Science & Education
https://doi.org/10.1007/s11191-025-00719-z

ARTICLE

A Professional Development Program to Improve NOSI Views and Lesson Plan Design Skills of Science Teachers Utilizing Argumentation-Driven Inquiry

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Received: 21 March 2025 / Revised: 13 December 2025 / Accepted: 18 December 2025

Abstract
Nature of Scientific Inquiry (NOSI) is a cornerstone of effective science education, yet research consistently demonstrates that teachers possess inadequate understanding of its aspects. One promising approach to address these challenges is argumentation-driven inquiry, a method that combines argumentation with NOSI aspects and emphasizes the construction, evaluation of evidence-based arguments, and reasoning, which ultimately would result in having an adequate understanding of NOSI. In line with this, this study aims to address these issues by providing teachers with a 10-week-long hybrid argumentation-driven inquiry professional development (PD) program and to investigate the effect on science teachers' understanding of NOSI and their lesson plan design skills to integrate these concepts. Additionally, the study explores teachers' perceptions of the impact of the program on their professional growth and the challenges they encountered. The study employed an action research methodology, where teachers acted as active participants by receiving training, then carrying out NOSI-focused classroom implementations, reflecting, receiving and providing feedback at each stage in an iterative context. The participants were six (2 females, 4 males) in-service middle school science teachers working in different regions in Türkiye. The data sources included the Views about Scientific Inquiry Questionnaire, argumentation-driven inquiry lesson plans designed by teachers, reflection reports, and focus group interviews. The findings indicated that teachers' understanding of NOSI aspects and lesson plan design skills notably improved following the interventions with variations in different aspects yet indicating enhanced quality of instructional practices. In line with the results, implications are critically discussed in terms of designing and delivering effective PD programs.

Keywords Nature of Scientific Inquiry · Argumentation-driven Inquiry · Professional Development Program · Science Teachers · Lesson Plan Design Skills

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1 Introduction

One of the central aims of science education is to cultivate scientific literacy, a multifaceted construct that includes not only an understanding of scientific concepts but also insights into how scientific knowledge is developed, validated, and applied in real-world contexts (Roberts, 2007; OECD, 2016). Scientific literacy enables individuals to make informed decisions, engage with socio-scientific issues, and participate in civic life. Understanding how science works, the values, assumptions, and methods of scientific inquiry is a fundamental component of scientific literacy (AAAS, 1993; Bybee, 1997; NGSS Lead States, 2013). Within this broader vision, the Nature of Science (NOS) has emerged as a core domain, referring to the epistemology of science, how scientific knowledge is constructed, its limitations, and the practices that sustain it (Abd-El-Khalick & Lederman, 2000a; Lederman, 2007). Scientific Inquiry (SI), on the other hand, pertains to the practices and processes scientists use to investigate natural phenomena, including question formulation, evidence collection, and explanation construction (Crawford, 2000; Duschl, 2008; Doğan et al., 2020). While these constructs are often addressed separately in research and curricula, there is a growing recognition that they are deeply interconnected and mutually reinforcing (Erduran & Dagher, 2014; Osborne et al., 2004). Building upon this connection, some scholars have proposed the concept of the Nature of Scientific Inquiry (NOSI), which emphasizes the epistemic principles embedded in the actual practices of inquiry (Lederman et al., 2014; Schwartz et al., 2008). NOSI integrates selected aspects of NOS, such as the role of evidence, interpretation, and the tentativeness of knowledge, with the procedural and social dimensions of inquiry. However, there is ongoing debate in the literature regarding whether NOSI should be treated as a distinct construct or as a subset of NOS (Duschl, 2008; Khishfe, 2012). While NOSI is not universally recognized as "central" to science education, it has gained traction in specific educational frameworks that prioritize inquiry-based and epistemologically informed teaching (Erduran, 2019; Osborne, 2010). Accordingly, in this study, we approach NOSI as a pedagogically useful bridge between NOS and inquiry. As outlined by Lederman et al. (2014), NOSI encompasses the essential processes and practices through which scientific knowledge is generated and justified. This framework provides educators and learners with critical insights into the epistemological underpinnings and methodological approaches that guide scientific investigation. By emphasizing inquiry as a central component of scientific literacy, NOSI fosters a deeper understanding of how science works in practice (Schwartz et al., 2023).

NOSI is characterized by several key aspects that collectively define the processes and outcomes of scientific investigation (Lederman et al., 2014; Schwartz et al., 2008). First, all scientific investigations are driven by questions that guide the process of inquiry. While hypotheses can be an integral part of some studies, they are not always a requirement; the central role of inquiry lies in the formulation and pursuit of meaningful questions. Moreover, there is no single, universal method in science. The approaches and techniques that scientists use vary depending on the context, research goals, and the nature of the phenomenon being studied. The methods chosen by scientists are closely aligned with the questions they aim to address. This flexibility in methodology underscores the dynamic nature of scientific inquiry. Furthermore, scientists working on similar questions or using similar procedures may still arrive at different results. These differences often stem from variations in data interpretation, methodological choices, and theoretical perspectives. Such variability highlights the subjective and iterative nature of scientific work. The procedures and methods selected during the inquiry process also play a significant role in shaping the outcomes. Decisions made at each stage of the investigation can influence the type, quality, and reliability of the results obtained. However, any conclusions drawn from an investigation must be firmly rooted in the data collected. These conclusions must be supported by thorough analysis and must accurately reflect the evidence derived from the data. It is important to note that scientific data and evidence are not synonymous; data refers to raw observations, whereas evidence is generated through the interpretation and contextualization of that data. Finally, scientific explanations represent a synthesis of new data with prior knowledge and theoretical frameworks. Scientists integrate fresh observations with existing scientific understanding to develop explanations that are coherent, logically consistent, and reflective of the available evidence.

Despite the importance of NOSI to science education, research consistently demonstrates that many teachers possess an incomplete or superficial understanding of their components (Cofre et al., 2019; Mesci et al., 2020). This limitation often prevents them from effectively incorporating NOSI into their instructional practices, thus hindering their ability to foster scientific literacy in students (Khishfe & Lederman, 2006; Mesci et al., 2020; Osborne, 2010). To address this gap, innovative professional development programs are needed, combining theoretical training with opportunities for practical application in classroom settings.

One promising approach to addressing these challenges is argumentation-driven inquiry, a pedagogical method that emphasizes the construction and evaluation of evidence-based arguments (Erduran et al., 2005; Jiménez-Aleixandre & Erduran, 2007; Osborne, 2005). Argumentation is a central process in both science and science education, facilitating critical thinking and reflective practices among teachers and students alike (Aglarci Özdemir et al., 2025). Toulmin's (1958) seminal work, The Uses of Argument, provided a foundational framework for understanding the structure of arguments, identifying six key components: claims, evidence, warrants, backing, qualifiers, and rebuttals. This model has become a cornerstone of argumentation-based pedagogy, particularly in the context of NOSI.

In science education, argumentation serves as a powerful tool for engaging learners in evidence-based reasoning and the justification of knowledge (Sadler, 2006). By aligning closely with NOSI aspects such as the use of evidence and the justification of conclusions, argumentation-driven inquiry enhances learners' understanding of how scientific knowledge is constructed and validated. Studies by Osborne et al. (2004) and Mesci et al. (2023) have shown that argumentation-based teaching improves inquiry skills, fosters collaborative learning, and promotes deeper engagement with the nature of science. For teachers, argumentation provides a framework for integrating NOSI into their lesson plans, enabling them to model and scaffold evidence-based reasoning for their students. Despite its promise, limited research exists on how argumentation-driven inquiry affects teachers' professional development and classroom practices. In line with that, this study seeks to address these gaps by providing teachers with a structured, feedback-rich professional development (PD) program that combines argumentation with NOSI aspects, emphasizing both theoretical knowledge and practical application. Consequently, this study investigates the effect of argumentation-driven inquiry PD training on science teachers' understanding of NOSI and their ability to integrate these concepts into lesson plans. Additionally, the study explores science teachers' perceptions of the effect of PD on their professional growth and the challenges they encountered during implementation. The following research questions guide the study:

1. How does argumentation-driven inquiry PD program affect science teachers' NOSI views?
2. How does argumentation-driven inquiry PD program affect teachers' lesson-plan design skills?

3. How do science teachers perceive the effect of argumentation-driven inquiry PD program on their professional development and growth?
4. How do science teachers describe the difficulties they encountered throughout the process?

2 Theoretical Framework

The study is grounded in four interrelated theoretical perspectives, each of which provides a robust foundation for designing and implementing the professional development program for science teachers. Together, these perspectives offer a comprehensive lens for understanding how argumentation-driven inquiry affects teachers' understanding of NOSI and their ability to integrate it into their lesson planning.

Firstly, Sociocultural Learning Theory (Vygotsky, 1978) highlights the role of social interaction in learning, where knowledge is co-constructed through dialogue and shared experiences (Osborne et al., 2004; Zohar & Nemet, 2002). Teachers in this study engage in collaborative activities such as peer discussions, reflective feedback sessions, and group-based inquiry, which help them refine their understanding of NOSI and develop strategies to incorporate it into their teaching practices. This collaborative environment aligns with Vygotsky's concept of the Zone of Proximal Development (ZPD), enabling teachers to move beyond their current capabilities with the support of their peers and facilitators.

Constructivist Learning Theory (Bruner, 1960; Piaget, 1972) emphasizes the active role of learners in constructing their understanding through experiences. This study incorporates inquiry-based activities and argumentation exercises, encouraging teachers to connect NOSI concepts with their existing practices. By engaging in meaningful tasks, teachers transform their understanding of NOSI and develop strategies for classroom integration, leading to professional growth (Duschl & Osborne, 2002).

The third theoretical foundation is Dialectical Argumentation Theory, which is particularly relevant to the argumentation-driven inquiry approach employed in this study. Rooted in epistemology and the philosophy of knowledge (van Eemeren et al., 1996), dialectical argumentation theory emphasizes the importance of constructing claims and justifying them through connections to both theoretical and experimental evidence (Jiménez-Aleixandre & Erduran, 2007). According to Osborne (2005), argumentation is central to proving, predicting, and evaluating evidence and involves critically considering opposing arguments during the process of knowledge construction. Aristotle's classification of argumentation into didactic, rhetorical, and dialectical functions further highlights its multifaceted nature (van Eemeren & Grootendorst, 2004). In dialectical argumentation, opposing ideas and counterarguments are integral to the reasoning process, allowing for the coordination of diverse perspectives and the re-evaluation of one's own ideas in light of alternative viewpoints (Grooms et al., 2014; Walton, 2000). This theoretical perspective aligns closely with the argumentation-based inquiry instructional approach, originally introduced as the "Science Writing Heuristic" by Keys et al. (1999). This approach is designed to enhance students' engagement in scientific discussions and deepen their understanding of science by reflecting the argumentation and dialectical processes used by scientists (Burke et al., 2006). By experiencing these processes, students and teachers alike gain insight into how theories, explanations, and models are constructed (Erduran et al., 2005; Mesci et al., 2023). In this study, teachers are introduced to the dialectical argumentation framework as a tool to strengthen their reasoning skills and their ability to foster evidence-based thinking in their classrooms.

Finally, Desimone's Professional Development Model (2009) provides an overarching structure, emphasizing content-specific training, active learning, coherence with instructional goals, and iterative feedback. By combining NOSI and argumentation training with classroom applications, this study ensures that teachers gain both theoretical understanding and practical skills for lesson planning and implementation (Cavagnetto, 2010).

By weaving together Sociocultural Learning Theory, Constructivist Learning Theory, Dialectical Argumentation Theory, and Desimone's Professional Development Model, this study offers a comprehensive framework for investigating how argumentation-driven inquiry influences teachers' NOSI understanding and lesson planning sessions. This integrated approach not only addresses the theoretical foundations of NOSI and argumentation but also provides practical insights into how these concepts can be effectively implemented in professional development settings.

3 Methodology

The study employed an action research methodology, incorporating a hybrid professional development intervention program based on argumentation-driven inquiry in Türkiye. The PD program aimed to improve teachers' understanding of NOSI while improving their lesson plan design skills. Additionally, challenges encountered by teachers during the process were identified, and measures were taken to improve the implementation, indicating a cyclical process, which is a key characteristic of action research. The study involved a three-stage PD program where teachers received feedback at each stage, leading to iterative improvements. This aligns with the plan, act, observe, reflect, and reapply cycle, which is fundamental in action research (Calhoun, 2002). Teachers first received training, then applied NOSI-focused lesson plans in their classrooms and reflected on their experiences. This is consistent with action research's emphasis on solving practical problems (O'Brien, 1998). In this study, teachers were not just data providers but also active participants shaping the process. Their continuous reflection on lesson plan design and classroom implementation supports the reflective practice component of action research (Zeichner & Liston, 2014). Teachers developed NOSI-related lesson plans, received feedback from instructors and peers, implemented them in classrooms, and then reassessed their effectiveness. This iterative process is highly aligned with reflective practice strategies, which are frequently employed in action research (McNiff, 2016). The intervention aims to support teachers' professional development while addressing practical challenges, improving instructional practices, and actively involving participants in shaping the process. This approach ensures that action research is the most suitable research design for this study.

3.1 Participants

Six (2 females, 4 males) in-service middle school science teachers, agreed to participate in the study. The study sample consists of varying levels of professional experience, educational backgrounds, and workplace settings. Most participants had between 10–15 years (50%) or 5–10 years (33.3%) teaching experience, while smaller proportions had either less than 5 years or more than 20 years in the profession. Regarding educational qualifications, the majority (80%) hold a bachelor's degree, 33.3% have a master's degree, and none

Table 1 Details about study participants

Name	Gender	Professional experience	Degree	Workplace context
Evan	Male	10–15 years	Bachelor	Urban center
Bella	Female	10–15 years	Master	District center
Yale	Male	0–5 years	Bachelor	Urban center
Sam	Male	5–10 years	Bachelor	Urban center
Hazel	Female	5–10 years	Bachelor	Urban center
Miles	Male	10–15 years	Master	District center

have earned a doctorate. Regarding school location, 80% of teachers work in urban centers, 33.3% in district centers, and none work in rural areas. These insights highlight the teachers' diverse professional and educational backgrounds, as well as the varying academic performance levels of students in different school settings (Table 1).

The sample was selected using convenience sampling, one of the purposeful sampling methods, from teachers who enrolled in '*Argumentation-Driven NOSI Training Professional Development Community*' program that is organized by Ministry of National Education's Inservice Teacher Training Directorate in Türkiye. Pseudonyms were used to maintain confidentiality. All 3 authors served as the facilitators of the professional development program and held training sessions.

3.2 Implementation process: Argumentation-Driven Inquiry Professional Development Program

The argumentation-driven inquiry PD program carried out in this study was a hybrid professional development program that consisted of three stages and lasted a total of 10 weeks. Stage I was conducted entirely online, whereas Stage II and III followed a hybrid format. The necessary infrastructure and the learning platform used for online sessions were provided by the Ministry of National Education's Inservice Teacher Training Directorate, in accordance with the guidance and expertise of the facilitators. The hybrid nature of the program facilitated professional support for teachers while allowing them to continue their teaching careers in their respective provinces (Bozkurt, 2017). It also enabled them to receive ongoing feedback throughout the process (Darling-Hammond et al., 2017). The structure of the PD program is summarized in Fig. 1.

The program aimed to provide first-hand experience to science teachers and support them with iterative constructive feedback throughout the process.

PD Stage I, conducted entirely online over three weeks, consisted of theoretical training sessions organized for teachers by the facilitators aiming to introduce the basic knowledge about NOSI and argumentation concepts as well as how to use argumentation as a teaching method in science classes. Details on the weekly content of the first stage are provided in Table 2.

PD Stage II, conducted in a hybrid format for over five weeks, involved both the introduction and the implementation of the argumentation-inquiry focused lesson plans. During this stage, facilitators designed five lesson plans that integrated argumentation as a teaching method while incorporating key aspects of NOSI. Details regarding the lesson plans (grade level, subject, objectives, and addressed NOSI aspects) are provided in Appendix 1. Each week during the PD sessions, one lesson plan was introduced to participants allowing them to experience and practice these lesson plans as if they were students.

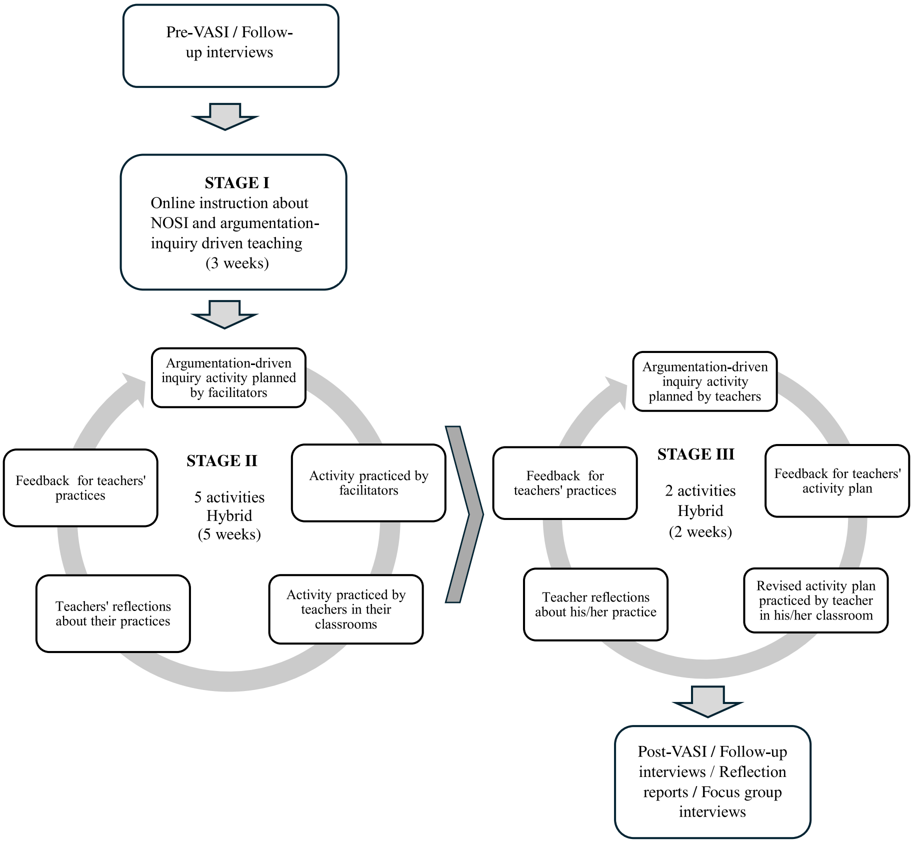

Fig. 1 Three stages of the argumentation-driven inquiry professional development program

Table 2 Content and the details of PD stage I

Week/Content	Details of the content
Week 1 • NOSI and its aspects • Activity: 'Mr. Star's Death'	During the first week of theoretical training, a presentation was given on NOSI and its key aspects. To enhance teachers' understanding of NOSI aspects, the activity called 'Mr. Star's Death' was implemented
Week 2 • Argumentation and its components • Activity: Is Global Warming a Human Activity?	During the second week of theoretical training, a presentation was given on Toulmin's Argumentation Model and its essential components: formulating a claim, presenting evidence, and constructing a proposition. The activity 'Is Global Warming a Human Activity?' designed by instructors was used as a sample argumentation application, and an argumentation map was created based on it
Week 3 • Argumentation examples • Argumentation-driven teaching • The role of the teacher in argumentation-driven teaching	During the third week of the training, teachers were introduced to argumentation as a teaching method through various examples and strategies for effectively managing the process. The argumentation examples used in this training were determined by considering the textbooks' contexts and the curriculum's achievements

Facilitators acted as teachers in the classroom to provide first-hand experience for teachers to learn about these practices. Subsequently, teachers implemented the lesson plans in their classrooms on a weekly basis, reflected on their experiences, and provided feedback on each other's implementations. In Stage II, the sessions where facilitators introduced lesson plans allowed teachers to experience them as students, and provided feedback on teachers' reflections from previous implementations were conducted online. During this phase of the professional development program, teachers implemented the lesson plans face-to-face in their classrooms with their students.

Lastly, Stage III, which also conducted in a hybrid format and lasted for two weeks, focused on teachers' independent design and implementation of argumentation-driven NOSI lesson plans in their own classrooms. At this stage, each teacher first shared their initial designs with their colleagues and facilitators during the PD meetings. Throughout the meetings, each teacher received constructive feedback from both their colleagues and facilitators. Based on the feedback and comments gathered, the initial designs were revised and subsequently implemented in their classrooms. In the following meetings, teachers first were asked to reflect on their classroom practices, discuss the challenges they encountered particularly in integrating NOSI and argumentation and share their experiences. This iterative process lasted for two consecutive weeks, with the same procedure systematically followed each week. During Stage III, sessions where teachers presented their self-designed lesson plans and received feedback from peers and facilitators were conducted online. Teachers then refined their lesson plans based on the feedback and implemented them in their classrooms through face-to-face instruction.

3.3 Data Collection Process and Tools

Four data collection tools used in the study, and these tools and addressed research questions are listed as follows:

1. Views About Scientific Inquiry (VASI) Questionnaire (Lederman et al., 2014) and its follow-up interviews were used to answer the first research question while examining pre-and post-views of teachers on NOSI aspects.
2. Argumentation-driven inquiry-based lesson plans designed by the teachers were used to investigate the second research question.
3. Reflection reports of teachers were used to investigate the third research question.
4. Focus group interviews were used to investigate the fourth research question.

3.3.1 The Views About Scientific Inquiry (VASI) Questionnaire and Follow-up Interviews

The Views About Scientific Inquiry (VASI) Questionnaire was initially developed by Lederman et al. (2014) and later translated and adapted into Turkish by Mesci et al. (2020). The VASI addresses eight key dimensions of NOSI and consists of seven open-ended questions (see Appendix 2). The VASI questionnaire was administered to teachers at the beginning of Stage I as a pre-test, and at the end of the study as a post-test. Following each administration, semi-structured follow-up interviews were conducted with each participant to further explore their views and clarify their responses to the questionnaire. Each interview lasted approximately 30 min.

3.3.2 Argumentation-driven Inquiry Lesson Plans

In Stage III, teachers were asked to design argumentation-driven inquiry-based lesson plans. An argumentation-driven inquiry activity lesson plan template was used in the study to standardize the material development process, ensure coherence with curricular objectives, and enhance the visibility of integrated NOSI and argumentation aspects. The template used was an adapted version of argumentation-driven inquiry activity lesson plan template, originally developed by Mesci et al. (2023). The original template was designed for argumentation-based nature of science lesson plans and consisted of eight dimensions including pre-lesson preparation, agreement on the investigative question, students' testing/inquiry/experimenting the research questions, generating claim and evidence, defense of arguments and consensus process, comparison of findings with readings/resources, providing opportunities for reflecting on changes in ideas, and nature of science. The adapted version used in this study retained all eight dimensions, however NOSI dimension was incorporated in place of the general nature of science dimensions.

After the introduction of argumentation-driven inquiry lesson plans in Stage II, teachers were asked to independently design two argumentation-driven inquiry lesson plans without support. Facilitators provided feedback on each plan before implementation in the classroom. These lesson plans served as data sources to examine teachers' lesson plan design skills and their development in integrating NOSI and argumentation.

3.3.3 Reflection Reports and Focus Group Interviews

During Stage III, after each lesson plan implementation, teachers were required to write reflection reports to document their planning process and classroom implementations. These reports included reflections on what worked, what did not work, challenges encountered, positive and negative outcomes, strengths, areas for improvement, and overall evaluations. Each teacher completed two reflection reports in total. The questions used in the reflection reports are listed below:

- Did you prepare your lesson plan? If so, did you encounter any challenges during the process? If yes, what were they?
- Did you implement the lesson plan in your classroom? If so, did you face any challenges during the implementation? If yes, what were they?
- Did you experience difficulties in integrating the aspects of the NOSI into the learning objectives while preparing your lesson plan? Why?
- Did you encounter challenges in addressing the aspects of the NOSI while implementing your lesson plan? Why?

In addition to reflection reports, at the end of the Stage III, a focus group interview was conducted with the teachers to understand their perceptions of the effect of PD on their professional growth. The challenges teachers encountered throughout the process were also discussed in the focus group interview. Data from the 40-min focus group interview was used to support teachers' reflection reports.

3.4 Data Analysis

3.4.1 The Views About Scientific Inquiry (VASI) Questionnaire and Follow-up Interviews

The pre- and post-VASI responses, along with follow-up interview data from each participant, were categorized based on the eight aspects of NOSI framework, as described by Lederman et al., (2014, p. 72). These responses were assessed on a continuum scale, ranging from naive views ('−') to mixed views ('+') to progressively more informed levels of understanding ('+', '+ +', '+ + +'), in line with Schwartz et al. (2008). A '−' label was used when participants' views contradicted or did not align with the consensus perspective on a given NOSI aspect. A '+' designation reflected agreement with the established view, while '+ +' indicated the participant's ability to explain the aspect in their own words. Those placed in the '+ + +' category demonstrated not only the ability to explain the concept but also provided additional examples beyond what was discussed in class (Schwartz et al., 2008). If participants showed conflicting or inconsistent views, they were categorized in the '(+)' range, representing 'mixed' views. To ensure reliability of analysis, researchers first analyzed all VASI surveys independently and then conducted discussions to reach consensus. All data were analyzed in this manner by reaching consensus.

3.4.2 Argumentation-driven Inquiry Lesson Plans

The argumentation-driven inquiry activities planned by teachers were analyzed by using 'Argumentation Based Inquiry Rating Scale' developed by Mesci et al. (2023). The original rating scale was designed on a 5-point scale (0 = not acceptable; 1 = poor; 2 = average; 3 = good; 4 = very good) and consisted of two sections. The first section included 33 items organized into 11 categories, enabling raters to quantitatively assess how well lesson plans and their execution align with the principles of the argumentation-driven inquiry-based approach. The second section provided space for a general evaluation, allowing raters to express their views on the strengths and weaknesses of the implemented argumentation-driven inquiry lessons. For this study**,** the researchers revised the rating scale based on the adapted lesson plan template to assess teachers' argumentation-driven inquiry lesson plans. The revised scale includes 25 items grouped into eight categories (pre-lesson preparation, agreement on the investigative question, students' testing/inquiry/experimenting the research questions, generating claim and evidence, defense of arguments and consensus building, comparison of findings with readings/resources, opportunities for reflecting on changes in ideas, and nature of scientific inquiry). The revised rating scale follows a 5-point structure and begins with a scoring criteria section, providing raters with guidelines for assigning scores to argumentation-driven inquiry activities. To ensure reliability, researchers first analyzed all lesson plans independently and then conducted discussions to reach a consensus.

3.4.3 Reflection Reports and Focus Group Interviews

The data, including reflection reports and focus group interviews, were analyzed holistically using content analysis to examine teachers' perceptions of the effect of argumentation-driven inquiry-based training on their professional development and to explore how they described the challenges they encountered throughout the process (Krippendorff, 2013).

4 Findings

4.1 Findings regarding the Nature of Scientific Inquiry Views

This section presents pre- and post- assessment results of six teachers' views on the aspects of NOSI, analyzed using the NOSI views continuum framework (Schwartz, 2007; Lederman et al., 2002). A descriptive analysis of the changes in teachers' views on NOSI are provided in Table 3.

As shown in the table, the findings indicate a general trend of improvement across NOSI aspects, particularly among teachers who initially held mixed views. The findings demonstrate varied shifts in understanding across different aspects. Details regarding the changes in each aspect are provided below:

4.1.1 Scientific Investigations All Begin with a Question and Do Not Necessarily Test a Hypothesis (SI-1)

According to the pre-test and post-test results, teachers demonstrated varying shifts in their understanding of this aspect. For instance, Bella progressed from a mixed understanding (+) to a more articulated understanding (++), while Hazel shifted from a naïve understanding (-) to a mixed understanding (+). Example quotation from Bella's progression with more sophisticated statements and Hazel's slightly improved pre-post VASI responses with minor changes in his statements in this aspect are provided below:

> [Bella-pre-test]: "*1a: Yes, they began the investigation process by formulating a hypothesis, determining the dependent and independent variables, and reached a conclusion. 1b: Yes, it is, as I answered in the 1a section of the question. 2: Yes. Curiosity is necessary to formulate a hypothesis. I believe curiosity begins with questioning and asking questions.*"
> [Bella-post-test]: "*1a: It's a scientific investigation. Because it started with a question and tried to prove the similarity it noticed by collecting data with evidence. 1b: It's an experiment. Because it collected comparative data in terms of quantity*

Table 3 Teachers' pre-post views of NOSI aspects

Teacher	SI-1		SI-2		SI-3		SI-4		SI-5		SI-6		SI-7		SI-8	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Bella	(+)	+ +	-	+ + +	+	+ +	(+)	+ +	-	+ +	+	+ +	+	+ +	+	+ +
Evan	+	+	+	+ +	-	+ +	+	+ +	(+)	+ + +	+	+ +	-	+	+	+ +
Hazel	-	+	(+)	(+)	-	+	+	+	+	+	+	+	+	+ +	(+)	(+)
Miles	(+)	(+)	+	+ + +	(+)	(+)	+	+ + +	-	+ + +	+	+ +	+	+ + +	+	+ + +
Sam	+ +	+ +	+ +	+ + +	+ +	+ +	+ +	+ +	+	+	+	+ +	+ +	+ +	+ +	+ +
Yale	(+)	+	+	+	+	+	+	+ +	+	+ +	+ +	+ +	+	+ +	(+)	+ + +

> *and quality. 2: Yes. Because science is curiosity. It's the why and wherefore questions that arise in the mind that create curiosity."*
> [Hazel-pre-test]: "*1a: It is not scientific research, because it is just an observation! 1b: Yes, it is a short-term observation. 2: Yes, investigations all begin with a question"*
> [Hazel-post-test]: "*1a: No, just based on observation. 1b: Yes, it can be an investigation. 2: Yes, it would be more accurate to start with a research question."*

In contrast, Evan, Miles, Sam and Yale maintained their views on this aspect throughout the study.

4.1.2 There Is No Single Set or Sequence of Steps Followed in All Investigations (SI-2)

According to Table 3, notable changes and improvements were observed in this aspect among teachers. Bella, who initially held a naïve understanding (-), progressed to a comprehensive informed view (+++) by the end of the study. Example quotation from her improved pre-post VASI responses in this aspect are provided below:

> [Bella-pre-test]: "*1b: Yes, he started the research process by establishing a hypothesis, determining the dependent and independent variables, and reached the view. 1c: No, probably one method exists, because I think using the formal research steps is sufficient.*"
> [Bella-post-test]: "*1b: Yes, it is an experiment. Because he has collected comparative data in terms of quantity and quality. 1c: And there is no single method in scientific research. Each research is designed by considering its own context. Some are carried out through observation, some in a laboratory environment.*"

A similar trend was observed in Miles, whose understanding shifted from a mixed view (+) to a comprehensive informed view (+++). Example quotation from his improved pre-post VASI responses in this aspect are provided below:

> [Miles-pre-test]: *"1b: Yes, there are dependent and independent variables and there is a relationship between them. 1c: Yes, for example, for an experimental methodology brightness and number of batteries experiment can be conducted whereas for a descriptive methodology attitude surveys can be used"*
> [Miles-post-test]: *"1b: This investigation process relies on observation rather than experimentation. 1c: Multiple methods can be employed. For example, someone who wants to study the honey-making process of bees might observe bee colonies in different regions. Or they might manipulate environmental conditions and observe the results themselves. In the second example, someone who wants to establish a link between student achievement and the activity being performed might create different environments and make observations, as well as conduct a survey on student achievement."*

In addition to, Evan and Sam also made progress, each advancing one level higher, indicating an improvement in their understanding of this aspect. In contrast, Hazel and Yale showed no change in their views throughout the study.

4.1.3 Inquiry Procedures are Guided by the Question Asked (SI-3)

In this aspect, major shifts were observed in several teachers' views. Evan and Hazel, who initially held the most naïve views, improved their understanding to more adequate levels by the end of the study. Example quotation from Evan's pre-post VASI responses in this aspect are provided below:

> [Evan-pre-test]: "*Team B is better.*"
> [Evan-post-test]: "*Team A's approach is more logical and rational. Different car models use very different types of tires. Some of them might not have been damaged on the road described in the experiment and could have adapted more easily to the conditions.*"

Similarly, Bella's understanding advanced to a more informed (++) level. Example quotation from Bella's pre-post VASI responses in this aspect are provided below:

> [Bella-pre-test]: "*Team A. Because the research question is limited to certain brands, different brands need to be compared to understand the result.*"
> [Bella-post-test]: "*The path followed by team A is correct, because they can only decide on the durability of the tire in question by looking at the performance of different tires on the same road.*"

In contrast, Sam and Yale showed no change in their views on this aspect.

4.1.4 All Scientists Performing the Same Procedures May Not Get the Same Results (SI-4)

According to Table 3, it seemed that the teachers held adequate understanding at the beginning of the study. Yet, improvements occurred to a more comprehensive understanding, especially on Miles, Bella, Evan, and Yale's views were transformed to a more articulated understanding on this aspect by being able to provide extensive examples regarding the concepts. In contrast, no changes occurred in Hazel and Sam's views on this aspect. Example quotation from Miles's and Yale's pre-post VASI improved responses in this aspect are provided below:

> [Miles-pre-test]: "*There are studies that are subjective and contain bias as a result of the research.*"
> [Miles-post-test]: "*Even if scientists investigate the same question, they may not reach the same conclusion. There may be several reasons for this. For example, the methods used in the research process may be different or errors in the data collection process may differ. At the same time, scientists' perspectives and experiences on the research topic can also affect the results. For this reason, scientists wait for other scientists to repeat and verify the results before publishing their research results. This process increases the reliability of science.*"
> [Yale-pre-test]: "*No, because they might interpret the data differently.*"
> [Yale-post-test]: "*No, they might not all reach the same conclusions. Even if they use the same methods, they might obtain different data and make different claims out of it.*"

4.1.5 Inquiry Procedures Can Influence Results (SI-5)

Teachers showed notable growth in this aspect. For instance, teachers who held inadequate understandings at the beginning such as Bella, Evan, and Miles, became the ones who improved their views the most, while Yale also progressed to the next level. In contrast, Hazel and Sam showed no change in their views on this aspect. Example quotation from Evan's and Miles's pre-post VASI responses in this aspect are provided below:

> [Evan-pre-test]: *"They may reach different conclusions. The sample they work with may be different."*
> [Evan-post-test]: *"If the geographies and environments they conduct research are different, they may reach different conclusions. For example, if a scientist who collects information and data about mammals encounters a platypus, he may reach different conclusions about the way this animal reproduces."*
> [Miles-pre-test]: "*This applies to all studies that produce objective results."*
> [Miles-post-test]: *"No, scientists investigating the same question and using different methods to collect data may not always reach the same conclusions. The reasons are: The methods used to collect data can vary. The data collected can be interpreted differently. Even if two scientists use the same methods to collect data, they can interpret the data differently. This can lead to different conclusions. For example, it is possible to interpret survey results from different perspectives. Scientists' biases can influence their results. Many reasons, such as these, may not lead to the same conclusion."*

4.1.6 Research Conclusions must be Consistent with the Data Collected (SI-6)

Teachers' pre-test results indicated an adequate but not fully articulated understanding of this aspect, as nearly all held mixed (+) views. However, all the teachers, who had mixed (+) views, except Hazel, showed an improvement in their views by moving to the next level of understanding. In contrast, Hazel and Yale showed no change in their views on this aspect. Example quotation from Evan's pre-post VASI responses in this aspect are provided below:

> [Evan-pre-test]: *"Option II. Plants grow more with less sunlight. I examined the data in the table and made my decision accordingly. No, the data was not what I expected."*
> [Evan-post-test]: *"Option III. Plant growth has nothing to do with sunlight. The amount of sunlight, opposite the amount of growth of 5 cm and 10 cm made me think of this result. No, the data was not what I expected. I would expect the amount of growth in the height of the plant to increase as the amount of time it receives sunlight increases."*

4.1.7 Scientific Data are not the Same as Scientific Evidence (SI-7)

Teachers held inadequate understandings regarding this aspect at the beginning of the study, however notable improvements were observed, particularly in Miles, who held mixed (+) views at the beginning, whereas at the end of the study progressed to a fully informed understanding. Similarly, Bella, Hazel and Yale, who also began with mixed (+)

views at the beginning, all improved their views to a more comprehensive understanding of this aspect (++), whereas Evan also improved his views. In contrast, no changes were observed in Sam's views. Example quotation from Bella's and Miles's pre-post VASI responses in this aspect are provided below:

> [Bella-pre-test]: *"Data, while the numerical results obtained for the answers to the research question. Evidence: I think the data that confirms the probability obtained in the light of the data."*
> [Bella-post-test]: *"Data, while the qualitative or quantitative values collected on a subject of interest; evidence are the elements that provide proof of the collected data."*
> [Miles-pre-test:]: "*Data is obtained through measurement, experimentation, observation, counting, or research. Evidence, on the other hand, is the trace that can lead people to the truth they seek."*
> [Miles-post-test]: "*Data and evidence are different concepts. Data is raw information that can take many different formats, such as numbers, text, images, or sounds. Evidence, on the other hand, is evidence that supports or refutes a claim. For example, if you want to prove that a particular drug is effective in treating a particular disease, you need to collect data on the results of clinical trials. This data will include information such as the number of patients recovered, the number of patients experiencing side effects, and the severity of these side effects. This data will then be used to support your claim that the drug is effective in treating the disease. In other words, evidence is data that has been interpreted and analyzed to support a claim. Data is simply the raw information used to create evidence."*

4.1.8 Explanations are Developed from a Combination of Collected Data and What Is Already Known (SI-8)

Similar to SI-6 aspect, teachers' pre-test results showed adequate but not fully articulated views on this aspect. However, significant positive shifts were observed, particularly in Miles's and Yale, who progressed from a naïve understanding to a fully informed understanding. Example quotation from Miles's and Yale's pre-post VASI responses in this aspect are provided below:

> [Miles-pre-test:]: *"Physiologically,* Figure 1 *seems correct. Otherwise, it cannot survive in terms of movement and hunting and disappears before completing its development. If the body's movement and body size (bone size) are considered, the center of gravity and the load that the skeleton will carry are examined. It is examined in terms of physics and zoology."*
> [Miles-post-test]: "*Actually, there could be two images. The reason is that what is known about dinosaurs' hands and feet is that some dinosaurs' hands were larger than their feet. For example, the hands of the dinosaur called Tyrannosaurus rex were larger than its feet. They made a comparison with today's living creatures. Comprehensive research should be done. Every option should be considered."*
> [Yale-pre-test]: *"This may be due to dinosaurs had short forelimbs and long hindlimbs. This was determined through observation and speculations."*
> [Yale-post-test]: "*Influenced by the knowledge we obtain from our surroundings and nature, they will likely choose skeleton number 1. Furthermore, skeleton number 1 is more useful for hunting. This can be concluded based on scientific knowledge, data, observations, and inferences."*

Similarly, Bella and Evan improved their views to the next level. In contrast, Hazel and Sam showed no change in their views on this aspect.

Overall, Bella, Evan, and Miles demonstrated the most significant growth, transitioning from lower continuum levels—typically naïve or mixed views—to informed (+++) views across multiple aspects. Conversely, teachers with initially inconsistent views, such as Sam and Hazel, maintained stable understanding throughout the study.

4.2 Findings regarding Argumentation-driven Inquiry Lesson Plans

The study also evaluated the effect of the professional development interventions on six teachers' argumentation-driven inquiry lesson plan design performance by comparing their 1st and 2nd lesson plan scores. In this section, findings regarding the lesson plan design performances and some highlights from the lesson plans of teachers are presented. As was indicated in the Methodology section, lesson plans consisted of 8 different criteria, each had different sub-items to be evaluated.

Figure 2 presents individual, and group's overall scores of 1st lesson plans (LP1) and the 2nd lesson plans (LP2) of the teachers. As can be seen in Fig. 2, the overall mean score of the cohort's 1st lesson plans was 48.17 (SD = 19.61), whereas it increased to 66.67 (SD = 11.22) in the 2nd lesson plans resulting in a mean improvement of + 18.5 points. Moreover, as can be seen in Fig. 2, each participant improved their performance by increasing overall scores with different margins of their lesson plans as an indicator of improved quality. Specifically, the most substantial improvements were observed among participants with the lowest 1st lesson plan scores, particularly Sam (+43 points) and Hazel (+17 points). In addition, Bella and Evan, who had the highest scores on the 1st lesson plans, also showed gradual improvements (+10 and +3, respectively). Moreover, Table 4 presents the 1st and 2nd lesson plan scores of each teacher on these 8 different criteria. Based on these scores, overall and individual analyses were also conducted for each criterion. These findings highlight the intervention's potential to support individuals with greater needs for improvement. In addition, mean scores for each criterion in both lesson plans were also analyzed to monitor the changes in detail and presented in Table 4. The researchers evaluated teachers' lesson plans using a set of criteria to assess their quality and effectiveness. The 1st lesson plans (LP1) and 2nd lesson plans (LP2) were rated, and the results, including means, standard deviations (SD), and standard error of the means (SEM), are presented in Table 5. The difference between 1st lesson plans and 2nd lesson plans was also evaluated for each aspect separately.

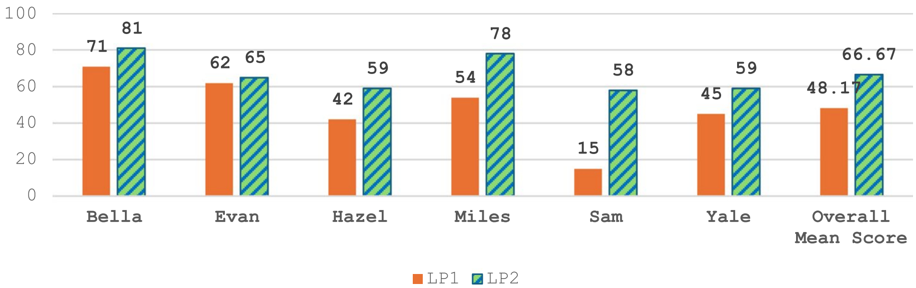

Fig. 2 Overall performance pre- and post-intervention scores

Table 4 Teachers' pre- and post argumentation-driven inquiry lesson plan (LP) scores

Teacher's Name	Bella		Evan		Hazel		Miles		Sam		Yale	
Criteria	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2
1. **Pre-Lesson Preparation**												
■ The selected concepts and/or skills for the lesson are appropriate according to the current Ministry of National Education Science Curriculum	4	4	4	4	3	4	4	4	2	4	4	4
■ The lesson plan contains appropriate learning outcomes	4	4	4	3	2	4	4	4	2	4	3	4
Total Score	**8**	**8**	**8**	**7**	**5**	**8**	**8**	**8**	**4**	**8**	**7**	**8**
2. **Agreement on the Investigative Question**												
■ The introductory activity is planned in a way that reveals students' prior knowledge regarding the learning outcomes	3	3	3	4	2	3	3	4	0	3	3	3
■ The introductory activity is engaging and leads students to the questions they are curious about	3	3	3	4	2	3	3	4	0	3	3	3
■ The introductory activity is planned to provide opportunities for students to discuss and ask questions	3	3	3	4	2	3	3	4	0	3	3	3
■ The introductory activity includes questions that will initiate and continue discussions	4	4	3	4	2	3	3	4	0	1	3	3
■ The research questions expected from students are clearly specified in the lesson plan	3	4	3	4	2	3	3	3	0	1	0	1
■ Plans are made for situations where the expected research questions do not arise from students	1	1	1	1	1	2	1	1	0	1	0	1
■ The materials that students might need are listed completely	4	4	4	4	4	4	4	4	0	4	3	4
Total Score	**21**	**22**	**20**	**25**	**15**	**21**	**20**	**24**	**0**	**16**	**15**	**18**
3. **Students' testing/inquiry/experimenting the research questions**												
■ Students are guided to perform experiments, inquiry, or observations relevant to the research questions	4	4	4	4	2	2	3	4	1	4	2	1
■ The planned learning activities are student-centered for testing the research questions	4	4	4	3	1	2	4	4	1	4	3	4
■ The necessary precautions during experiments/research/observations are clearly listed with examples	4	4	3	3	3	2	2	4	1	2	2	2
Total Score	**12**	**12**	**11**	**10**	**6**	**6**	**9**	**12**	**3**	**10**	**7**	**7**
4. **Generating Claim and Evidence**												

Table 4 (continued)

Teacher's Name	Bella		Evan		Hazel		Miles		Sam		Yale	
Criteria	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2
■ The lesson plan explains how students will generate evidence and claims based on the data they gather	1	2	1	1	1	2	2	2	1	4	2	2
■ The lesson plan clarifies how students will establish the relationship between questions, claims, and evidence	1	2	1	1	1	2	2	2	1	2	2	2
■ The lesson plan describes how students will create a convincing argument related to the research questions	1	2	1	1	1	2	2	2	1	2	2	2
Total Score	**3**	**6**	**3**	**3**	**3**	**6**	**6**	**6**	**3**	**8**	**6**	**6**
5. **Defense of Arguments and Consensus Process**												
■ The lesson plan includes how student groups will present their claims and evidence in an order that suits the topic and the flow of the discussion	3	4	1	1	1	2	0	1	0	1	1	1
■ Teacher questions guiding the discussion are explicitly stated in the lesson plan	1	1	1	1	0	1	1	3	1	0	0	1
■ The lesson plan includes questions and directions to encourage students to support, refute, or create counterarguments	1	1	1	1	0	1	1	3	1	0	0	1
■ The plan indicates how students will come to a conclusion from the discussions at this stage	2	3	2	2	2	1	1	4	1	1	0	2
Total Score	**7**	**9**	**5**	**5**	**3**	**5**	**3**	**11**	**3**	**2**	**1**	**5**
6. **Comparison of Findings with Readings/Resources**												
■ Students are directed to reliable sources relevant to the topic	3	4	4	3	3	4	0	2	0	4	1	1
7. **Providing Opportunities for Reflecting on Changes in Ideas**												
■ The lesson plan explains how students' changing thoughts on the lesson's topic during the research process will be highlighted	3	4	1	2	1	2	0	3	0	1	2	1
■ The lesson plan clearly explains how students' understanding of the lesson will be assessed	4	4	2	2	2	2	2	3	1	2	2	4
■ The planned assessment and evaluation activity is appropriate to the topic	4	4	2	2	2	2	2	3	1	2	2	4
Total Score	**11**	**12**	**5**	**6**	**5**	**6**	**4**	**9**	**2**	**5**	**6**	**9**
8. **Nature of Scientific Inquiry**												
■ At least one aspect of the nature of scientific inquiry is explicitly addressed in the plan	3	4	3	3	1	3	2	4	0	3	1	3

Table 4 (continued)

Teacher's Name	Bella		Evan		Hazel		Miles		Sam		Yale	
Criteria	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2	LP 1	LP 2
■ The lesson plan specifies examples of when students will be provided with opportunities to engage with the nature of scientific inquiry and how to emphasize it in the lesson	3	4	3	3	1	0	2	2	0	2	1	2
Total Score	**6**	**8**	**6**	**6**	**2**	**3**	**4**	**6**	**0**	**5**	**2**	**5**
Grand Total Out of 100	**71**	**81**	**62**	**65**	**42**	**59**	**54**	**78**	**15**	**58**	**45**	**59**

Table 5 Descriptive statistics of each criterion in LP1 and LP2

Criteria	Mean	N	SD	SEM
LP1-Pre-Lesson Preparation	6,6	6	1,7	0,7
LP2-Pre-Lesson Preparation	7,8	6	0,4	0,1
LP1-Agreement on the Investigative Question	15,1	6	7,8	3,2
LP2-Agreement on the Investigative Question	21,0	6	3,4	1,4
LP1-Students' testing/inquiry/experimenting the research questions	8,0	6	3,3	1,3
LP2-Students' testing/inquiry/experimenting the research questions	9,5	6	2,5	1,02
LP1-Generating Claim and Evidence	4,0	6	1,5	0,6
LP2-Generating Claim and Evidence	5,8	6	1,6	0,6
LP1-Defense of Arguments and Consensus Process	3,6	6	2,0	0,8
LP2-Defense of Arguments and Consensus Process	6,1	6	3,2	1,3
LP1-Comparison of Findings with Readings/Resources	1,8	6	1,7	0,7
LP2-Comparison of Findings with Readings/Resources	3,0	6	1,2	0,5
LP1-Providing Opportunities for Reflecting on Changes in Ideas	5,5	6	3,0	1,2
LP2-Providing Opportunities for Reflecting on Changes in Ideas	7,8	6	2,6	1,0
LP1-Nature of Scientific Inquiry	3,3	6	2,4	0,9
LP2-Nature of Scientific Inquiry	5,5	6	1,6	0,6

4.2.1 Pre-Lesson Preparation Criteria

In this criteria, overall performance of teachers was moderate at the beginning while they prepared the 1st lesson plans (LP1) (M = 6.67, SD = 1.7, SEM = 0.7). Yet, 2nd lesson plans (LP2) received higher ratings (M = 7.83, SD = 0.4, SEM = 0.1) compared to the 1st lesson plans. This suggests that the teachers demonstrate improved quality of the content in this criterion in LP2 by addressing the outcomes, objectives and concepts appropriately the current MONE science curriculum. The total scores for pre-lesson preparation across the teachers showed some consistency for Bella and Miles and slight improvements for Hazel (5 to 8), Sam (4 to 8) and Yale (7 to 8).

4.2.2 Agreement on the Investigative Questions Criteria

The mean score for this criterion, which consisted of 7 sub-items, for LP1 (M = 15.1, SD = 7.8, SEM = 3.2) whereas the mean increased in LP2 to (M = 21.0, SD = 3.4, SEM = 1.4) indicating greater clarity and alignment in defining the investigative questions in the 2nd lesson plans. This trend was also seen in the individual performances as the scores for this aspect showed an increase for each teacher. Especially, the dramatic increase on Sam's performance is noteworthy (0 to 16) where he started to include investigative questions in his plans in the 2nd versions where he did not do so at the beginning. For instance, it was seen that Sam included reasoning-based, integrative, and multi-perspective investigative questions in his design of LP2 which encouraged students to synthesize information (e.g., interconnecting different roles, content knowledge, and argumentation) in the context of fossil fuels and another related topic to the content on the effects of gas poisoning. Moreover, in the LP2 he also included a task where students were asked to generate an argument map based on the investigative questions, claims, and rebuttal and for allowing longer debates among them. Notable improvements were also observed for Hazel and Yale (15 to 21 and 15 to 18 respectively), in which they were scored lower for addressing the investigative questions in their LP1 whereas they improved their scores in the LP2. In line with that, especially in Hazel's LP2 design where the topic was human reproduction, growth and development, it was encountered with the teacher prompted debate through guided and open investigative questions following a single video on YouTube that was used to draw attention and to spark interest. Following that, in the LP2 Hazel also encouraged students to generate and refine research questions especially around video reactions and key biological concepts, followed by relatable examples and open-ended questions, a strategy in which LP1 lacked. This approach naturally leads students to wonder and pose their own questions and address them to structure their arguments based on their prior knowledge on the topic.

4.2.3 Students' Testing Inquiry/Experimenting the Research Questions Criteria

In this criterion, which consisted of 3 sub-items, ratings for LP2 (M = 9.5, SD = 2.5, SEM = 1.02) exceeded those for LP1 (M = 8.0, SD = 3.3, SEM = 1.3), reflecting enhanced support, facilitation, inclusion of instructions and addressing the student centeredness for student engagement in inquiry-based activities in LP2. A notable improvement is observed in Miles's scores (9 to 12) and Sam's (3 to 12), suggesting better integration of inquiry-based activities. However, Hazel (6 to 6) and Yale (7 to 7) scores remained unchanged, implying that LP2 lacked sufficient emphasis on guiding students through inquiry-based procedures which might highlight challenges in sustaining student-centered approaches in inquiry-based procedures across iterations.

4.2.4 Generating Claim and Evidence Criteria

In this criteria, teachers' LP2 performance was found higher (M = 5.8, SD = 1.6, SEM = 0.6) than LP1 (M = 4.0, SD = 1.5, SEM = 0.6), suggesting richer content on addressing evidence-based reasoning in the 2nd lesson plans. This aspect saw no change for some teachers, such as Evan (3 to 3), Miles (6 to 6), and Yale (6 to 6). However, notable increases in scores for Bella (3 to 6), Hazel (3 to 6) and Sam (3 to 8) recorded suggest challenges in helping students establish robust connections between evidence and research questions in 2nd LP.

4.2.5 Defense of Arguments and Consensus Process Criteria

Similarly, the overall performance of teachers was found higher in LP2 (M = 6.1, SD = 3.2, SEM = 1.3) compared to LP1 (M = 3.6, SD = 2.0, SEM = 0.8) in these criteria, indicating providing improved opportunities for students to defend arguments and engage in consensus-building in 2nd LP. Scores generally improved with Bella increasing her score to 9 from 7; and Hazel from 3 to 5 and especially for Miles from 3 to 11 and Yale from 1 to 5. However, Evan showed no significant change (remained at 5), while Sam's scores decreased (3 to 2). As indicated above, this criterion seeks to ensure that this section of lesson plans clearly outlines the order of student group presentations, includes explicit teacher questions to guide the discussions, encourages students to support, refute, or create counterarguments, and demonstrates how students will reach conclusions based on the discussions. In line with that, especially for Miles's LP2 design was found to be distinctive in terms of culminating in group activities where students shared and presented their claims, evidence, and counterarguments. Miles designed this segment of the LP2 effectively by structuring a well-sequenced activity on the Ecology and Carbon Footprint topic that guided students through inquiry, data collection, argument development, and presentation while also incorporating investigative questions to stimulate critical thinking and encouraging them to reach reasoned conclusions through collaborative discussions. Similarly, it was also found that Yale had major improvements in terms of the quality of the segment's content where in his LP2 design on Ecology and Pollution topic, he incorporated students to engage in argument mapping while forming claims, gather evidence, and facilitating interactions between opposing views by allowing groups with contrasting claims to debate, or encouraging groups with similar claims to strengthen each other's positions, fostering support and refutation.

4.2.6 Comparison of Findings with Readings/Resources Criteria

Teachers slightly improved their score in this criterion, where there is only one sub-criteria, as LP2 received higher ratings (M = 3.0, SD = 1.2, SEM = 0.5) than LP1 (M = 1.8, SD = 1.7, SEM = 0.7), reflecting better integration of lesson findings with relevant readings and resources. Substantial increases were recorded for Miles (0 to 2) and Sam (0 to 4) who lacked competence in this aspect in the 1st LP. The minimal changes also occurred for Bella (3 to 4) and Hazel (3 to 4) whereas no change occurred for Yale who remained at 1.

4.2.7 Providing Opportunities for Reflecting on Changes in Ideas Criteria

Teachers exhibited strong improvement trends in this aspect as LP1 had lower mean scores (M = 5.5, SD = 3, SEM = 1.2) and LP2 mean scores increased (M = 7.8, SD = 2.6, SEM = 1.0) where each teacher improved his/her score. Especially the improvements for Miles (4 to 9), Sam (2 to 5) and Yale (6 to 9) were noteworthy. Similarly, Bella (11 to 12), Evan (5 to 6), Hazel (5 to 6) followed a similar trend where they improved their scores, including relevant assessment strategies aligned with the content to evaluate students' learning processes.

4.2.8 Nature of Scientific Inquiry Criteria

The overall scores of teachers addressing the nature of scientific inquiry aspects into their plans generally increased in the LP2 (M = 5.5, SD = 1.6, SEM = 0.6) compared to LP1 (M = 3.3, SD = 2.4, SEM = 0.9). Teachers Miles (4 to 6), Sam (0 to 5) and Yale (2 to 5) exhibited notable improvements suggesting stronger alignment addressing the aspects of scientific inquiry in the 2nd LP. For instance, it was encountered in Sam's LP2 design that he integrated key components of the nature of scientific inquiry by focusing on how inquiry processes impact results and how scientific explanations emerge from combining data with prior knowledge by offering students meaningful opportunities to practice these elements through argumentation and reflection, deepening their understanding of scientific investigation as a dynamic and interpretative process. Similarly, Yale also integrated the nature of scientific inquiry by explicitly focusing on argument construction, data-evidence distinction, and reflective inquiry processes by providing semi-structured opportunities for students to engage in authentic scientific practices, fostering a deep understanding of how scientific knowledge is generated and evaluated whereas it was lacked in his LP1 designs.

In addition to, marginal changes also occurred for the following teachers Bella (6 to 8), Hazel (2 to 3) and Miles (4 to 6) who showed slight improvements in their 2nd LP.

The overall results on teachers' lesson plan design performance indicate that the 2nd LP consistently outperformed the 1st LP across all criteria. Improvements were particularly notable in the following criteria of "*Agreement on the Investigative Question*", "*Defense of Arguments and Consensus Process*", and "*Nature of Scientific Inquiry*".

4.3 Findings regarding the Reflection Reports and Focus Group Interviews

As stated in the Methodology section, teachers were asked to write reflection reports after preparing and implementing the lesson plans reflecting on their experiences, also about the difficulties they encountered and the effect on their professional development. Moreover, they were asked to state these experiences and difficulties within the scope of the focus group interviews. This section provides the findings regarding teachers' reflection reports and focus group interviews as well as examples from their quotations.

4.3.1 Difficulties regarding Lesson Plan Design

Regarding the planning and designing of the lesson plans, only Bella stated that she had no difficulty while planning her 1st LP thanks to her prior undergraduate program's similar practices about designing lesson plans and the guidelines and samples provided by the researchers within the scope of this training program. Example quotations of Bella's given below:

> [Bella]: "*I prepared my first lesson plan. It was easier to prepare because the sample lesson plan provided guided and our professors (facilitators), explained in class and shared with us was very similar to the assignments we received and were asked to prepare during our undergraduate education course at the university.*"

On the contrary, other teachers listed the difficulties encountered while designing their 1st LPs as the following:

- Lack of experience and knowledge about NOSI (Evan, Miles):

> [Evan]: "*I had no prior experience or knowledge about the topic of nature of scientific inquiry based on argumentation*"

- Lack of similar resources available online about NOSI and argumentation (Miles, Evan):

> [Miles]: "*During the plan preparation phase, it was challenging because there were few similar plans available with a similar structure to refer to when utilizing different sources and one of the difficulties was incorporating a new concept, namely the concept of argumentation into the plan*"

- Time allocation for segments of the LPs (Miles)

- Finding relevant assessment tools for evaluating argumentation-driven inquiry process (Miles)

> [Miles]: "…*Choosing how to evaluate the argument work at the end of the plan was also one of the difficulties*."

- Lack of experience about how to integrate NOSI aspects with curricular objectives and the alignment (Sam, Yale, Evan)

> [Sam]: "*I was uncertain about how to structure the flow of the plan and integrate the themes of the nature of scientific inquiry*."
> [Yale]: "…*While preparing the first lesson plan, I faced difficulty in determining the objectives for the nature of scientific inquiry*"

- Lack of experience about how to integrate argumentation with curricular objectives and the alignment (Yale, Evan)

> [Yale]: "*I faced difficulty in determining the objectives for the nature of scientific inquiry*."
> [Evan]: "*I found it challenging to design the themes and objectives of the NOSI in a way that students could easily understand"*

Similar to the 1st LPs, Bella stated that she did not struggle with the design of her 2nd lesson plan. However, in addition to Bella, in this time for the 2nd lesson plans, Evan, Yale, and Sam also stated that they had little or no difficulty at all while designing their LPs.

> [Evan]: "*I had some knowledge about the topic of nature of scientific inquiry and argumentation. So, I did not have much difficulty. Especially after preparing the 1st LP, I had a better grasp of the topics."*
> [Yale]: "… *When preparing the 2nd LP I did not have much difficulty because we evaluated them with the group (colleagues) in the training and identified the mistakes we made within the 1st LPs."*
> [Sam]: "*I faced some difficulty in incorporating the learning outcomes related to NOSI while preparing the 2nd LP however the difficulty was much less when compared to 1st LPs. I believe I've became more practical preparing plans*"

They listed the contributing factors as being more experienced with the NOSI and its aspects, being familiar with the lesson plan structure and segments, and the constructive feedback they gathered for their 1st LPs from their peers as well as from the researchers. On the other hand, Miles stated that he still had few difficulties such as effectively allocating time for each segment of the LP and about how to integrate argumentation process into those segments effectively.

> [Miles]: "*Now I prepared the 1st LP I have an example what to refer when creating these plans. But the challenge was integrating the argumentation process within the lesson plan. In fact, the most challenging part is to determine how much time to allocate for each phase…"*

4.3.2 Difficulties regarding Classroom Implementations and Students' Reactions & Feedback

Regarding the implementations of the 1st and 2nd LPs, teachers stated that they encountered various difficulties. These difficulties can be grouped as student-related difficulties, material-related and other difficulties. The difficulties listed within each group are listed below:

- Student-related difficulties:
- Students' struggle with the generating arguments and claims (Yale, Miles)

  [Yale]: *"I noticed that students really struggled with the process of forming claims"*
  [Miles]: *"I struggled with helping my students identify a problem or to create an argument during the argument creation phase"*

- Students' struggle following the instructions and carrying out the investigations (Yale)

  [Yale]: *"I also realized that some students struggled to perform the experiment or carry out the activity as instructed in the lesson plan"*

- Students' unfamiliarity to inquiry practices and lack of experience (Miles, Sam)

  [Sam]: "*Students faced many difficulties because they were lacking both theoretical and practical experiences in these practices"*

- Students' demotivation for inquiry-based practices (Miles, Evan, Hazel, Yale)

  [Miles]: "*Even though we tried to make the lesson as engaging as possible, most of the student's motivation was quite low for the activities*"
  [Hazel]: "*I implemented the LP in the classroom but only a few students participated, the rest preferred to study for their test*"
  [Evan]: "*The number of students in the groups were quite high as well as in the classroom. Thus, students were not really motivated to engage in inquiry activities"*

- Students' instructor-centered classroom practices habits (Miles)

  [Miles]: "*…The majority of students seemed to have developed a mindset of wanting the teacher providing the information and knowledge for memorization rather than engaging in discovery process*"

- Students' multiple-choice test related habits and unfamiliarity with the formative assessment methodologies (Miles, Evan)

  [Miles]: "*Many students asked, 'why don't you give us a (multiple-choice) test'*

and they were reluctant to engage in tasks like creating argument maps, writing arguments and collecting evidence to support their claims"
[Evan]: "*I faced challenges because 8^{th} grade students focused on the high school entrance exam, so they preferred to have multiple-choice tests.*"

- Vast number of refugee students (Syrians, Iraqians, Crimeans) and their lack of Turkish language skills (Bella)
- *Material-related difficulties:*
- How to align NOSI and argumentation objectives with curricular objectives (Yale)

[Yale]: *"I had difficulty linking the themes of NOSI with MONE objectives in my classroom*"

- Effective time management within the segments (Sam, Miles)

[Sam]: *"I faced difficulties regarding the timing of the lesson and managing the time effectively, we had limited time left for students' inquiries.*"

- *Other difficulties:*
- Lack of technical and financial resources and problems related to the infrastructure of schools (e.g. post-earthquake conditions) (Yale, Miles, Bella)

[Miles]: "*…Due to earthquake, our school building was unfit, and we were temporarily relocated to other schools. That's why with the activities we could not achieved what we aimed for.*"
[Bella]: "*Since I work in Adana, one of the 11 provinces affected by the Kahramanmaraş-centered earthquakes on February 6, 2023, the number of students attending school was quite low and the infrastructure of the schools were not sufficient*".

On the other hand, despite the difficulties that the teachers encountered during the implementations, they also shared positive feedback and reactions gathered from students related to the rich learning environments that the lesson plans provided for them. For instance, during the interviews Miles stated that "*…especially after an inquiry and discovery task is completed, students stated that they enjoyed the lessons very much and did not even realize how the time passed*!" Similarly Hazel stated that "*when the topic was the reproduction and growth of living things and the activities related to content required observations and learning-by-doing tasks through inquiry that could be conducted in an outdoor setting such as planting seeds in the school garden, she observed that this type of environment outside the school classroom allowed students to connect with nature and segments of the lesson plan reinforced learning*". Thus, in line with this, she mentioned her plans to incorporate more activities like these into her teaching. Moreover, as Sam observed, students with prior experience in argumentation activities did not struggle as much and engaged more in the tasks compared to those with no prior experience. These reflections suggest that, despite initial challenges, the thoughtfully designed lesson plans fostered engagement, inquiry, argumentation, and deeper learning among students, ultimately encouraging teachers to embrace more interactive and student-centered approaches in the context of argument-driven inquiry in their future practice.

4.4 Effect on Teachers' Professional Development and Strength of the Program

Teachers stated that the training program contributed to their professional development in various aspects. They listed these aspects as follows:

- Improved lesson plan design and development competencies (Bella, Miles, Sam, Yale)
- Improved knowledge about NOSI and its' aspects (Evan, Hazel, Miles)
- Improved knowledge about argumentation (Evan, Hazel)
- Increased awareness about the importance of the nature of scientific inquiry (Yale, Sam)
- Learnt how to allocate time effectively within lesson plan segments (Hazel)
- Learnt to integrate effective teaching tools such as argumentation maps (Miles)

Moreover, during the focus group interviews teachers also emphasized that the program had the following strengths to support their professional development as listed below:

- Detailed structure and content of the program,
- Emphasis on the NOSI and argumentation
- Introduction of state-of-the-art concepts, methodologies, materials and tools in science teaching
- Researchers' expertise on the subjects,
- Program structure to provide opportunities for teachers to implement new strategies and practices in their classrooms
- Constructive feedback provided by the researchers
- Continuous support of researchers throughout the program and its' implementation process
- Online modality.

5 Discussion and Conclusion

This study investigated the effect of argumentation-driven inquiry training on science teachers' understanding of NOSI and their lesson planning skills. The findings provide compelling evidence that the intervention improved teachers' conceptual understanding of NOSI and enhanced their instructional design capabilities.

The findings indicate that teachers notably improved their understanding of NOSI aspects following the intervention. Particularly, progress was observed in areas such as *multiple scientific methods (SI-2)*, *procedures guided by the question asked (SI-3) and inquiry procedures influence results (SI-5).* In the scope of the interventions, all activities presented to teachers began with a research question in the context of argumentation-driven inquiry learning, and the teachers were guided to answer the relevant questions through inquiry. In line with that, they were able to naturally grasp one of the aspects of NOSI, which was that each investigative study starts with a question but does not necessarily require testing a hypothesis. They observed that research questions directed them to utilize different methods and guided their inquiry processes. For instance, the teachers collected data using the tools they identified in line with their research problems. Following the designated steps, they analyzed the data they collected, delivered evidence, and constructed arguments to support their claims. They structured these arguments by incorporating evidence, justification, and conclusions and then interactively presented their findings to their fellow teachers. As a result of this process, they might have developed the capability to distinguish between data and evidence and recognized the importance of drawing conclusions based on available data and prior knowledge. Due to its inherent nature, the argumentation-driven approach automatically provided teachers with opportunities for inquiry-based learning, enabling them to directly grasp the themes of NOSI. These results align with previous studies emphasize the effectiveness of argumentation-driven approaches in fostering a deeper comprehension of NOSI (Osborne, 2010; Erduran et al., 2005; Metin-Peten, 2022). The integration of explicit-reflective teaching strategies, coupled with argumentation-driven activities, contributed to these improvements, as suggested by previous research on science teacher education (Mesci et al., 2023; Metin-Peten, 2022; Sadler, 2006).

One of the key implications of these findings is the potential of argumentation-driven inquiry to challenge and reshape teachers' preconceptions about NOSI. Prior research suggests that teachers and teacher candidates often hold naive or mixed views of NOSI (Mesci & Erdas-Kartal, 2021; Özer & Sarıbaş, 2023; Wang & Zhao, 2016). The structured training program with multiple phases in this study allowed teachers to engage critically with these concepts, leading to more informed, nuanced perspectives and sophisticated understandings.

In this study, unlike previous studies (Antink-Meyer et al., 2016; Leblebicioglu et al., 2017; Metin-Peten, 2022) notable improvements were also observed in the aspects as the *same procedures might not provide the same results (SI-4)* and *inquiry procedures influence results (SI-5)*. It was found that all teachers who had naive or mixed views on these aspects before the training improved their views notably in the final interviews. Compared to others, one distinctive aspect of this study is that it provided teachers with opportunities to learn while teaching. Supporting our study, Kartal and Mesci (2022) and Özer and Sarıbaş (2023) similarly found that when teacher candidates were allowed to experience teaching, their NOSI views improved more significantly compared to when they only participated in the training as students. Thus, it is very critical not to ignore the role of teaching practices in teacher training programs.

Moreover, the change in the teachers' lesson design performance indicated that the second lesson plans were consistently advanced compared to the first versions across all evaluation criteria. Notable improvements were especially observed in the areas of "*agreement on the investigative question*", "*defense of arguments and consensus process*", and "*nature of scientific inquiry*". These findings align with studies emphasizing the role of structured professional development in enhancing teachers' instructional practices (Cavagnetto, 2010; Desimone, 2009).

To integrate the argumentation process into their teaching, teachers must first understand what argumentation is and how to implement it (Chan et al., 2021; McNeill et al., 2017; Aglarci Özdemir et al., 2025). Similarly, to incorporate NOSI aspects into their teaching, it is crucial for teachers to develop a well-developed understanding of these themes. The theoretical training provided in the first stage of the study (Stage-I), followed by the teachers' experience of the prepared lesson plans first as students and then as instructors, may have made them familiar with understanding these concepts and how to incorporate them into a lesson plan. This might explain why their scores from the first lesson plans were not so low. Although their scores on the 1st lesson plans were not particularly low; their improvement in the 2nd lesson plans highlights the striking effect of reflection and feedback. The improvements were particularly pronounced in teachers who initially struggled with aligning NOSI aspects with curricular goals, highlighting the necessity of continued support and feedback in professional development programs. According to a review by Darling-Hammond et al. (2017), reflection and feedback are one of the seven key features of effective professional development. Such professional development programs help teachers improve their pedagogical approaches and make their lesson-planning processes more effective. Teachers who receive continuous feedback can better structure lesson content and adapt it to meet students' needs.

Despite these positive outcomes, several challenges were also identified. Teachers reported difficulties integrating NOSI with existing curricular objectives, managing time effectively, and facilitating student engagement in argumentation. These challenges are consistent with prior findings highlighting the complexities of shifting from traditional instructional methods to inquiry-based approaches (Duschl & Osborne, 2002; Zohar & Nemet, 2002). Student-related barriers, such as lack of familiarity with argumentation and limited experience in inquiry-based learning, posed difficulties during implementation. To address these challenges, professional development programs should incorporate sustained mentorship and iterative feedback loops, ensuring that teachers receive ongoing support beyond initial training sessions. Furthermore, embedding argumentation practices within the existing curriculum, rather than treating them as supplementary activities, could enhance their feasibility and effectiveness in classroom settings.

A distinctive feature of this study is that teacher development was facilitated through a hybrid program. By integrating the advantages of online education without disregarding teaching practices, teacher training can be conducted in many ways. Most importantly, this approach can contribute to the sustainability of professional development efforts, ensuring long-term effect and continuous improvement. With the advancement of technology, significant transformations have occurred in the field of education, and online learning has become an essential component of teacher training. Online education stands out as a tool that supports teachers' professional development by providing opportunities for learning independent of time and place. Online education offers teachers flexible learning opportunities, allowing them to continue their professional development without being constrained by time and place (Garrison & Vaughan, 2008). The time limitations and transportation issues encountered in traditional face-to-face training are eliminated with online education. Especially for in-service teachers, online learning enables them to learn at their own pace and convenience (Bozkurt, 2017). Furthermore, the use of various learning materials, such as videos, interactive lessons, and e-books, enhances the efficiency of the learning process (Means et al., 2010). Online teacher education fosters collaboration among teachers through virtual classrooms, discussion forums, and webinars. These interactions facilitate the exchange of pedagogical approaches and teaching strategies (Schlager & Fusco, 2003). Additionally, online platforms create social learning environments where teachers can learn from one another (Lave & Wenger, 1991). Compared to traditional teaching methods, online education provides teachers with quick access to recent academic research, teaching techniques, and educational materials (Mishra & Koehler, 2006). Online education helps teachers improve their digital literacy and use technology-supported teaching materials effectively (Koehler & Mishra, 2009). The COVID-19 pandemic highlighted the necessity of enhancing teachers' digital skills, further increasing the importance of online teacher training programs (Hodges et al., 2020; Özer & Han-Tosunoğlu, 2024). While traditional in-service training programs are conducted periodically, online education is continuously accessible, allowing teachers to maintain their professional development throughout the year (Darling-Hammond et al., 2017). This enables teachers to quickly adapt to evolving educational approaches and curricula. Online education eliminates physical space and transportation expenses, offering teachers a more cost-effective training alternative (Means et al., 2010). Additionally, using digital materials reduces paper consumption, contributing to environmental sustainability (Özer & Han-Tosunoğlu, 2024).

In addition to the improvements observed at the NOSI level and improved capacity for designing lesson plans, the findings of this study can also be interpreted within a broader science education framework, particularly through their relevance to the principles of scientific inquiry and the nature of science. While this study focused on the NOSI, its findings have broader implications for science education, particularly in relation to well-established constructs such as the NOS and scientific inquiry. The observed improvements in teachers' abilities to formulate investigable questions, guide inquiry, evaluate evidence, and design epistemically rich learning environments reflect key competencies emphasized in global science education frameworks (e.g., NGSS Lead States, 2013; OECD, 2016). This suggests that argumentation-driven NOSI training can serve as a gateway for teachers to enact core principles of both NOS and SI in practice.

Importantly, several NOSI aspects addressed in this study—such as the tentativeness of scientific knowledge, the role of evidence, and the subjective nature of data interpretation—are directly aligned with longstanding NOS frameworks (Abd-El-Khalick & Lederman, 2000b; Lederman, 2007). Likewise, the integration of student-centered investigations and reflective practices resonates with the inquiry-based learning approaches widely advocated in science education (Crawford, 2000; Duschl, 2008). By explicitly connecting argumentation and NOSI, this study advances an instructional model that operationalizes key tenets of scientific inquiry and NOS in a coherent, practice-oriented format.

Thus, the findings not only validate the pedagogical utility of NOSI as a conceptual bridge but also contribute to the field by demonstrating how targeted professional development can facilitate teachers' engagement with broader scientific epistemologies. These outcomes are particularly relevant for science education contexts seeking to foster deep, inquiry-oriented learning that reflects the nature of real scientific practice (Erduran & Dagher, 2014; Osborne et al., 2004).

6 Implications and Recommendations

Overall, this study contributes to the growing body of research advocating for argumentation-driven inquiry as a means to improve science teachers' understanding and implementation of NOSI aspects. The findings suggest that structured professional development programs integrating explicit instruction, practical application, and reflective feedback can significantly improve teachers' pedagogical skills and conceptual understanding.

Future research should explore long-term effects by examining how teachers maintain and adapt their NOSI integration strategies over extended periods. Additionally, expanding the study to a larger and more diverse sample could provide further insights into the scalability and generalizability of argumentation-driven inquiry training.

In conclusion, argumentation-driven inquiry presents a promising approach to advancing science education by equipping teachers with the necessary tools to foster a deeper understanding of scientific inquiry among students. By addressing implementation challenges and refining professional development models, educators and researchers can further enhance the effectiveness of NOSI-focused instruction in science classrooms.

This study also provides concrete evidence of how online and hybrid modalities can effectively be utilized in the scope of teacher training programs. Expanding the use of online and hybrid models is strongly recommended to make teacher education programs more accessible, sustainable, and cost-effective and to provide continuous professional support throughout the academic year.

Appendix 1. Argumentation-driven NOSI Lesson Plans' Details at PD Stage II

Week/Activity	Addressed NOSI Aspects	NOSI Relation with Context
Week 1 • Sun Energy (7th grade)	• Begins with a question • Procedures are guided by the questions asked • Data/evidence • Explanations are developed • from data and what is already known	The teacher can remind students that they have created a research question but not a hypothesis because they have not conducted an experiment, emphasizing that scientific research begins with a question but does not have to test a hypothesis. It can be noted that the variables they consider in their research problems (sustainability, economy, environmental and human friendliness, etc.) form the basis for determining the parts they will include in their models and that the questions asked to affect the inquiry process. It can be emphasized that students use both the information presented in the scenario and their prior knowledge when designing vehicle models. Therefore, scientific explanations are developed based on previous knowledge and collected data. It can be emphasized that the information presented in the scenario turns into evidence when students use it to support their arguments
Week 2 • Biodiversity (5th grade)	• Begins with a question • Multiple scientific methods • Procedures are guided by the questions asked • Data/evidence • Explanations are developed from data and what is already known	In this activity, where students go out into the schoolyard to make observations and collect data according to the instructions on the activity sheet, the teacher can emphasize to the students that every research study starts with a question but that it does not necessarily have to be tested with a hypothesis when creating research questions. The teacher can also emphasize that research questions affect the inquiry process. It can also be emphasized that there is no single scientific method and that scientists can sometimes conduct their studies by observing, experimenting, and conducting research. At the end of the activity, it can be noted that students should be careful that the claims and explanations they will make are compatible with the data they collect, and that scientists should produce scientific knowledge by producing explanations in this way. It is also emphasized that data and evidence differ, that the information students obtain from their observations is data, and that this data becomes evidence when analyzed and used to support their claims

Week/Activity	Addressed NOSI Aspects	NOSI Relation with Context
Week 3 • Nuclear Energy (8th grade)	• Inquiry procedures influence results • Same procedures may not get the same results • Explanations are developed from data and what is already known	In this activity, where students individually collect data from reliable sources to present their claims about nuclear power plants through the roles they are given, it can be emphasized that scientists can reach different conclusions by following the same procedures, that the inquiry procedure they choose for their research affects the results they obtain, and that they form the judgment they reach at the end of the process by integrating the data they already know with the data they have collected throughout this research
Week 4 • Simple Machines (8th grade)	• Begins with a question • Multiple scientific methods • Procedures are guided by the questions asked • Inquiry procedures influence results	In this activity, where students write research problems and claims for situations where single and multiple mass objects are placed on both sides of the balance and test their claims through simulation, it can be emphasized that all scientific research begins with a question and does not always test a hypothesis. It can be noted that the question asked guides the inquiry process. It can be emphasized that the inquiry procedure students follow to test their claims effectively determines the results. Again, it can be noted that students follow different inquiry procedures for similar situations and that there is more than one method
Week 5 • Organ Donation (6th grade)	• Begins with a question • Multiple scientific methods • Procedures are guided by the questions asked • Data/evidence • Explanations are developed from data and what is already known • Conclusion consistent with data collected	In the activity where students write research problems and claims based on newspaper articles presented to them, the teacher can remind students that every research study starts with a question but does not necessarily have to be tested with a hypothesis. The teacher also emphasizes that research questions affect the inquiry process. It can also be said that there is no single scientific method and that scientists can sometimes conduct their studies by observing, experimenting, and conducting research. Students should be informed that they should be careful that their claims and explanations are compatible with the data they collect and that scientists need to produce explanations in this way to produce scientific knowledge. At the end of this activity, it is emphasized to students that evidence and data are not the same and that data becomes evidence when used to support or prove their claims. At the end of the second activity, where students write the tasks, they will give to various institutions to increase organ donations, it is emphasized that they may have combined their previous knowledge with their current research data when determining these tasks

Appendix 2. The Views About Scientific Inquiry (VASI) Questionnaire

1. A person interested in birds looked at hundreds of different types of birds who eat different types of food. He noticed that birds who eat similar types of food, tend to have similar shaped beaks. For example, birds that eat hard-shelled nuts have short, strong beaks, and birds who eat insects have long, slim beaks. He wondered if the shape of a bird's beak was related to the type of food the bird eats, and he began to collect data to answer that question. He concluded that there is a relationship between beak shape and the type of food birds eat.

   a. Do you consider this person's investigation to be scientific? Please explain why or why not.
   b. Do you consider this person's investigation to be an experiment? Please explain why or why not.
   c. Do you think that scientific investigations can follow more than one method?

If no, please explain why there is only one way to conduct a scientific investigation.
If yes, please describe two investigations that follow different methods, and explain how the methods differ and how they can still be considered scientifically.

2. Two students are asked if scientific investigations must always begin with a scientific question. One of the students says "yes" while the other says "no". Whom do you agree with and why?
3. a. If several scientists ask the same question and follow the same procedures to collect data, will they necessarily come to the same conclusions? Explain why or why not. b. If several scientists ask the same question and follow different procedures to collect data, will they necessarily come to the same conclusions? Explain why or why not.
4. Please explain if "data" and "evidence" are different from one another.
5. Two teams of scientists were walking to their lab one day and they saw a car pulled over with a flat tire. They all wondered, "*Are certain brands of tires more likely to get a flat*?".

   - Team A went back to the lab and tested various tires' performance on one type of road surface.
   - Team B went back to the lab and tested one tire brand on three types of road surfaces.

   Explain why one team's procedure is better than the other one.

6. The data table below shows the relationship between plant growth in a week and the number of minutes of light received each day. Given this data, explain which one of the following conclusions you agree with and why.

Minutes of light each day	Plant growth-height (cm per week)
0	25
5	20
10	15
15	5
20	10
25	0

Please circle one:

a. Plants grow taller with more sunlight.
b. Plants grow taller with less sunlight.
c. The growth of plants is unrelated to sunlight.

Please explain your choice of a, b, or c below:

7. The fossilized bones of a dinosaur have been found by a group of scientists. Two different arrangements for the skeleton are developed as shown below.

    a Describe at least two reasons why you think most of the scientists agree that the animal in Figure. 1 had the best sorting and positioning of the bones?
    b Thinking about your answer to the question above, what types of information do scientists use to explain their conclusions?

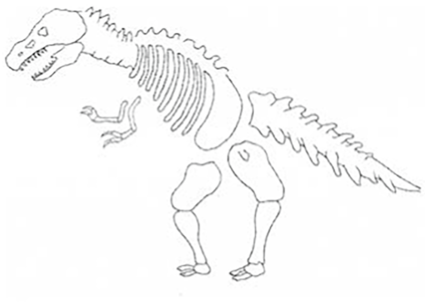

Figure 1

Figure 2

Acknowledgements This study was supported by the Turkish Ministry of National Education's Inservice Teacher Training Directorate under Professional Development Communities Program with code number 202300006. The authors would like to express gratitude for their support to Turkish Ministry of National Education and participating teachers.

Author Contribution All authors made equal and substantial contributions to the conception and design of the study, data collection and analysis, and the drafting and critical revision of the manuscript. Each author has approved the final version of the work and agrees to be accountable for all aspects of the research.

Funding Open access funding provided by the Scientific and Technological Research Council of Türkiye (TÜBİTAK). This study was supported by the Turkish Ministry of National Education's Inservice Teacher Training Directorate.

Data Availability The data that supports the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Ethics The study was conducted following the written ethical permissions obtained from the Turkish Ministry of National Education's Inservice Teacher Training Directorate (Approved Permission Official Letter Number Information: Dated 07.02.2023 and Numbered E-43501582–774.01.01–70062946-2023000060) as well as participant in-service teachers.

Competing interests Authors declare that there is no conflict of interest.

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