Still, through their participation in the project, they were able to transform their perspectives. At the end of the science project and in the subsequent retention test, it was noted that no PSTs had naive views. The finding that a science project incorporating activities based on ADI in the context of climate change contributes to PSTs' improved understanding of multiple methods of science is important. This may lead to opportunities for ADI that allow students to engage in scientific practices, such as formulating arguments, collecting and analyzing data, and communicating findings (Sampson et al., 2011). Through these activities, students gain firsthand experience of the diverse methods scientists employ to investigate and understand natural phenomena (Eymur et al., 2022), including climate change. The immersive nature of science project, coupled with ADI, allows PSTs to actively explore different approaches to scientific inquiry, fostering a deeper appreciation for the range of methods available. By engaging in these activities, PSTs not only gain theoretical knowledge but also develop practical skills in applying multiple methods of science. This finding highlights the efficacy of incorporating ADI within the context of climate change education, enabling PSTs to grasp the nuanced nature of scientific investigation and reinforcing their understanding of the multitude of approaches scientists use to explore complex scientific phenomena. In line with these results, Akerson et al. (2024) demonstrated that explicit instruction of inquiry practices like ADI enhances skills in planning investigations, collecting data, and interpreting conclusions, and students would gain from this type of teaching, which fosters inquiry-based conceptual knowledge of the nature of scientific inquiry and the application of scientific inquiry to explore scientific questions. Also, Senler (2015) found that merely engaging in hands-on activities does not suffice to enhance teachers' or students' perceptions of inquiry. S/he observed that these activities need to be complemented by deliberate reflection on the nature of science and inquiry processes.

Moreover, in parallel with this finding, Leblebicioglu et al. (2017) found that their science camp program, in which students conducted four inquiries through their questions about surrounding soil, water, plants, and animals under the guidance of university science educators, was most effective in the aspect of multiple methods. Additionally, in Çetin's (2021) study, which aimed to enhance 10th-grade students' views of NOSI through inquiry-based laboratory instruction, it was noted that initially, only a quarter of the students held naive views regarding the multiple methods aspect. However, by the end of the study, none of the students had a naive view. Similarly, the finding that a science project incorporating activities based on ADI in the context of climate change enhances PSTs' understanding of the distinction between data and evidence is remarkable. ADI emphasizes the critical evaluation and interpretation of data collected during scientific investigations (Metin Peten, 2022). Metin Peten's (2022) study, which involved ADI activities with PSTs, revealed notable advancements in their comprehension of NOSI aspects. The results of the study suggest that the implementation of the ADI model, combined with explicit-reflective teaching of NOSI, has shown promising outcomes in improving the PSTs' understanding of NOSI in specific aspects. Metin Peten (2022) has proposed investigating the ADI model with explicit-reflective NOSI instruction in various contexts to validate its potential benefits. In the light of this, the remarkable outcomes of ADI activities conducted in the context of climate change lend support to this recommendation. These results underscore the significance of utilizing the ADI model with explicit-reflective teaching in enhancing PSTs' understanding of NOSI, particularly in relation to climate change. By engaging in activities that require analyzing and interpreting data related to climate change, they are able to develop a deeper comprehension of the distinction between raw data and evidence. Through the iterative process of constructing arguments based on data, students learn to identify patterns, draw meaningful conclusions, and differentiate between the information collected and the conclusions drawn from that data (Walker et al., 2012).

Leblecioglu et al. (2019) reached a similar conclusion. In that study, the students struggled to differentiate between data and evidence, and the researchers attempted to explain it with reference to the Turkish education system. According to them, in the Turkish education system, teachers commonly refer to data obtained from experiments as "results of the experiment" and draw conclusions based on these results. As they often do not discuss both supporting and non-supporting results in relation to their conclusions, students become less familiar with the term “evidence.” Indeed, it is not surprising to observe an increase in the number of students with informed views when the difference between data and evidence is consciously taught to them. When students are explicitly taught and guided to understand the distinction between data and evidence, their understanding and recognition of these concepts are likely to improve, leading to a more informed perspective.

On the other hand, the project seemed to be less effective in developing ideas about “multiple purposes of scientific investigations.” At the end of the project, only 19% of the PSTs had informed views about the multiple purposes of scientific investigation. While ADI is known for its effectiveness in promoting scientific practices and critical thinking skills, it seems that in this particular context, it may not have fully addressed the aspect of understanding the various purposes of scientific investigation. This finding suggests that additional strategies or modifications to the project curriculum may be necessary to enhance PSTs' understanding of this area. It could be beneficial to explore alternative approaches, such as incorporating explicit discussions, real-world examples, or case studies that highlight different purposes of scientific investigation related to climate change. By doing so, PSTs can gain a more comprehensive understanding of how scientific investigations serve multiple purposes, including exploring new phenomena, testing hypotheses, developing theories, and informing decision-making processes.

The results regarding the aspect of “recognition and handling of anomalous data” deserve further discussion. At the beginning of the project, a majority of the PSTs (67%) held naive views, but this percentage decreased to 38% in the post-test and in the retention test. The decrease in the prevalence of naive views can be regarded as a favorable result, indicating that the implementation of the project was effective. The decline in naive views indicates that the methods and tasks utilized throughout the project effectively confronted and converted the PSTs' initial misconceptions or restricted comprehension. At this point, it should be noted that a longitudinal study is needed to definitively determine whether the decrease in the naive view is permanent. Although the percentage of PSTs with informed views in the post-test and in the retention test may not be as high as expected, the significant number of students transitioning from naive views to mixed views can be regarded as a success of the project. This suggests that the project effectively facilitated a shift in the PSTs' initial misconceptions or limited understandings, leading them towards a more nuanced perspective. While achieving a high percentage of students with informed views would have been ideal, the fact that a considerable number of students progressed from a naive to a mixed view indicates the positive impact of the project. This outcome highlights the project's success in promoting cognitive growth and fostering a more sophisticated understanding of the subject matter. It also emphasizes the importance of acknowledging and celebrating the progress made by PSTs, even if they have not yet fully reached the desired level of informed views. Anomalous data, which deviate from expected patterns or contradict initial hypotheses, pose challenges and opportunities in scientific inquiry. By engaging in ADI activities that involve analyzing and interpreting data related to climate change, PSTs develop a deeper understanding of the significance of anomalous data and how to handle them effectively within the scientific process. Through iterative argumentation and evidence evaluation, PSTs learn to recognize the value of anomalous data in refining scientific explanations and constructing robust arguments.

The project provides a supportive environment for PSTs to actively engage with anomalous data, encouraging critical thinking, problem-solving, and scientific reasoning skills. By gaining a better understanding of the recognition and handling of anomalous data, PSTs develop a more nuanced perspective on the complexities and uncertainties inherent in scientific investigations, ultimately contributing to their overall scientific literacy and ability to critically evaluate scientific claims. This finding highlights the effectiveness of incorporating ADI activities within the project curriculum to enhance PSTs' views of the recognition and handling of anomalous data, a crucial aspect of the nature of scientific investigation in the context of climate change.

Based on the results of this research, some implications on science education can be discussed. As the Earth's climate patterns undergo rapid and unprecedented changes, it is imperative that science education incorporate this topic into its curriculum. The multifaceted and complex nature of climate change necessitates a deep understanding of NOSI in the field of education. Climate change involves interconnected systems, intricate feedback loops, and various factors that influence its occurrence and impacts. By comprehending NOSI, educators can guide students in exploring the dynamic processes involved in climate change research, such as data collection, analysis, modeling, and interpretation.

## 6 Conclusion and Limitations

The results of the study reveal important findings for teaching practices related to the ADI model and the understanding of NOSI in the context of climate change. This study highlights the importance of using ADI to teach NOSI to PSTs within the context of climate change and shows that using the ADI model creates an inquiry environment that includes essential NOSI characteristics. It describes one of the initial attempts to investigate the role of the ADI model as an inquiry context for explicitly and reflectively teaching NOSI to PSTs in climate change education. The ADI model, coupled with explicit-reflective teaching of NOSI, offers a remarkable opportunity for PSTs to engage in authentic climate change research and gain a comprehensive understanding of its interconnectedness with various aspects of NOSI. The study was conducted as part of a science project that lasted five days and included four ADI activities in the context of climate change; however, it is important to recognize the limits of this research. To tackle the importance of climate change, it is vital to conduct comprehensive studies that merge scientific investigation with various groups and educational curricula. Future research should explore its potential benefits with diverse learner groups to further validate the effectiveness of the ADI model with explicit-reflective NOSI teaching in the context of climate change. This will provide a more comprehensive understanding of the model's efficacy in teaching NOSI within the broader context of climate change education.

## Appendix. VOSI-270A [preservice_inservice K-8] (from, Schwartz 2007, Schwartz, Lederman, Lederman, 2008)

**Appendix 1. VOSI-270A [preservice_inservice K-8] ( from, Schwartz 2007, Schwartz, Lederman, Lederman,2008)**

Name: ___________________________________

Date: __________________________________

*You have had some experience with learning science and have certain views about the type of things you learn in science class and where the science information comes from. There are no right or wrong answers to the questions on this survey. We are interested in your ideas about science and how science is done.*

RED FONT: TARGET ASPECTS (secondary aspects that often emerge from responses are contained within the parentheticals)

****Remove targets before administrating survey.

1. What types of activities do scientists (e.g., biologists, chemists, physicists, earth scientists) do to learn about the natural world? Discuss how scientists (biologists, chemists, earth scientists) do their work.

Questions, methods, purpose

2. (a) What do you think a scientific experiment is? Give an example from something you have done or heard about to support your answer.

Methods; useful for interpreting other responses

(b) Does the development of scientific knowledge **require** experiments?

- If yes, explain why. Give an example to defend your position.
- If no, explain why. Give an example to defend your position.

Methods, justification

3. (a) What does the word "data" mean in science?

Data/evidence distinction

(justification)

(b) Is "data" the same or different from "evidence" ? Explain.

4. A person interested in animals looked at hundreds of different types of animals who eat either meat or plants. He noticed that those animals who eat similar types of food tend to have similar teeth structures. For example, he noticed that meat eaters, such as lions and coyotes, tend to have teeth that are sharp and jagged. They have large canines and large, sharp molars. He also noticed that plant eaters, such as deer and horses, have smaller or no canines and broad, lumpy molars. He concluded that there is a relationship between teeth structure and food source in the animals.

Do you consider this person's investigation to be an **experiment**? Please explain why or why not.

Methods
(purpose, questions)

Do you consider this person's investigation to be **scientific**? Please explain why or why not by describing what it means to do something "scientifically."

This investigation **is** / **is not** (circle one) scientific because….

Methods, justification,
(questions, purpose)

5. (a) What type of information do you think is required for scientists to justify and accept a scientific claim? (In other words, how do scientists know when they are ready to make their research results public? What do they need to report to convince others of their claim?)

Justification
(purpose, anomalies, methods)

Do you think all types of scientists have the same requirements as you stated in (a) for justifying and accepting scientific claims? Explain and give examples.

6. The "scientific method" is often described as involving the steps of making a hypothesis, identifying variables (dependent/independent), designing an experiment, collecting data, reporting results. Do you agree that to do good science, scientists must follow the scientific method?

   **_______YES, scientists must follow the scientific method**

   **_______NO, there are many scientific methods**

   - If YES (you think all scientific investigations must follow a standard set of steps or method), describe why scientists must follow this method.

   methods

   - If NO (you think there are multiple scientific methods), explain how the methods differ and how they can still be considered scientific.

7. Scientists sometimes encounter inconsistent findings (anomalous information).

   (a) How are anomalies identified in science? (i.e. What is considered "inconsistent" in scientific research?) Provide an example, if possible.

   Anomalies
   (justification, purpose, methods)

   (b) What do you think scientists do when they find an anomaly?

   (c) Do you think **all** scientists identify and handle anomalous information this same way? Why or why not?

   (d) How do *students* typically identify and handle anomalies (inconsistent data) in a **science classroom**? What do you think is the motivation for students to do this?

   (e) Do you think students and scientists handle anomalies in the same way? YES / NO

   For the same reasons? YES / NO

   Explain your choices.

**Acknowledgements** This study was conducted as part of the scientific education initiatives supported under the TUBITAK 2237-A program.

**Funding** Open access funding provided by the Scientific and Technological Research Council of Türkiye (TÜBİTAK).

## Declarations

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



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