

| Research Article / Araştırma Makalesi |

## Formative Assessment Embedded Scientific Inquiry Practices: Changes in Pre-Service Science Teachers' Knowledge and Views

### Biçimlendirici Değerlendirme ile Desteklenmiş Araştırma Sorgulama Uygulamaları: Fen Bilgisi Öğretmen Adaylarının Bilgi ve Görüşlerindeki Değişimler

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Keywords	Abstract
Scientific inquiry Formative assessment Preservice science teachers	Developing preservice teachers' scientific inquiry skills is an important goal of teacher education because these skills support critical thinking and problem solving. This study examined how a training program integrating formative assessment with scientific inquiry influenced preservice science teachers' knowledge of and views about scientific inquiry. A qualitative case study was conducted with 15 fourth-year preservice science teachers. Data were collected through the Scientific Inquiry Inventory (SII) (pre-post), the Views About Scientific Inquiry (VASI) questionnaire (Lederman et al., 2014), semi-structured interviews, and reflective journals. The intervention consisted of an 18-week training program including four inquiry-based activities integrating formative assessment. Descriptive analysis examined preservice teachers' knowledge and views, while content analysis was used for their opinions about the training. Results showed clear improvements in preservice teachers' knowledge of and views about scientific inquiry. Participants reported that integrating formative assessment within inquiry supported deeper understanding, student engagement, and lasting learning. However, some components, particularly research report writing, remained challenging. Integrating formative assessment with inquiry-based practices in teacher education can support preservice teachers' inquiry competencies. Structured feedback and reflection opportunities may further strengthen these skills.
Anahtar Sözcükler	Öz
Araştırma sorgulama yöntemi Biçimlendirici değerlendirme Fen bilgisi öğretmen adayları	Fen bilgisi öğretmen adaylarının araştırma sorgulama becerilerini geliştirmek öğretmen eğitimi açısından önemlidir; çünkü bu beceriler günümüzün bilimsel ve toplumsal sorunlarını ele alabilmek için gerekli olan eleştirel düşünme ve problem çözme yetilerini destekler. Bu çalışmanın amacı, biçimlendirici değerlendirmeyi içeren bir eğitim programı aracılığıyla fen bilgisi öğretmen adaylarının araştırma sorgulamaya ilişkin bilgi ve görüşlerini geliştirmektir. Araştırma, dördüncü sınıfta öğrenim gören 15 fen bilgisi öğretmen adayı ile yürütülen nitel bir durum çalışmasıdır. Veriler, Araştırma Sorgulama Envanteri (ön test-son test), Araştırma Sorgulama Görüşleri anketi (Lederman vd., 2014), yarı yapılandırılmış görüşmeler ve yansıtıcı günlükler aracılığıyla toplanmıştır. Uygulama süreci, biçimlendirici değerlendirmeyi içeren dört araştırma sorgulama etkinliğinden oluşan 18 haftalık bir eğitim programını kapsamaktadır. Öğretmen adaylarının araştırma sorgulamaya ilişkin bilgi ve görüşlerini incelemek için betimsel analiz; eğitime yönelik görüşlerini incelemek için içerik analizi kullanılmıştır. Bulgular, öğretmen adaylarının araştırma sorgulamaya ilişkin bilgi ve görüşlerinde dikkate değer gelişmeler olduğunu göstermiştir. Katılımcılar, biçimlendirici değerlendirme ile bütünleştirilen araştırma sorgulama etkinliklerinin derin öğrenmeyi, öğrenci katılımını ve kalıcı öğrenmeyi desteklediğini belirtmiştir. Bununla birlikte, araştırma raporu yazma gibi bazı bileşenlerin katılımcılar için zorlayıcı olmaya devam ettiği görülmüştür. Sonuçlar öğretmen eğitimi programlarında biçimlendirici değerlendirmenin araştırma sorgulama ile bütünleştirilmesinin öğretmen adaylarının araştırma sorgulama yeterliklerini destekleyebileceğini göstermektedir. Araştırma sorgulama etkinlikleri sırasında yapılandırılmış geri bildirim sağlanması ve yansıtma fırsatlarının sunulması bu becerileri daha da güçlendirebilir.

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## Introduction

Science education aims to develop scientifically literate individuals who are able to understand the processes by which scientific knowledge is generated. In this context, scientific inquiry constitutes a fundamental component of science teaching and learning. Inquiry-based learning encourages students to ask questions, design investigations, collect and analyze data, and construct explanations based on evidence. Through these processes, learners actively engage in knowledge construction and develop higher-order thinking skills such as critical thinking and problem solving (Uum et al., 2016).

For inquiry-based instruction to be implemented effectively, teachers must possess a strong understanding of scientific inquiry and be able to guide students through the processes of questioning, investigation, and interpretation. Accordingly, teacher education programs are expected to provide preservice teachers with opportunities to experience and practice inquiry processes during their training (Plummer & Özçelik, 2015). Experiencing these processes allows preservice teachers to better understand how inquiry-based learning environments function and how such environments can be implemented in classroom practice.

In addition to understanding inquiry processes, preservice teachers must also develop an understanding of the Nature of Scientific Inquiry (NOSI). NOSI refers to the characteristics of scientific investigations and the ways in which scientific knowledge is generated and justified (Lederman et al., 2014). According to Lederman et al. (2014), scientific inquiry includes several key components such as investigations beginning with questions, the use of diverse methodological approaches, the possibility of obtaining different results even when similar methods are used, the distinction between data and evidence, and the requirement that explanations be consistent with empirical evidence.

Research indicates that teachers' and preservice teachers' understandings of scientific inquiry significantly influence their instructional practices (Lederman et al., 2014). Studies conducted with preservice teachers frequently report that their views about scientific inquiry are often categorized as naive or mixed, indicating incomplete or partially developed understandings of inquiry processes (Concannon et al., 2020; Penn & Ramnarain, 2021). Similarly, research conducted with both teachers and preservice teachers suggests that structured instructional interventions are necessary to improve their understanding of scientific inquiry (Al-Momani, 2019; Inel-Ekici & Ekici, 2021; Karışan et al., 2017; Lederman & Lederman, 2019). These findings highlight the importance of supporting the development of scientific inquiry competencies within teacher education programs.

## Formative Assessment in Inquiry-Based Science Teaching

Effective inquiry-based science teaching requires assessment approaches that support learning throughout the instructional process. Formative assessment plays a critical role in this regard because it enables teachers to monitor students' understanding, provide feedback, and adjust instruction accordingly. Formative assessment refers to activities carried out by teachers and students that generate information used as feedback to modify teaching and learning processes (Black & Wiliam, 2006).

Through formative assessment practices, teachers collect evidence of students' learning, identify misconceptions, and design instructional responses that help students progress toward learning goals. This process involves clarifying learning objectives, eliciting evidence of student understanding, providing feedback, and supporting students in regulating their own learning (Moss & Brookhart, 2019; Stiggins, 2008). In science education, formative assessment practices are particularly valuable because inquiry-based learning environments require continuous monitoring of students' reasoning and investigative processes.

Educational policies also emphasize the importance of formative assessment. For example, the Turkish Science Curriculum highlights that assessment should focus not only on learning outcomes but also on learning processes, emphasizing continuous evaluation throughout instruction (Ministry of National Education, 2018, 2024). These policy documents underline the importance of integrating formative assessment practices into science teaching.

## **Integrating Formative Assessment and Scientific Inquiry**

Recent research has increasingly explored the integration of formative assessment practices within inquiry-based science teaching. Studies have examined this integration from different perspectives, including its impact on students' academic achievement (Köksalan, 2019; Nishizuka, 2022), its role in the development of preservice teachers' pedagogical content knowledge (Talanquer et al., 2013; Vogt & Schmiemann, 2020), and its influence on teachers' beliefs and competencies (Chi et al., 2021). Research also indicates that formative assessment practices embedded in inquiry-based activities can improve students' conceptual understanding and engagement in learning processes (Arnold et al., 2018; Ruiz-Primo & Furtak, 2007).

Although previous studies demonstrate the potential benefits of combining formative assessment and scientific inquiry, most research has focused primarily on student learning outcomes or teachers' pedagogical knowledge. Comparatively fewer studies have explored how preservice teachers experience instructional processes in which formative assessment practices are systematically integrated into scientific inquiry activities within teacher education contexts. In particular, limited research has examined how preservice teachers' understandings of scientific inquiry develop while they actively engage in formative assessment-embedded inquiry practices over an extended instructional process. Addressing this gap may provide important insights for designing teacher education programs that aim to develop inquiry-oriented teaching competencies.

### **Purpose of the Study**

Teacher education programs play a critical role in preparing future teachers to design inquiry-based learning environments and to use formative assessment effectively in science classrooms. Therefore, examining instructional processes that integrate formative assessment with scientific inquiry can provide valuable insights into how preservice teachers develop inquiry-related competencies.

This study investigates a teacher education process in which scientific inquiry training integrated with formative assessment was implemented with preservice science teachers. By examining preservice teachers' developing knowledge, views, and experiences throughout this instructional process, the study aims to contribute to the literature by providing a detailed account of how formative assessment-embedded inquiry practices function within teacher education.

Based on the theoretical background and the identified gap in the literature, the present study focuses on understanding both the development of preservice teachers' scientific inquiry understanding and their experiences during the formative assessment-embedded inquiry process implemented in teacher education.

This study addresses the following research questions:

1. How did preservice science teachers' knowledge of scientific inquiry develop during the formative assessment-embedded scientific inquiry training process?
2. How did preservice science teachers' views about scientific inquiry evolve throughout the formative assessment-embedded scientific inquiry training?
3. How did preservice science teachers experience the formative assessment-embedded scientific inquiry process, and what kinds of learning patterns emerged during this process.

## **Method**

### **Research Design**

This study employed a qualitative single case study design. Case studies aim to examine a phenomenon in depth within its real-life context by drawing on multiple sources of evidence (Merriam, 1998). In the present study, the case represents a teacher education process in which scientific inquiry training integrated with formative assessment was implemented with preservice science teachers. The study aimed to describe preservice science teachers' prior knowledge and views about scientific inquiry and to examine how these developed during the training process. In addition, the study explored participants' opinions regarding the integration of formative assessment and scientific inquiry.

## Participants

The study group consisted of 15 fourth-year preservice science teachers enrolled in a science teacher education program at a public university in Türkiye. In Türkiye, science teacher education programs are typically four-year undergraduate programs designed to prepare preservice teachers to teach science at the middle school level. The program generally includes courses related to subject matter knowledge, pedagogical knowledge, and teaching practice. Throughout the program, preservice teachers take courses focusing on science content, teaching methods, classroom management, and assessment in education.

Participants in this study were selected through convenience sampling, as the research was conducted within the context of a course attended by the researcher's students. The preservice teachers shared several common characteristics: they had previously completed courses such as Principles and Methods of Instruction, Measurement and Evaluation, and Science Teaching I, but had not taken a course specifically focused on formative assessment. Among the participants, 14 were female and 1 was male. Ethical considerations were followed throughout the study. Gazi University Ethics committee approval was obtained (Approval No: 17311665-302.08.01-140496, dated 29.12.2020). Participants were informed about the purpose of the study and assured that their responses would be used solely for research purposes and would not affect their course grades. Participation was voluntary, and pseudonyms were assigned to protect participants' anonymity.

## Data Collection Tools

This study employed multiple qualitative data collection tools to address its research objectives. To evaluate preservice teachers' knowledge of scientific inquiry implementation (Research Question 1), Scientific Inquiry Inventory (SII), a novel instrument developed for this investigation, was used. For examining their perspectives on scientific inquiry (Research Question 2), the Views About Scientific Inquiry (VASI) Questionnaire, originally developed by Lederman et al. (2014) and validated in Turkish by Karişan et al. (2017), was used. Research Question 3, focusing on the integration of formative assessment with scientific inquiry, was explored through semi-structured interviews. Additionally, the researcher maintained detailed reflective journals documenting participant progress, which informed the interpretation of results. Ethics Committee approval was obtained for this study. The following sections provide comprehensive descriptions of each instrument's development and implementation.

### Scientific Inquiry Inventory (SII)

The Scientific Inquiry Inventory (SII) was developed to evaluate preservice science teachers' ability to apply the components of scientific inquiry when addressing scientific questions. Grounded in the framework proposed by Minner et al. (2010), the SII has five core components: posing questions, designing investigations, collecting data, drawing conclusions, and communicating findings. During its development, these stages were systematically defined, and questions were formulated based on both Minner et al.'s (2010) framework and a thorough review of relevant literature (Kruit et al., 2018; Lederman et al., 2014). To ensure content validity and reliability, a specifications table and rubric were created. These materials, along with the draft SII, underwent review by three scientific inquiry experts, whose feedback guided revisions before finalization. Sample questions are shown in Table 1.

**Table 1**

#### *Sample Questions of SII*

Case	Scientific Inquiry Components	Question
The science teacher assigned Ali a research project. He is supposed to investigate a phenomenon he is curious about in his surroundings, following the steps of the scientific inquiry method. Ali wants to research the effect of light intensity on the rate of photosynthesis in plants.	Formulating research questions	Write a research question suitable for this problem.
	Designing experiments	Design an experiment that could provide an answer to this research question.

In Table 1, sample questions of SII are shown. A total of 29 open-ended questions were prepared across six different scenarios to assess preservice teachers' ability to utilize the components of scientific inquiry. Based on the specification table, the distribution of the items across the inquiry components was as follows: posing questions (7 items), designing investigations (9 items), data-related processes including data collection and organization (5 items), drawing conclusions including data analysis and interpretation (5 items), and communicating findings through research report writing (1 item).

### **Views About Scientific Inquiry (VASI) Questionnaire**

The Views About Scientific Inquiry (VASI) questionnaire, developed by Lederman et al. (2014) and adapted into Turkish by Karışan et al., (2017), was used to assess preservice science teachers' understanding of scientific inquiry. This validated instrument examines eight core aspects of scientific inquiry: (1) investigations begin with questions rather than necessarily testing hypotheses, (2) there is no single universal scientific method, (3) research questions guide the inquiry process, (4) identical procedures may yield different conclusions, (5) methodology influences outcomes, (6) conclusions must align with collected data, (7) data and evidence are distinct concepts, and (8) inferences integrate prior knowledge with empirical findings. To ensure coding reliability, an independent expert co-coder analyzed a portion of the data, resulting in an 89% inter-coder agreement rate, which demonstrates strong consistency in the qualitative analysis.

### **Interview Form**

A semi-structured interview protocol was developed to gather preservice science teachers' opinions about the scientific inquiry training integrated with formative assessment. The initial interview form consisted of 12 questions. After being reviewed by two subject matter experts (SMEs), the questions were modified for clarity and relevance, and the final form included 10 questions. The final interview questions focused on four key areas: (1) teachers' opinions about designing inquiry-based lessons with formative assessments, (2) their positive and negative experiences with the approach, (3) their views on the method's practicality, and (4) their willingness to use it in future teaching. This expert validation process helped ensure the interview questions effectively captured teachers' opinions about the integrated teaching method.

### **Researcher's Journal**

The researcher maintained a reflective journal throughout the training process. The journal included observations about classroom interactions, preservice teachers' participation levels, engagement in inquiry activities, responses to feedback, and reflections on the instructional process. In addition to documenting classroom events, the journal served as a tool for reflexivity, allowing the researcher to reflect on the instructional process and interpret preservice teachers' learning progress. These reflections supported the interpretation of changes observed in the SII and VASI findings.

## **Data Collection**

### **Pre-test and Post-test Administration**

The pre-test and post-test instruments were administered face-to-face during regular class sessions within the teacher education course in which the intervention was implemented. The pre-test was conducted before the beginning of the training process in order to determine preservice teachers' initial knowledge and views about scientific inquiry. The post-test was administered after the completion of the training. Both instruments were applied in the classroom environment, and participants completed the open-ended questions individually. Each administration took approximately one class period, and preservice teachers were given sufficient time to provide detailed responses.

### **Activity Development and Implementation Process**

The study incorporated four scientific inquiry activities, each integrated with formative assessment components, designed for preservice teachers. These activities were developed using a research-based framework (Kruit et al., 2018; Lederman et al., 2014; Inaltun & Ateş, 2018; Minner et al., 2010) that systematically combines scientific inquiry stages with formative assessment strategies (detailed in Table 2). The activities addressed four key physical science concepts: (1) electrical conductivity, (2) density, (3) heat

transfer, and (4) germination, aligned with specific learning objectives established through researcher-expert collaboration. Prior to implementation, all activities underwent rigorous review by two field specialists to ensure their scientific and pedagogical validity. Table 2 shows the activity framework that explains how formative assessment is integrated into scientific inquiry practices.

**Table 2***Activity Framework*

<b>SI and FA Components</b>	<b>Practices</b>
Determining Learning Objectives and Success Criteria (Formative Assessment)	Learning objectives and success criteria are collaboratively established with students for a specific learning outcome aligned with the scientific inquiry method.
Obtaining Information About Student Learning (Formative Assessment)	Effective classroom dialogue is fostered. Students' readiness levels, scientific knowledge, misconceptions, incomplete knowledge, and common alternative conceptions are identified.
Instructional Decision Making (Formative Assessment)	If any misconceptions are present, move to the conceptual change texts. If not, move to the next step in lesson.
Providing Feedback (Formative Assessment)	Feedback is provided to students at every stage.
Questioning (Scientific Inquiry)	A research question is formulated. A hypothesis is established.
Designing (Scientific Inquiry)	Variables are identified. Operational definitions of variables are established. An experiment is designed.
Data (Scientific Inquiry)	Data are collected, organized, and analyzed.
Conclusions (Scientific Inquiry)	Conclusions are drawn.
Communication (Scientific Inquiry)	A research report is written.
Planning the Next Step (Formative Assessment)	The next instructional step is planned based on the data obtained from student learning.

**Training Content**

The 18-week training program commenced with a 7-week theoretical foundation on scientific inquiry and formative assessment, during which preservice teachers participated in four inquiry-based activities incorporating formative assessment. Throughout the training, they received weekly feedback. This article specifically examines three key outcomes of the training: preservice teachers' acquired knowledge of scientific inquiry, their evolving views on inquiry-based teaching, and their reflective evaluations of the training program's effectiveness.

**Data Analysis****Analysis of Knowledge of Scientific Inquiry**

Participants' responses to the Scientific Inquiry Inventory were evaluated using an analytic rubric developed for each component of scientific inquiry based on the relevant literature (Baykara, 2019; Ebenezer et al., 2011; Kruit et al., 2018; Lederman et al., 2014; Temiz, 2007). Each response was scored on a four-level scale (0 = unclear/blank, 1 = naïve, 2 = mixed, 3 = informed). These scores correspond to the categories used in the literature to describe levels of understanding of scientific inquiry (Lederman et al., 2014). After scoring each item, the scores obtained from the questions representing the same inquiry component were combined to determine participants' overall levels (informed, mixed, naïve, or unclear) for that component. This procedure enabled the systematic evaluation of open-ended responses while allowing the results to be presented through categorical distributions.

Preservice teachers' responses were evaluated using an analytic rubric developed for the Scientific Inquiry Inventory. Each item was scored on a scale from 0 to 3 according to the level of scientific inquiry understanding reflected in the response. To ensure reliability in the coding process, a portion of the responses was independently coded by a second researcher experienced in science education. Inter-coder agreement was calculated using the formula proposed by Miles and Huberman (1994), which defines

reliability as the ratio of agreements to the total number of agreements and disagreements. The agreement between coders was found to be 91%, indicating a high level of consistency in the coding process.

### Analysis of Views About Scientific Inquiry

Preservice teachers' views on scientific inquiry were examined through descriptive analysis. Lederman et al. (2014) employed the categories "Informed," "Mixed," "Naïve," and "Unclear" to classify individuals' views concerning the components of scientific inquiry. An individual was classified as "informed" if their responses fully aligned with the target response for a specific component throughout the questionnaire; "mixed" if there was partial alignment or contradictory answers; "naïve" if the answers contradicted accepted views; and "unclear" if the answers were incomprehensible or irrelevant to the topic. For each stage, students' views were scored according to these categories by determining the highest and lowest points, with category scores assigned as 3 for "Informed," 2 for "Mixed," 1 for "Naïve," and 0 for "Unclear." Inter-coder agreement was calculated using the formula proposed by Miles and Huberman (1994), which defines reliability as the ratio of agreements to the total number of agreements and disagreements. The agreement between coders was found to be 89%, indicating a high level of consistency in the coding process.

### Analysis of Views on the Training

Data pertaining to preservice science teachers' views on the scientific inquiry training integrated with formative assessment were analyzed using content analysis. The derived codes and categories were supported with examples from the literature.

## Findings

### Findings Related to Preservice Science Teachers' Knowledge of Scientific Inquiry

This section presents findings regarding preservice science teachers' knowledge of scientific inquiry based on the Scientific Inquiry Inventory (SII). Table 3 summarizes the distribution of participants across four levels of understanding (informed, mixed, naïve, and unclear) for each scientific inquiry component before and after the training.

**Table 3**

*Changes in Preservice Science Teachers' Knowledge of Scientific Inquiry*

SI Stages	Informed (f)/%		Mixed (f)/%		Naïve (f)/%		Unclear (f)/%	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Formulating research questions	5/33	12/80	7/47	3/20	3/20	0	0	0
Hypothesizing	3/20	11/73	6/40	4/27	6/40	0	0	0
Designing experiments	1/7	11/73	9/60	4/27	5/33	0	0	0
Identifying and controlling variables	5/33	12/80	6/40	3/20	4/27	0	0	0
Establishing operational definitions of variables	1/7	10/67	8/53	4/27	6/40	1/7	0	0
Collecting data	1/7	11/73	8/53	3/20	5/33	0	1/7	1/7
Organizing data	2/13	12/80	4/27	2/13	3/20	1/7	6/40	0
Analyzing data	0	9/60	4/27	2/13	6/40	3/20	5/33	1/7
Drawing conclusions	2/13	11/73	4/27	4/27	6/40	0	3/20	0
Writing a research report	0	0	0	7/47	4/27	4/27	11/73	4/27

Table 3 indicates a clear shift in preservice teachers' levels of understanding across most components of scientific inquiry following the formative assessment–embedded inquiry training. In general, the number

of participants categorized at the informed level increased considerably, while the proportions of mixed, naïve, and unclear responses decreased.

The most substantial improvements were observed in components related to formulating research questions, designing investigations, and identifying variables. For example, the proportion of preservice teachers demonstrating informed understanding in formulating research questions increased from 33% in the pre-test to 80% in the post-test. Similarly, informed responses for hypothesizing increased from 20% to 73%, and for designing experiments from 7% to 73%. These findings suggest that the inquiry activities helped participants better understand how scientific investigations are structured and how research questions guide the inquiry process.

Qualitative evidence from participants' responses also illustrates this development. For example, in the pre-test, participant DD responded to a scenario about investigating the effect of fuel additives on automobile efficiency by writing the following statement: "Observe the distance traveled and efficiency rating of five cars after adding varying amounts of a fuel additive to gasoline." This response was coded as naïve, as it presented a statement rather than a research question and included multiple dependent variables without clearly identifying the independent variable. However, in the post-test, the same participant formulated the following research question: "Does the amount of additive mixed into gasoline affect car efficiency?" This response was coded as informed, as it clearly defined the independent variable (additive amount) and the dependent variable (car efficiency), demonstrating a clearer understanding of how research questions should be structured in scientific inquiry.

Substantial improvements were also observed in components related to data organization and drawing conclusions. For instance, the proportion of informed responses for organizing data increased from 13% to 80%, while informed responses for drawing conclusions increased from 13% to 73%. These results suggest that preservice teachers developed a stronger understanding of how data should be interpreted and used to support scientific conclusions during the inquiry process.

However, development was more limited in the data analysis component. Although the number of informed responses increased from 0% to 60%, several participants still remained at the mixed or naïve levels after the training. This pattern suggests that interpreting data and drawing analytical conclusions may represent a more complex cognitive process that requires more sustained practice.

The research report writing stage showed the most limited improvement. No participants reached the informed level either before or after the training. Nevertheless, a positive shift was observed in that the number of unclear responses decreased substantially, while several participants moved to the mixed level. This suggests that although participants began to develop an emerging understanding of research reporting, they still experienced difficulties articulating inquiry findings in a formal written format.

Overall, the findings indicate that the formative assessment–embedded inquiry activities contributed to a meaningful development in preservice teachers' knowledge of scientific inquiry, particularly in the early and middle stages of the inquiry process such as question formulation, experimental design, and variable identification.

### **Findings Related to Preservice Science Teachers' Views About Scientific Inquiry**

Findings regarding preservice teachers' views about scientific inquiry were obtained through the Views About Scientific Inquiry (VASI) questionnaire. Table 4 presents the distribution of participants' views across the categories of informed, mixed, naïve, and unclear before and after the training.

**Table 4***Changes in Preservice Science Teachers' Views About Scientific Inquiry*

VASI Components	Informed (f)		Mixed (f)		Naïve (f)		Unclear (f)	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Component 1. Scientific investigations all begin with a question and do not always test a hypothesis	4/27	12/80	11/73	3/20	0	0	0	0
Component 2. There is no single scientific path/method followed in all investigations	3/20	11/73	5/33	4/27	7/47	0	0	0
Component 3. The question asked guides the scientific inquiry process	7/47	12/80	4/27	1/7	4/27	2/13	0	0
Component 4. Scientists applying the same procedure may not reach the same conclusions	2/13	12/80	10/67	3/20	2/13	0	1/7	0
Component 5. The inquiry process affects results	1/7	7/47	8/53	8/53	5/33	0	1/7	0
Component 6. Research findings must be consistent with collected data	3/20	10/67	12/80	5/33	0	0	0	0
Component 7. Scientific data and scientific evidence are not the same thing	1/7	9/60	9/60	5/33	5/33	1/7	0	0
Component 8. Inferences are based on prior knowledge and collected data	1/7	13/87	12/80	2/13	2/13	0	0	0

The results demonstrate a noticeable shift toward more informed views of scientific inquiry following the training process. The most significant improvement was observed in the component stating that scientific inferences are based on prior knowledge and collected data. In this component, the proportion of preservice teachers categorized as informed increased from 7% in the pre-test to 87% in the post-test, representing the highest level of improvement among all components.

Another substantial improvement occurred in the component indicating that scientists applying the same procedure may reach different conclusions. Informed responses increased from 13% to 80%, while naïve responses were eliminated after the training. This shift suggests that preservice teachers developed a deeper understanding of the interpretive nature of scientific reasoning.

A similar pattern was observed for the component stating that scientific investigations begin with questions rather than necessarily testing hypotheses, where informed responses increased from 27% to 80%. These findings indicate that participants gained a clearer understanding of the diversity of inquiry approaches in scientific practice.

Qualitative responses from participants also illustrate this conceptual development. For example, when asked whether multiple scientists would reach the same conclusions if they used identical methods, participant ZNK initially responded: "Most would, but experimental errors may occur." This response was coded as naïve, as it attributed differences in conclusions solely to experimental error. In the post-test, the same participant responded: "No, because scientists may interpret data differently depending on their perspectives, experiences, and prior knowledge." This response was coded as informed, as it acknowledges the interpretive role of scientists in drawing conclusions from data.

Moderate development was observed in components such as "the inquiry process affects results" and "scientific data and scientific evidence are not the same thing." Although the proportion of informed responses increased in these areas, a notable number of participants remained at the mixed level, suggesting partial but incomplete conceptual change.

Overall, the findings indicate that the training helped preservice teachers move toward more sophisticated views of scientific inquiry, particularly regarding the role of research questions, the diversity of scientific methods, and the interpretive nature of scientific reasoning.

## Findings Related to Preservice Science Teachers' Views on Training Integrated with Formative Assessment and Scientific Inquiry

Preservice teachers' views regarding the integration of formative assessment and scientific inquiry were analyzed through content analysis of the interview data. Three main themes emerged from the analysis: (1) perspectives on scientific inquiry, (2) contributions to student learning, and (3) future applications of the approach. Table 5 presents the themes, subthemes, and representative participant statements.

**Table 5**

*Content Analysis Table*

Theme	Sub-Theme	Definition	Example Quote	Notes/Comments
Perspective on Scientific Inquiry	Way of Thinking	Expresses the view that scientific inquiry is a way of thinking because it is used in daily life.	"I think it's a way of thinking because we use it in daily life as well."	Includes a different emphasis from the majority.
	Research Method	Expresses the view that scientific inquiry is a research method because it involves following specific steps, similar to how scientists conduct research.	"I think it's more of a research method because its steps guide scientists." (MK)	
	Both Method and Way of Thinking	Expresses the view that it can be considered both a way of thinking and a research method.	"Half and half, I think... I'm probably closer to it being a way of thinking." (EE)	Closer to the view of it being a way of thinking.
Contribution to Student Learning	Permanent Learning	Expresses the view that permanent learning is achieved by providing students with hands-on learning opportunities and connecting concepts to daily life.	"First of all, when a student learns by doing themselves, they reach a conclusion through experimentation with cause-and-effect relationships, and it stays in their mind more..." (HNI) "...connecting it to daily life makes it concrete and is important for permanence." (HNI)	
	Meaningful Learning	Expresses views that the integration of scientific inquiry and formative assessment makes learning more meaningful.	"we achieve meaningful learning through the activity." (AK) "It helps to arouse curiosity and learn the topic meaningfully." (AD)	Emphasized by all participants.
	Active Student Engagement	Expresses views that this integration encourages student participation and active involvement in class.	"I think it's very advantageous because it involves the student in the lesson and keeps them active..." (AD)	Includes an emphasis on student-centered instruction.
	Grabbing Attention	Expresses the view that starting with a problem situation motivates students and captures their attention.	"Starting with a problem situation motivates students and grabs attention, ensuring effective and permanent learning." (AK)	Includes comments related to the introductory phase of the lesson.
	Arousing Curiosity	Expresses the view that this integration arouses students' curiosity about the topic.	"Arousing curiosity, making them think..." (AK)	Emphasized by all participants.
	Cause-and-Effect Relationship	Expresses the view that conducting experiments helps students develop cause-and-effect reasoning.	"...when they reach a conclusion through experimentation with cause-and-effect relationships, it stays in their mind more..." (HNI)	
	Problem Solving	Expresses the view that identifying a problem situation contributes to discovering the problem and generating solutions.	"...when identifying a problem situation, they discover the problem and try to find a solution themselves..." (HNI)	
Teaching Scientific Thinking	Expresses the view that this integration develops scientific thinking skills, similar to those of scientists.	"It teaches them to think like a scientist." (AD)		

Theme	Sub-Theme	Definition	Example Quote	Notes/Comments
Future Applications	To Make It Interesting	Expresses the desire to use this method in the future because of its engaging nature.	"Our lessons were generally monotonous... that's why I would use it. I think grabbing attention is beneficial." (AK)	Emphasizes the pedagogical rationale of the method.
	To Develop Scientific Thinking Skills	Expresses the reason for using this method in the future as engaging students in the lesson and developing their thinking skills.	"Yes, absolutely. To engage students in the lesson, to develop their thinking skills." (SG)	Emphasizes the pedagogical rationale of the method.
	Learning Outcomes Alignment	Expresses the reason for using this method in the future as its alignment with curriculum learning outcomes.	"Yes, I'm considering it. Because it's a comprehensive plan, especially for science, that can deliver the learning outcomes in the most accurate way." (HNI)	Emphasizes the pedagogical benefit of the method.
	Efficiency	Expresses the view that conducting experiments, identifying problem situations, and classroom dialogue are efficient components of the method.	"The experiment part, the problem situation, classroom dialogue are very important in my opinion, it would be quite efficient." (HNI)	Emphasizes the elements of the method.
	Applicability Doubt	Contains views expressing uncertainty about the adaptability of this integration to every topic and its suitability for every age group.	"I don't know if it can be adapted to every topic, and I'm not sure if it's suitable for every age." (EE)	Undecided about implementing this method in the future.
	Misconception Uncertainty	Expresses doubts about whether student misconceptions might arise.	"I also don't know if misconceptions will occur." (EE)	Undecided about implementing this method in the future.

### Perspectives on Scientific Inquiry

Participants expressed different perspectives regarding the nature of scientific inquiry. A majority of preservice teachers described scientific inquiry primarily as a research method, emphasizing its structured stages and systematic procedures ( $n = 11$ ). Participant MK explained: "I think it is more of a research method because its steps guide scientists." Some participants, however, emphasized the cognitive dimension of inquiry and described it as a way of thinking ( $n = 3$ ). Participant HNI stated: "I think it is a way of thinking because we use it in daily life as well."

Participant EE expressed a hybrid perspective, suggesting that inquiry could be understood as both a research method and a way of thinking: "Half and half, I think... I am probably closer to it being a way of thinking."

These responses suggest that preservice teachers conceptualized scientific inquiry in multiple ways, reflecting both procedural and epistemological understandings.

### Contributions to Student Learning

Participants widely emphasized the educational benefits of integrating scientific inquiry with formative assessment. The most frequently mentioned contribution was meaningful learning, which was highlighted by nearly all participants. Participant AK explained: "We achieve meaningful learning through the activity because students actively explore the topic."

Many preservice teachers also emphasized the role of inquiry activities in promoting long-term retention. According to participant HNI: "When students learn by doing the experiment themselves and see the cause-and-effect relationship, it stays in their minds longer."

Another commonly mentioned benefit was increased student engagement. Participants indicated that problem situations and inquiry-based activities encouraged students to participate actively in the lesson. Participant AD: "I think it is very advantageous because it involves the student in the lesson and keeps them active."

Participants also noted that the approach helped develop scientific thinking skills, enabling students to approach problems similarly to scientists. Participant AD: "It teaches them to think like a scientist."

These statements suggest that preservice teachers perceived the integration of formative assessment and inquiry not only as an instructional method but also as a way to foster deeper conceptual engagement.

### **Future Applications**

Most preservice teachers indicated that they would consider using this approach in their future teaching practices ( $n = 13$ ). Participants reported that the method could make lessons more engaging and help students better understand scientific concepts. For example, Participant AK stated: "Our lessons are often monotonous, but this approach attracts students' attention and makes the lesson more interesting."

Participant SG emphasized the role of the approach in developing students' thinking skills: "Yes, I would definitely use it. It helps students participate in the lesson and develop their thinking skills."

However, a small number of participants expressed concerns regarding practical implementation. Some questioned whether the approach could be applied to every topic or grade level. For example, participant EE stated: "I do not know if it can be adapted to every topic, and I am not sure if it would work for every age group." These comments suggest that while preservice teachers generally perceived the integration of formative assessment and scientific inquiry positively, some participants still had reservations regarding its classroom feasibility.

Overall, the findings indicate that preservice teachers largely viewed the integration of formative assessment and scientific inquiry as an effective instructional approach that can promote meaningful learning, student engagement, and scientific thinking.

## **Discussion**

### **Preservice Science Teachers' Knowledge of Scientific Inquiry**

Beyond the observed improvements in preservice teachers' knowledge and views about scientific inquiry, the training process revealed important learning dynamics consistent with a case study perspective. The formative assessment–embedded inquiry activities created an instructional environment in which preservice teachers repeatedly engaged in cycles of planning investigations, generating evidence, receiving feedback, and revising their explanations. Researcher journal notes indicated that many participants initially approached inquiry activities primarily as procedural tasks. However, as the training progressed, classroom dialogue and feedback processes increasingly encouraged participants to justify their reasoning and reconsider their explanations in light of experimental evidence and peer discussion. These observations suggest that the intervention functioned not only as an instructional program but also as a developmental learning process in which preservice teachers gradually reconstructed their understanding of scientific inquiry.

An examination of preservice science teachers' performance across the stages of the scientific inquiry process—including question formulation, hypothesizing, experimental design, variable definition, data collection and analysis, drawing conclusions, and report writing—revealed an overall improvement following the training. These findings align with previous studies indicating that applied inquiry-based instruction can support the development of inquiry-related competencies among preservice teachers (İnel-Ekici & Ekici, 2021). In particular, the improvements observed in formulating research questions, constructing hypotheses, and designing investigations suggest that explicit instruction combined with structured feedback can effectively support preservice teachers in planning scientific investigations.

However, development across inquiry components was not uniform. Earlier interpretations attributed limited progress primarily to irregular participation in feedback sessions. Although participation patterns may have influenced individual performance, the present findings suggest that conceptual challenges inherent in certain inquiry components also played a role. Inquiry tasks such as defining operational variables or interpreting data require the coordination of multiple cognitive processes, including translating conceptual ideas into measurable indicators, analyzing empirical evidence, and connecting findings with theoretical

explanations. These cognitive demands may explain why some preservice teachers continued to experience difficulties even when they participated consistently in the training.

The operational definition of variables is widely recognized as one of the most challenging aspects of scientific inquiry (Ateş, 2005), and the findings of this study support this observation. Although many preservice teachers improved in this stage, several remained at mixed or naïve levels. Researcher journal notes suggested that these difficulties were often associated with incomplete explanations of how variables would be measured or controlled. Similar challenges in defining variables and designing investigations have also been reported in previous studies examining inquiry skills development among preservice teachers (Yoon et al., 2012).

Similarly, although substantial improvement was observed in data collection and organization, some participants experienced difficulties during the data analysis stage. Interpreting experimental data requires both analytical reasoning and the ability to connect results to conceptual explanations. While many preservice teachers progressed from descriptive observations toward explanatory interpretations, others struggled to integrate empirical findings with theoretical reasoning. These difficulties are consistent with earlier research indicating that learners often experience challenges when linking experimental data with theoretical interpretations (Chang et al., 2010).

The weakest performance was observed in the research report writing stage, where none of the participants reached the informed level after the training. This finding suggests that scientific communication represents an additional challenge for preservice teachers developing inquiry competencies. Writing a research report requires organizing evidence, articulating reasoning, and presenting conclusions within a coherent explanatory structure. For preservice teachers who are still developing inquiry skills, translating experimental experiences into structured scientific arguments may represent a cognitively demanding task. This finding highlights the importance of integrating explicit support for scientific writing and argumentation within inquiry-based teacher education programs.

Overall, the findings suggest that integrating formative assessment practices within inquiry-based instruction supports preservice teachers' learning not only by improving their procedural understanding of scientific inquiry but also by engaging them in iterative cycles of evidence generation, feedback, and explanation revision. Through this process, preservice teachers gradually shifted from viewing inquiry primarily as a sequence of steps toward understanding it as a reasoning process that requires interpreting evidence and justifying conclusions.

### **Preservice Science Teachers' Views About Scientific Inquiry**

Changes in preservice teachers' views about scientific inquiry can be interpreted in relation to the learning processes experienced during the training. Before the intervention, preservice teachers generally demonstrated mixed views about scientific inquiry, a finding consistent with previous research involving both in-service and preservice teachers (Karısan et al., 2017; Valente et al., 2022). Following the training, a noticeable improvement was observed across several components of scientific inquiry understanding. One of the most significant developments occurred in the component stating that scientific inferences are based on prior knowledge and collected data. This development can be interpreted in relation to the formative assessment practices embedded in the training. By eliciting preservice teachers' prior ideas at the beginning of inquiry activities, formative assessment created opportunities for participants to compare their initial explanations with the evidence generated during investigations. Classroom dialogue and feedback processes encouraged preservice teachers to justify their conclusions and reconsider their reasoning. Through this process, participants increasingly recognized that scientific inferences emerge from the interaction between empirical data and prior conceptual understanding. These findings are consistent with previous studies suggesting that inquiry-supported instructional environments can promote deeper understanding of scientific inquiry concepts (Ünlü, 2021).

Substantial development was also observed in components related to the nature of scientific inquiry, including the understanding that scientists applying the same procedures may reach different conclusions and that scientific investigations do not always follow a single universal method. These improvements suggest that preservice teachers began to perceive inquiry as a flexible and interpretive process rather than

as a rigid sequence of steps. Such shifts align with contemporary perspectives on the nature of science emphasizing the interpretive, creative, and socio-cognitive aspects of scientific knowledge production (Lederman, 2004; Hodson, 1996; Vygotsky, 1978). Similar developments in preservice teachers' understanding of scientific inquiry have been reported in previous studies (Çiğdemoğlu-Köseoğlu, 2019; Ünlü, 2021).

Nevertheless, development across components remained uneven. For example, the component stating that research questions guide the inquiry process showed relatively limited change for some participants. This result suggests that certain aspects of scientific inquiry understanding may require more sustained conceptual engagement and repeated opportunities for explanation and reflection. Similarly, although many preservice teachers improved in distinguishing between scientific data and scientific evidence, some participants continued to demonstrate partial understandings. Distinguishing between these concepts requires recognizing that evidence involves interpreting data in relation to scientific claims, a reasoning process that may require extended practice.

These findings also contribute to the literature by illustrating how formative assessment practices may support the development of epistemic understanding in inquiry learning environments. By making preservice teachers' initial ideas visible and subject to discussion, formative assessment created opportunities for participants to examine how scientific explanations are constructed through the interaction of prior knowledge and empirical evidence.

In conclusion, the integration of formative assessment with scientific inquiry training effectively enhanced most preservice teachers' understanding of scientific inquiry, supporting existing literature on the value of structured, applied professional development (Arnold et al., 2018). The practical orientation of the intervention aligned with Karaman's (2007) recommendation that teachers need both conceptual understanding and authentic inquiry experiences. While significant progress was observed, persistent gaps in specific components suggest the need for more robust teacher education approaches featuring three key elements: (1) enhanced practical applications, (2) guided reflection opportunities, and (3) targeted individualized feedback to address remaining misconceptions and proficiency variations.

### **Preservice Science Teachers' Opinions Regarding Training in Formative Assessment and Scientific Inquiry Integration**

This section analyzes preservice science teachers' opinions on the integrated formative assessment and scientific inquiry training, exploring three key dimensions: (1) their evaluation of the inquiry method itself, (2) perceived benefits for student learning, and (3) anticipated implementation challenges and opportunities in future practice. These qualitative insights address the study's final research question through in-depth interviews examining both the theoretical and practical aspects of the integrated approach. Under the theme Perspective on Scientific Inquiry, the finding that most preservice teachers perceive scientific inquiry as a "research method" with specific steps aligns with Bybee's (2006) emphasis on scientific inquiry in the science education literature concerning the teaching of scientific process skills. This perspective suggests that the scientific inquiry method offers students the opportunity to experience how scientists think and conduct science. Conversely, some preservice science teachers describing scientific inquiry as a "way of thinking," and one participant suggesting it could be a synthesis of both, reflects the diverse viewpoints in the literature. For instance, Lederman (2004) underscores the importance of internalizing science as a way of thinking by emphasizing that science is a flexible and creative process. Similarly, Hodson (1996) highlights the importance of students embracing scientific inquiry not merely as a method but as a cognitive framework that includes critical thinking and problem-solving processes. These findings, supported by the literature, indicate that both the methodological and the cognitive and structural aspects of scientific inquiry should be considered when training teachers.

Analysis of preservice teachers' reflections reveals unanimous agreement on the educational value of this integrated approach, particularly its effectiveness in promoting deep, lasting learning through authentic applications. These outcomes substantiate established learning theories, including Dewey's (1910) principles of experiential education and Piaget's (1972) constructivist framework, while also validating contemporary science standards (National Research Council [NRC], 2014). The observed development of scientific reasoning

skills and conceptual understanding through inquiry-based methods corroborates existing research (Arnold et al., 2018), with Köksalan's (2019) findings specifically confirming the synergistic benefits of combining formative assessment with inquiry-based instruction to enhance conceptual mastery through structured feedback mechanisms. Similarly, this study's findings align with established research, showing the integrated approach enhances engagement through active learning and curiosity-driven instruction while developing scientific reasoning and literacy (Al-Momani, 2019; Crawford, 2007). The results particularly support Ruiz-Primo and Furtak's (2007) findings that formative assessment during inquiry deepens learning and scientific thinking, confirming preservice teachers' recognition of this method's value in creating authentic, cognitively engaging science learning experiences. Finally, examining the Future Applications theme, it was determined that the majority of preservice science teachers exhibited a positive attitude toward incorporating this method into their future lesson plans. Among the most frequently cited justifications for this positive attitude were making lessons engaging, developing students' scientific thinking skills, and alignment with curriculum learning outcomes. These results indicate that preservice teachers wish to utilize the knowledge and experiences gained in their faculties of education once they become teachers. However, the hesitation expressed by two preservice teachers regarding the method's applicability and uncertainty about misconceptions aligns with some difficulties mentioned in the literature. Studies in the literature reveal that challenges teachers face include time constraints, misconceptions, student characteristics, and insufficient materials (Crawford, 2007). Additionally, studies emphasize that not every learning outcome in the curriculum may be suitable for scientific inquiry-based instruction and that students' pre-existing misconceptions need to be managed (Pozo & Gomez Crespo, 2005). Considering these factors, it is believed that teacher education needs to provide more practical experience and studies on adaptability to different classroom conditions. In conclusion, preservice teachers were found to be open to innovative science teaching approaches and willing to adopt strategies that promote more active, meaningful, and permanent student learning. This is a significant indicator that the future of science education will be student-centered and based on a scientific inquiry understanding (NRC, 2014).

### **Limitations**

This study has several limitations that should be considered when interpreting the findings. First, the study was conducted with a relatively small group of preservice science teachers enrolled in a single teacher education program. Therefore, the findings should be interpreted within the context of this specific group and may not be generalized to all preservice teachers. Second, the study focused on a particular instructional intervention implemented within a single course. Although the 18-week training process provided rich insights into preservice teachers' development, different implementations in other contexts or teacher education programs may lead to different outcomes. Finally, the data were collected primarily through written responses and interviews. Although these instruments provided valuable information about preservice teachers' knowledge and views about scientific inquiry, future studies could benefit from incorporating additional data sources such as classroom observations or teaching practices to gain a more comprehensive understanding of preservice teachers' inquiry skills.

### **Recommendations**

There are some recommendations based on the findings of this research. Future research could explore the combination of different assessment methods with various teaching approaches, investigating their effects on diverse student variables. Given the identified importance of the feedback process, it's recommended that participants receive detailed training specifically focused on developing their feedback skills. Since preservice teachers reported significant difficulties with formulating problem situations, operationally defining variables, and writing research reports, it's recommended that detailed studies be planned to investigate and address these specific areas. Preservice teachers should be offered courses that integrate formative assessment with various teaching methods as they prepare for their profession. In this study, a step-by-step feedback process was conducted with each preservice teacher from the beginning of the training, with the researcher playing an active role in assisting them throughout the process. It's recommended that in future implementations, teachers actively participate in providing feedback.

## Conclusion

This study examined the development of preservice science teachers' knowledge of and views about scientific inquiry within a formative assessment–embedded inquiry training process. The findings suggest that integrating formative assessment practices into inquiry-based instruction can support the development of inquiry-related competencies in teacher education contexts. Preservice teachers demonstrated improvements in several components of scientific inquiry, particularly in formulating research questions, designing investigations, and identifying variables. However, development was less evident in more complex components such as data analysis and research report writing, indicating that these areas may require more sustained instructional support and practice. In addition, participants' views about scientific inquiry showed a shift toward more informed understandings, especially regarding the role of prior knowledge in shaping inferences and the interpretive nature of inquiry processes. These changes may be associated with the opportunities for feedback, reflection, and classroom dialogue provided through formative assessment practices. Participants also reported that the integration of formative assessment and inquiry contributed to meaningful learning and increased engagement. Nevertheless, some concerns regarding the applicability of this approach across different topics and contexts highlight the need for further practice-oriented experiences in teacher education programs.

## Author's Note

This study is derived from the doctoral dissertation research conducted by Elif YALVAÇ ERTUĞRUL under the supervision of Prof. Dr. Salih ATEŞ.

## CRedit authorship contribution statement

Elif Yalvaç Ertuğrul: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. Salih Ateş: Supervision, Methodology, Validation, Writing – review & editing.

## Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Ethics Approval and Consent to Participate

Ethics committee permission for this study was obtained from the Gazi University Ethics Committee with the decision dated on 29.12.2020, and numbered 17311665-302.08.01-140496.

## Declaration of AI Usage Statement

AI-assisted tools (Chat GPT 5.2, Google AI Studio) were used only for language editing and improving the clarity of the manuscript. The authors take full responsibility for the content of the article.

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