ORIGINAL ARTICLE

Exploring Pre-service Chemistry Teachers' Understanding of Scientific Inquiry Skills through the Chemistry Laboratory Course

Filiz Kabapınar,[1] Destan Tekin,[1] Sevgi Tetik[2]

1. Marmara University, Istanbul, Turkey
2. Ministry of National Education, Istanbul, Turkey

***Abstract**: Scientific inquiry is a process in which individuals pose questions, think critically and engage in problem-solving research and investigation. It enables the explanation of observable scientific phenomena, problems, or events based on evidence. Through this process, students not only find answers to their questions but also structure their knowledge, opening the door to scientific practice. Scientific inquiry skills consist of six process components: defining the question or problem, developing a model to answer the question or find a solution to the problem, planning and realizing the research, analyzing and interpreting data, making evidence-based explanations and producing solutions, and evaluating and sharing knowledge. The aim of this study is to determine the readiness of pre-service chemistry teachers for the competency-based curriculum. Conducted as action research, the study involved 16 pre-service chemistry teachers over 12 weeks during the chemistry laboratory course in the fall semester of the 2023-2024 academic year. Data collection tools included open-ended questionnaire items to gauge pre-service teachers' perceptions of scientific inquiry skills, an activity sheet designed to foster these skills, and a rubric for evaluation. The study analysed the use of the components of scientific inquiry skills by pre-service teachers. The results indicated that the pre-service chemistry teachers most frequently utilized the components 'defining the question or problem' and 'planning and conducting research,' which are subcomponents of scientific inquiry. However, the components 'making evidence-based explanations and producing solutions' and 'evaluating and sharing knowledge' were used less frequently in the activities they designed.*

Science Insights Education Frontiers 2025; 28(2): 4637-4656
DOI: 10.15354/sief.25.or781

How to Cite: Kabapınar, F., Tekin, D., & Tetik, S. (2025). Exploring pre-service chemistry teachers' understanding of scientific inquiry skills through the chemistry laboratory course. Science Insights Education Frontiers, 28(2): 4637-4656.

***Keywords**: Chemistry Education Curriculum, Pre-Service Teachers, Scientific Inquiry Skills, Skill-Based Teaching*

***About the Authors**: Filiz Kabapınar, Professor, Department of Chemistry Education, Atatürk Faculty of Education, Marmara University, 34722 Istanbul, Turkey. E-mail: filizk@marmara.edu.tr. ORCID: https://orcid.org/0000-0001-5937-0880*

Destan Tekin, Ph.D, Department of Chemistry Education, Atatürk Faculty of Education, Marmara University, 34722 Istanbul, Turkey. E-mail: destan.tekin@marmara.edu.tr. ORCID: https://orcid.org/0000-0001-5031-3548

Sevgi Tetik, Chemistry Teacher, Ministry of National Education, İstanbul, Turkey. E-mail: sevgitetik14@gmail.com, ORCID: https://orcid.org/0009-0003-6983-2964

***Correspondence to**: Destan Tekin at Marmara University in Turkey.*

***Conflict of Interests**: None*

***Funding**: No funding sources declared.*

***AI Declaration**: The authors affirm that artificial intelligence did not contribute to the process of preparing the work.*

Introduction

THE ACQUISITION of skills, a key goal of science education from K-12 onward, plays a vital role in addressing real-world problems and professional challenges by integrating academic learning with field experience at the university level (Aktamiş, 2007; Baştaş, 2007; Derilo, 2019; Jack, 2013; Salas, Baldiris et al., 2016). In science education, the limited influence of the positivist paradigm in teaching concepts and skills has prompted the need for a shift toward the interpretivist paradigm in the reorganization of teaching and learning processes (Kabapınar, Tekin & Tetik, 2023; Thanh & Thanh, 2015; Treagust & Won, 2023). According to Willis (2007), a prominent figure in the interpretivist paradigm, reality is socially constructed through understanding specific contexts. He further defined the interpretivist paradigm as being open to multiple perspectives and change. Neumann (2011) emphasized the interconnectedness of scientific methods, including steps like analyzing data, identifying dependent and independent variables, and establishing cause-effect relationships.

The interpretivist paradigm, which has gained international attention for its redefinition of scientific concepts, has not only reshaped the understanding of the scientific method but also restructured the learning and teaching processes (Applefield et al., 2000; Bonache, 2021; Gichuru, 2017; Kabapınar, 2021a). Aligning with constructivist views on the nature of science, this paradigm posits that knowledge is constructed through interpretation, a process grounded in an individual's existing concepts and skills (Burns, 2022; Driver & Erickson, 1983; Glesne & Peshkin, 1992; Junjie & Yingxin, 2022; Nickerson, 2022; Pilarska, 2021; Tekin & Kabapınar, 2023; Yıldırım & Şimşek, 2013). Activities based on this paradigm aim to transcend traditional inductive and deductive reasoning, fostering active participation and holistic research. This approach has been shown to open doors to scientific literacy, which encompasses multiple dimensions such as the ability to comprehend scientific knowledge, the ability to apply it, the ability to evaluate it within the science-technology-society context, and the capacity to produce evidence-based outcomes (Bybee, 1997; Flick & Lederman, 2006; Lederman et al., 2014; Miller, 1983; National Research Council [NRC], 2000).

Turkey's revised curriculum 2024 aims to assess the impact of philosophical approaches and domain-specific skills in education. The "K-12 Skills Framework: Turkey Holistic Model" (MEB, 2023a) developed in collaboration with teachers, curriculum experts, and academics, introduces a comprehensive structure encompassing conceptual skills, social-emotional learning, dispositions, and literacy and competencies across four domains: Turkish, mathematics, science, and social sciences (MEB, 2023a).

The framework identifies 13 core science skills: "scientific observation, classification, prediction based on scientific observation, prediction based on scientific data, operational definition, forming hypotheses, experimentation, scientific reasoning, forming scientific models, inductive reasoning, deductive reasoning, using evidence, and scientific inquiry." These skills are essential across all areas of science, with "scientific inquiry skills" standing out as particularly challenging to develop in students. They are critical to the field of science education and are composed of six process components, but also encompass other skills (Chu et al., 2021; Lou, Blanchard & Kennedy, 2015; Stone, 2014; Sutiani et al., 2021; Teig, 2021, 2024).

Scientific inquiry is defined as "a set of systematic research methods and strategies that scientists use to understand and explain an observable scientific issue, problem or event on the basis of evidence" (MoNE, 2023a, p. 158). The primary aim of scientific inquiry is to help students develop the skills to analyse topics, problems, or events, formulate scientific ideas, and deepen their understanding of scientific knowledge. Beyond mastering scientific content, contemporary science education also emphasises helping students recognise the relevance of scientific phenomena in their own lives by relating science to real-world problems (Roberts & Bybee, 2014). Through scientific inquiry, students learn to ask effective questions through scientific inquiry, create a model related to the subject, conduct research for their needs, collect data and develop explanations based on data, collect evidence from primary and secondary sources, and explain the results of the evidence they obtain using appropriate methods. Scientific inquiry encompasses a variety of methods used to organise explanations based on evidence from research and investigation into the natural world (Ireland with the National Council for Curriculum and Assessment [NCCA], 2015). It also incorporates activities through which students learn about the investigative processes scientists use, while building knowledge and understanding of scientific concepts.

The components of science and engineering practices, as outlined by the National Research Council (NRC, 2012), include asking questions, developing and using models, planning and carrying out investigations, analysing and interpreting data, applying mathematics and computational thinking, constructing explanations, formulating evidence-based arguments, and acquiring, evaluating, and communicating information. These practices are interconnected and gain meaning when applied together in context (NRC, 2012; Rönnebeck et al., 2016). Similarly, the European Commission and the Directorate-General for Research and Innovation (2015) advocate for fostering both a deep understanding of science and an awareness of its practical applications and relevance to daily life, grounded in scientific inquiry. At its core, scientific inquiry involves systematically finding answers to well-defined questions through informed decision-making. In doing so, students actively engage in authentic scientific practices, taking significant steps toward achieving the educational goals and objectives of the science curriculum (Agrawal et al., 2016; Lederman et al., 2019, Tekin, 2020). In the 1996 National Science Education Standards (NSES) document on reforming science education (NRC, 1996), the concept of scientific inquiry is defined in detail as follows (NRC, 1996, p. 23):

"*A multifaceted activity that involves making observations, asking questions, examining books and other sources of information to see what is already known, planning investigations, revising what is already known in the light of empirical evidence, collecting, analyzing and interpreting data, using tools for interpretation, and communicating answers, explanations, predictions, propositions and conclusions.*"

Along with this definition, the NRC standards (2000, 2006) published in subsequent years elaborated on competencies such as defining a scientific question, designing and conducting research, using appropriate tools to collect and analyse data, and developing evidence-based explanations. The K-12 science education framework (NRC, 2012) places emphasis on a set of core ideas and concepts while integrating scientific practices and those required for engineering design. Notably, this framework highlights the importance of engaging students not only in scientific content but also in the practices of scientific inquiry and research (Rönnebeck et al., 2016). In 2012, the Next Generation Science Standards (Next Generation Science Standards [NGSS], 2012; NRC, 2012) introduced a more contemporary perspective, revising the standards necessary for science education at the K-12 level. According to Deboer (2006), who gives a similar definition, the process of asking questions about daily life and the research process planned to answer all these questions reveal the integrative role of scientific inquiry.

Deboer (2006) also highlighted the pedagogical dimension of scientific inquiry, particularly the value of laboratory-based teaching as an effective instructional method across disciplines within formal education settings. In the K-12 Skills Framework, the skills needed in the process of scientific inquiry are defined as process components, including: defining the question or problem, developing a model to answer the question or find a solution to the problem; planning and realizing the research; analyzing and interpreting data; making evidence-based explanations and producing solutions; and evaluating and sharing knowledge. The six components of scientific research skills and the sub-indicators of these components are as follows:

1. Defining the question or problem

1a. Formulating a researchable question based on observation and/or experience.

1b. Evaluating whether the question is researchable or not.

1c. Identifying qualitative and quantitative relationships between variables to define the question.

2. Developing a model to answer the question or find a solution to the problem

2a. Testing and improving the model in the context of different variables.

2b. Obtaining data and making calculations based on the model.

2c. Using the model to explain similar events.

2d. Making suggestions for solving the problem based on the model or theory.

3. Planning and realizing the research

3a. Selecting measurement instruments according to their sensitivity.

3b. Determining the number and frequency of measurements.

3c. Explaining the reasons for the hypothesis.

3d. Testing the accuracy of the hypothesis.

4. Analyzing and interpreting data

4a. Considering the limitations of the data analysis method when analysing and interpreting the data.

4b. Reorganising data or collecting new data if necessary.

4c. Using alternative graphical tools and mathematical calculations to interpret data.

4d. Generalising from data.

5. Making evidence-based explanations and producing solutions

5a. Comparing his/her solutions to the problem with those of scientists.

5b. Comparing the results with scientific evidence.

6. Evaluating and sharing knowledge

6a. Relating the evidence obtained in the process of solving the problem to reference scientific information.

6b. Sharing the results by using the supporting information obtained from scientific sources.

In this study, the K-12 Skills Framework, along with the Turkey Holistic Model — both of which are considered fundamental and foundational for the development of other skills — was used to assess the readiness of pre-service chemistry teachers for the new skills-based curriculum. The research questions of the study are as follows:

Question 1: How do pre-service chemistry teachers perceive scientific inquiry skills?
Question 2: To what extent do the activities prepared by pre-service chemistry teachers correspond to the process components of scientific inquiry skills?

Method

This study was conducted using action research methods. Within the scope of the research, the K-12 Skills Framework: Turkey Holistic Model (MoNE, 2023a) was employed, focusing specifically on the six process components of scientific inquiry skills. The study was implemented over a period of 12 weeks as part of a chemistry laboratory course for pre-service chemistry teachers and was designed following the principles of action research. Lewin (1946) initially conceptualised action research as a three-stage, though non-hierarchical, process involving careful planning, effective action, and the systematic examination of outcomes resulting from the action taken (Masters, 1995). Similarly, Kemmis (1988) described action research as a form of reflective inquiry undertaken by practitioners to improve their professional practices. Dewey (1929), who underscored the essential role of teachers in investigating and addressing pedagogical challenges within their classrooms, regarded action research as a valuable means of resolving practical issues encountered in the course of instructional activities (Mills, 2003; Watts, 1985).

Research Group

Twelve distinct experiments, specifically designed to develop scientific inquiry skills, were implemented by pre-service chemistry teachers over a 12-week period. These experiments aimed to investigate how pre-service teachers utilised the six process components of scientific inquiry skills.

The study was conducted as action research with a cohort of pre-service chemistry teachers (n = 16) over the course of 12 weeks within a chemistry laboratory course during the fall semester of the 2023–2024 academic year. The research process was guided by the K-12 Skills Framework: Turkey Holistic Model Teacher's Guide (MoNE, 2023b). Additionally, two expert chemistry educators, both of whom contributed to the development of the K-12 Skills Framework: Turkey Holistic Model Teacher's Guide (MoNE, 2023b), were actively involved in overseeing the implementation of the activities. Their participation ensured that the activities consistently adhered to the process components for cultivating scientific inquiry skills and helped to mitigate potential threats to the external validity of the study.

Data Collection

In this study, open-ended questionnaires and a rubric were employed as data collection tools. The open-ended questionnaire was designed to explore pre-service chemistry teachers' perceptions of scientific inquiry, while the rubric was used to assess the extent to which the activities prepared by these pre-service teachers at the conclusion of the chemistry laboratory course addressed the sub-components of scientific inquiry skills.

The open-ended questionnaire (see Appendix 1) aimed to capture the participants' perceptions regarding several aspects of scientific inquiry skills, including their understanding of what constitutes scientific inquiry, suggestions for activities to foster these skills, the changing roles of students and teachers in inquiry-based classroom environments, and their interpretations of the concepts of data and evidence within the scientific inquiry process. Additionally, at the end of the chemistry laboratory course, the participant was asked to design a new activity intended to develop scientific inquiry skills in chemistry education.

The activities designed by the pre-service teachers were analysed using a rubric developed by the researchers (see Appendix 2), which included criteria corresponding to the six sub-components of scientific inquiry. Through this analysis, the extent to which each activity addressed the sub-components was determined. A content analysis approach was applied to examine the pre-service teachers' incorporation of these sub-components into their activities.

To ensure the reliability of the coding process for the open-ended questionnaire responses, inter-coder reliability was calculated using the method proposed by Miles and Huberman (1994). The analysis revealed a high level of agreement between the two coders, with coding reliability ranging from 91% to 95% and an average reliability of 93%. Discrepancies between the coders were subsequently reviewed, discussed, and resolved, resulting in a final consensus and an agreement rate of 100%. To enhance the validity of the open-ended questions, they were reviewed by two experts in chemistry education, and revisions were made based on their feedback.

Chemistry Laboratory Course on Scientific Inquiry Skills

Within the scope of the chemistry laboratory course, pre-service chemistry teachers were asked to identify situations they wished to investigate by employing different experimental methods and materials. These investigations addressed topics such as changes in the acid–base properties of everyday materials in relation to variables like time, quantity, and temperature; the proper use of antacid substances in daily life; calculation of the heat released during a reaction; absorbency; surface tension; vapour pressure of liquids; electrical conductivity; reaction rates; neutralisation reactions; heat conduction in metals; the effect of the surface area of organic molecules on the enthalpy of combustion; physical and chemical dissolution processes; the greenhouse effect; and the activities of artificial sweeteners, among others. For each experiment, pre-service teachers were required to formulate a research question based on these topics.

Following this stage, all necessary glassware and chemical materials for the experiments were provided by field experts. To support the pre-service teachers in formulating research questions and structuring their inquiries, activity sheets prepared by an expert in chemistry education were distributed prior to each experiment. These activity sheets served as guides, encouraging pre-service teachers to develop unique and original research questions related to the subject matter and to explore different investigative approaches using varied materials. For instance, while one pre-service teacher calculated the amount of CO_2 released from a carbonated beverage by collecting the gas over water, another modified the research focus to investigate how pH levels changed with temperature and the presence of fruit acids. In another example, one pre-service teacher sought to examine the effectiveness of different quantities of toothpaste, while another designed a research question to determine the optimal water temperature for tooth brushing and planned an experiment to address this inquiry. This pattern of developing distinct research questions and experimental methods continued across 12 different activities conducted by the 16 participating pre-service teachers.

At the conclusion of each experiment, the pre-service teachers prepared reports detailing the research question(s) posed, the experimental procedure, the application process, and the final results. Additionally, during and after each experiment, the participants were encouraged to reflect on any challenges or difficulties encountered and to propose solutions for overcoming these issues. This reflective practice aimed to enhance their problem-solving skills and reinforce their understanding of the scientific inquiry process.

Results

During the chemistry laboratory course, pre-service chemistry teachers were asked to report the results of their investigations based on the different research questions and methods they employed. The aim was to actively engage the pre-service teachers in the process of scientific inquiry and to help them recognize and reflect upon their own areas for improvement throughout the inquiry process.

To address the first research question of the study, "How do pre-service chemistry teachers perceive scientific inquiry skills?", participants were asked to articulate their views on several aspects of scientific inquiry. Specifically, they were invited to share their understanding of scientific inquiry, suggest activities that could support the development of scientific inquiry skills, describe the evolving roles of students and teachers in classroom environments where scientific inquiry is implemented, and discuss whether the concepts of data and evidence used within the inquiry process are synonymous.

Finally, as a culminating task, the pre-service teachers were asked to design an original activity aimed at fostering scientific inquiry skills within the context of chemistry education. These activity designs were then compiled into activity sheets and evaluated according to the process components of scientific inquiry skills.

Results of Research Question 1:

How do pre-service chemistry teachers perceive scientific inquiry skills?

The pre-service chemistry teachers predominantly defined scientific inquiry as the process of obtaining statistically supported data through experimental methods and valued it as a form of scientific reasoning. They associated scientific inquiry with the principle of progressing from the concrete to the abstract, highlighting its necessity in making chemistry topics—often characterised by abstract concepts—more tangible and comprehensible.

Many of the pre-service teachers emphasised the importance of employing appropriate questioning strategies within the inquiry process, particularly valuing the role of probing questions such as why? and how? which encourage deeper exploration and understanding of the subject matter. Furthermore, several participants described scientific inquiry as an analytical thinking process, illustrating this by offering examples of integrating real-life problems with theoretical knowledge and demonstrating how different conditions can influence experimental outcomes.

In terms of pedagogical roles, the pre-service teachers consistently positioned the student at the centre of the inquiry process. They conceptualised the role of the teacher as a facilitator who not only intervenes when necessary but also guides the lesson through the use of well-structured activities, creates an environment conducive to discussion, and provides effective, constructive feedback throughout the learning process.

The following quotations, drawn from the pre-service teachers' responses in the open-ended questionnaire, exemplify their views regarding the definition of scientific inquiry, its relationship to other skills, and the dynamics of teaching and learning in classrooms where scientific inquiry is applied, including the roles of both students and teachers.

[PST 2]: "Scientific inquiry skills provide students with the ability to think scientifically, hypothesise, and experiment to arrive at scientific data. In this process, students should be given the opportunity to ask questions. Teachers, on the other hand, should take a supportive role in helping their students to find solutions by managing this challenging process."

[PST 10]: "In a classroom where scientific inquiry is taking place, the teacher does not give information directly. He/she helps the student to find information by giving appropriate clues. In this process, the teacher helps to deepen the knowledge with questions such as wh-questions. It is important that the student is enthusiastic and that the necessary requirements are provided for him/her to feel like a "little scientist."

These participants' reflections on scientific inquiry show different aspects from traditional teaching. They clearly indicated the roles of teacher and student. However, the selected participants do not mention the necessary steps of scientific inquiry.

Results of Research Question 2:

"To what extent do the activities prepared by pre-service chemistry teachers correspond to the process components of scientific inquiry skills?"

In this study, a rubric was employed to evaluate the use of process components — the sub-skills of scientific inquiry — by pre-service chemistry teachers as they designed activities intended to foster scientific inquiry skills within chemistry education. Analysis of the designed activities revealed that the pre-service teachers incorporated all components of scientific inquiry skills into their work. However, it was also observed that while some sub-skills were demonstrated at a sufficient level, others appeared to be only partially developed, indicating areas where further improvement and instructional support could be beneficial. Use of components of scientific inquiry skills by pre-service chemistry teachers (see **Table 1**).

[PST 11 Activity Sheet, Case Study]: A mother decides to sew clothes from pieces of textile so that her baby won't get cold during the winter months. However, she cannot decide which of two very similar pieces of textile will keep her warmer.

[Research question of PST11]: Which textile will keep my baby warmer?

Table 1. Use of Components of Scientific Inquiry Skills by Pre-service Chemistry Teachers.

PSTs	CoSIS 1	CoSIS 2	CoSIS 3	CoSIS 4	CoSIS 5	CoSIS 6
PST 1	✓	✓	✓	✓	✓	✓
PST 2	✓	✓	✓	✓	✓	✓
PST 3	✓	X	✓	X	X	X
PST 4	✓	✓	✓	✓	X	X
PST 5	X	✓	✓	✓	✓	X
PST 6	✓	✓	✓	X	X	X
PST 7	✓	✓	✓	X	✓	X
PST 8	✓	✓	✓	✓	✓	✓
PST 9	✓	✓	✓	✓	✓	X
PST 10	✓	✓	✓	✓	✓	✓
PST 11	✓	✓	✓	✓	X	X
PST 12	X	X	✓	✓	X	X
PST 13	✓	✓	✓	X	X	X
PST 14	✓	✓	✓	✓	✓	✓
PST 15	✓	✓	✓	✓	✓	X
PST 16	✓	✓	✓	✓	✓	✓
Total	14	14	16	12	10	5

PST: Pre-service teacher; CoSIS: Components of Scientific Inquiry Skills.
CoSIS 1: Defining the question or problem; CoSIS 2: Developing a model to answer the question or find a solution to the problem; CoSIS 3: Planning and realizing the research; CoSIS 4: Analyzing and interpreting data; CoSIS 5: Making evidence-based explanations and producing solutions; CoSIS 6: Evaluating and sharing knowledge.

[Experiment of PST11]: The textile is cut into equal sizes. Equal amounts of water at 100 ^{o}C are poured into the containers. Two different water containers at the same temperature are covered with two different pieces of cloth so that they are completely covered. A very small gap is left so that the thermometer can fit. The temperature of both containers is measured at regular intervals. The data is recorded. The proposition is written as to which container covered with textile is hotter for the same period of time.

[Result of PST11]: According to the results, textile B kept the water warmer for a longer time than textile A. It was concluded that it would be more appropriate for the mother to choose textile B when sewing clothes for her baby.

Upon reviewing the activity page of PST 11, it was observed that the steps associated with defining the question or problem, developing a model to address the issue, planning and conducting the research, and analysing and interpreting the data were not supported by evidence-based explanations. Furthermore, PST 11 did not employ scientific data to assess the proposed solution to the problem. In particular, PST 11 failed to conduct a scientific comparison of the textiles used in the experiment, neglecting to evaluate their structure, texture, weight, and fibre properties.

The research findings revealed that while all pre-service chemistry teachers consistently employed certain sub-components of scientific inquiry skills—specifically, "defining the question or problem" and "planning and conducting the research"—they utilised the components "making evidence-based explanations and producing solutions" and "evaluating and sharing knowledge" less frequently in the activities they designed.

Discussion, Conclusion and Recommendations

Scientific inquiry is a critical skill in science education; however, it is often challenging to develop effectively. Contrary to viewing science as a static set of outcomes, it is fundamentally a dynamic process that evolves through inquiry-based teaching (Bybee, 2006; Hanauer et al., 2006; Kunisch et al., 2023). When the nature of scientific inquiry is properly understood, plausible explanations for phenomena that spark curiosity become meaningful (Nelson & Ketelhut, 2007). Importantly, scientific inquiry addresses phenomena that are widely accessible and can be collectively experienced, as opposed to those that are purely individual (Brown, 1950; Novak, 1964). The significant advancements in science and the confidence in scientific knowledge stem from the fact that scientists have developed a method of thinking that is intricately linked to the processes of natural life. Scientific inquiry, therefore, emerges as a means of investigating problems through intellectual reasoning, sensory observation, and the mechanical extensions of these processes (Martin & Osherson, 1998; Rönnebeck et al., 2016; Tang, 2010).

This study aimed to investigate how pre-service chemistry teachers adapted to the evolving curriculum, specifically focusing on the K-12 Skills Framework: Turkey Holistic Model (MoNE, 2023a), in order to implement the associated skills. The study sought to determine the extent to which pre-service chemistry teachers were able to apply the process components of scientific inquiry skills in the activities they developed. The findings highlighted the frequency with which all process components of scientific inquiry were used by the pre-service teachers and identified areas where their use was sufficiently, partially sufficient, or in need of improvement. Specifically, it was found that the pre-service chemistry teachers used the process component "evaluating and sharing knowledge" less frequently than other components of scientific inquiry.

It was concluded that the pre-service chemistry teachers struggled to link the evidence they gathered in their experimental processes with established scientific knowledge. They also had difficulty using scientific data to support their findings. This challenge appeared to stem from the teachers' focus on the experimental activities themselves, without considering how their activities could be enhanced by scientific support and evidence. Additionally, most of the pre-service teachers did not experience difficulty in identifying the research question related to the problem, assessing whether the question was researchable, and determining the qualitative and quantitative relationships between variables. The pre-service teachers employed varied approaches to find solutions, conducting different experiments based on the variables they identified, selecting appropriate measurement tools, and determining the frequency of measurements.

The pre-service chemistry teachers demonstrated the ability to interpret the data they collected and present their mathematical interpretations effectively in tables and graphs. Following the experiments they conducted, the teachers had no difficulty in drawing generalisations from their experimental data. However, it was observed that, in the activities they designed, the solutions to the problems were not compared with established scientific data or solutions, and the results were not explained using evidence-based reasoning (Biesta, 2007; Elliott, 2001; Slavin, 2002; Timperley, 2010). This suggests that in those activities where the component of "evaluating and sharing knowledge" was least utilised, the evidence gathered during the problem-solving process was not linked to reference scientific information, and supporting evidence was not incorporated into their conclusions.

This research was conducted with pre-service chemistry teachers on the brink of graduation. The findings suggest that scientific inquiry skills, which are foundational to many other competencies, could be further examined across different student cohorts to provide more comprehensive insights into their development. The study incorporated various activity suggestions in the teaching of scientific inquiry skills, but it is suggested that a more intensive approach, involving a wider range and greater number of activities, would yield a more nuanced understanding of the sub-components of scientific inquiry.

It is recommended that pre-service teachers receive more support in the use of evidence-based skills, a key sub-component of scientific inquiry (Coburn et al., 2009). For example, pre-service teachers could be encouraged to self-assess the materials they design using measurement tools and reflect on the process through reflective journals (Bassot, 2015, 2024; Taggart & Wilson, 2005; Tekin, 2024).

In addition to planning lessons that encourage scientific inquiry, it is crucial to provide pre-service teachers with opportunities to design and implement teaching practices that explicitly target scientific inquiry skills. This hands-on experience would not only deepen their understanding of how students might approach scientific inquiry in their own future professional lives but also shape their expectations for teaching science based on inquiry (Hanauer et al., 2006; Lederman et al., 2013; NRC, 2012).

Acknowledgments

An earlier version of this study was presented at the conference of "16th National Science and Mathematics Education Congress, Trakya University Faculty of Education, Department of Mathematics and Science Education."

Reference

Agrawal, A., Goldfarb, A., & Teodoridis, F. (2016). Understanding the changing structure of scientific inquiry. American Economic Journal: Applied Economics, 8(1), 100-128. DOI: https://doi.org/10.1257/app.20140135

Aktamiş, H. (2007). Fen eğitiminde bilimsel süreç becerilerinin bilimsel yaratıcılığa etkisi: ilköğretim 7. sınıf fizik ünitesi örneği [Unpublished doctoral dissertation]. Dokuz Eylul University, Izmir

Applefield, J. M., Huber, R., & Moallem, M. (2000). Constructivism in theory and practice: Toward a better understanding. The High School Journal, 84(2), 35-53. DOI: https://doi.org/10.2307/40364404

Bassot, B. (2024). The reflective journal. Bloomsbury Publishing. ISBN: 9781350422995

Başdaş, E. (2007). İlköğretim fen eğitiminde, basit malzemelerle yapılan fen aktivitelerinin bilimsel süreç becerilerine, akademik başarıya ve motivasyona etkisi [Unpublished Master's thesis], Celal Bayar University, Manisa

Biesta, G. (2007). Why "what works" won't work: Evidence‐based practice and the democratic deficit in educational research. Educational theory, 57(1), 1-22. DOI: https://doi.org/10.1111/j.1741-5446.2006.00241.x

Bonache, J. (2021). The challenge of using a 'non‐positivist'paradigm and getting through the peer‐review process. Human Resource Management Journal, 31(1), 37-48. DOI: https://doi.org/10.1111/1748-8583.12319

Burns, M., Bally, J., Burles, M., Holtslander, L., & Peacock, S. (2022). Constructivist grounded theory or interpretive phenomenology? Methodological choices within specific study contexts. International Journal of Qualitative Methods, 21, 16094069221077758. DOI: https://doi.org/10.1177/16094069221077758

Bybee R.W. (1997). Towards an understanding of scientific literacy. In: W. Gräber & C. Bolte. (Eds.). Scientific literacy. An international symposium (pp. 37-68). Institut für die Pädagogik der Naturwissenschaften (IPN): Kiel, Germany

Bybee, R. W. (2006). Scientific inquiry and science teaching. In Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education (pp. 1-14). Dordrecht: Springer Netherlands. DOI: https://doi.org/10.1007/978-1-4020-5814-1_1

Chu, S. K. W., Reynolds, R. B., Tavares, N. J., Notari, M., & Lee, C. W. Y. (2021). 21st century skills development through inquiry-based learning from theory to practice. Springer International Publishing. DOI: https://doi.org/10.1007/978-981-10-2481-8

Coburn, C. E., Honig, M. I., & Stein, M. K. (2009). What's the evidence on districts' use of evidence. The role of research in educational improvement, 67-87.

Deboer, G. E. (2006). Historical perspectives on inquiry teaching in schools. In Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education (p. 17-35). Dordrecht: Springer Netherlands. DOI: https://doi.org/10.1007/978-1-4020-5814-1_2

Derilo, R. C. (2019). Basic and integrated science process skills acquisition and science achievement of seventh-grade learners. European Journal of Education

Studies. DOI: https://doi.org/10.5281/zenodo.265254

Dewey, J. (1929). The quest for certainty: A study of the relation of knowledge and action (Vol. 28). Putnam Adult. ISBN: 0399501916, 9780399501913

Driver, R. & Erickson, G. (1983). Theories-in-action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science. Studies in Science Education, 10, 37-60. DOI: https://doi.org/10.1080/03057268308559904

Elliott, J. (2001). Making evidence ‐ based practice educational. British educational research journal, 27(5), 555-574. DOI: https://doi.org/10.1080/01411920120095735

European Commission and Directorate-General for Research and Innovation. (2015). Science education for responsible citizenship: Report to the European Commission of the expert group on science education. Publications Office. DOI: https://doi.org/10.2777/12626

Flick, L. B., & Lederman, N. G. (2006). Scientific inquiry and nature of science. Kluwer Academic Publishers.

Gichuru, M. J. (2017). The interpretive research paradigm: A critical review of is research methodologies. International Journal of Innovative Research and Advanced Studies (IJIRAS), 4(2), 1-5. Available at: https://www.ijiras.com/2017/Vol_4-Issue_2/paper_1.pdf

Glesne, C. & Peshkin, A. (1992). Becoming qualitative researchers: An Introduction. Longman: Longman.

Hanauer, D. I., Jacobs-Sera, D., Pedulla, M. L., Cresawn, S. G., Hendrix, R. W., & Hatfull, G. F. (2006). Teaching scientific inquiry. Science, 314(5807), 1880/1881.DOI: https://doi.org/10.1126/science.1136796

Jack, G. U. (2013). The influence of identified student and school variables on students' science process skills acquisition. Journal of Education and Practice, 4(5), 16-22. Available at: https://api.semanticscholar.org/CorpusID:212451018

Junjie, M., & Yingxin, M. (2022). The Discussions of Positivism and Interpretivism. Online Submission, 4(1), 10-14. DOI: https://doi.org/10.36348/gajhss.2022.v04i01.002

Kabapınar, F. (2021). Pozitivist ve yorumlamacı felsefeyle ilişkisi bağlamında eğitim araştırmalarına bakmak. kuramdan uygulamaya sosyal bilgiler ve tarih öğretiminde eylem araştırmaları. (editor: Y. Kabapınar), Ankara, Pegem A. DOI: https://doi.org/10.14527/9786257582056

Kabapınar, F., Tekin, D., & Tetik, S. (2023). K12 Fen Bilimleri Alan Becerileri Eğitimi Kapsamında Hipotez Oluşturma Becerisinin Öğretimi ve Etkisinin Değerlendirilmesi: Kimya Dersinden Uygulamalar. Milli Eğitim Dergisi, 52(1), 287-322. DOI: https://doi.org/10.37669/milliegitim.1309215

Kemmis, S. (1988). Action research. in J. P. Keeves (Ed.). Educational Research, Methodology, and Measurement: An International Handbook (pp.177-190). Oxford: Pergamon.

Kunisch, S., Denyer, D., Bartunek, J. M., Menz, M., & Cardinal, L. B. (2023). Review research as scientific inquiry. Organizational Research Methods, 26(1), 3-45. DOI: https://doi.org/10.1177/10944281221127 29

Lederman & S. K. Abell (Eds.) (2013). Handbook of research on science education (Vol. 2, pp.) DOI: https://doi.org/10.4324/9780203097267

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L, Meyer, A. A. & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry—the views about scientific inquiry (VASI) questionnaire. Journal of Research in Science Teaching, 51(1), 65-83. DOI: https://doi.org/10.1002/tea.21125

Lederman, J., Lederman, N., Bartels, S., Jimenez, J., Akubo, M., Aly, S., ... & Zhou, Q. (2019). An international collaborative investigation of beginning seventh grade students' understandings of scientific inquiry: Establishing a baseline. Journal of Research in Science Teaching, 56(4), 486-515. DOI: https://doi.org/10.1002/tea.21512

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. International Journal of Education in Mathematics, Science and Technology, 1(3).

Lewin, K. (1946) Action research and minority

problems. Journal of Social Issues, 2, 34-46. DOI: https://doi.org/10.1111/j.1540-4560.1946.tb02295.x
Lou, Y., Blanchard, P., & Kennedy, E. (2015). Development and validation of a science inquiry skills assessment. Journal of Geoscience Education, 63(1), 73-85. DOI: https://doi.org/10.5408/14-028.1
Martin, E., & Osherson, D. N. (1998). Elements of scientific inquiry. MIT Press.
Masters, Janet. (1995). The history of action research. In I. Hughes (Ed) Action research electronic reader, The University of Sydney
Ministry of National Education of Turkey (MoNE) (2023a). K12 Beceriler Çerçevesi Türkiye Bütüncül Modeli. Ministry of National Education, Board of Education
Ministry of National Education of Turkey (MoNE) (2023b). K12 Beceriler Çerçevesi Türkiye Bütüncül Modeli Öğretmen Kılavuzu. Ministry of National Education, Board of Education.
Miller, J. D. (1983). Scientific Literacy: A Conceptual and Empirical Review. Daedalus, Spring, 112(2), 29- 48. Available at: https://www.jstor.org/stable/20024852
Ministry of National Education of Turkey (MoNE) (2024). Chemistry Education Curriculum for Secondary Grades (9, 10, 11, and 12th Grades), Ministry of National Education, Board of Education.
Ministry of National Education of Turkey (MoNE) (2024). Türkiye Yüzyılı Maarif Modeli (TYMM). Ministry of National Education, Board of Education
Mills, G. E. (2003). Action research: A Guide for the Teacher Researcher. (2nd ed.). Upper Saddle River, NJ: Merrill Prentice Hall.
National Council for Curriculum and Assessment [NCCA]. (2015). Junior cycle science: Curriculum specification. Author. Available at: https://www.curriculumonline.ie/getmedia/f668d804-6283-4d4a-84ab-c71e5b37d198/Specification-for-Junior-Cycle-Science.pdf
National Research Council [NRC] (1996). National Science Education Standards. National Academy Press. ISBN: 978-0-309-05326-6.
National Research Council [NRC] (2000). Inquiry and the national science education standards. Washington, DC: National Academy Press. DOI: https://doi.org/10.17226/9596
National Research Council [NRC] (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: National Academy Press. DOI: https://doi.org/10.17226/13165
Nelson, B. C., & Ketelhut, D. J. (2007). Scientific inquiry in educational multi-user virtual environments. Educational Psychology Review, 19(3), 265-283. DOI: https://doı.org/10.1007/s10648-007-9048-1
Nickerson, C. (2022). Interpretivism paradigm & research philosophy. Simply Sociology, 5.
Novak, A. (1964). Scientific inquiry. Bioscience, 14(10), 25-28. DOI: https://doi.org/10.2307/1293366
Pilarska, J. (2021). The constructivist paradigm and phenomenological qualitative research design. Research paradigm considerations for emerging scholars, 64-83.DOI: https://doi.org/10.21832/9781845418281-008
Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In N. G. Lederman, & S. K. Abell, Handbook of Research on Science Education (pp. 545-558). New York: Routledge. ISBN: 9780203097267
Rönnebeck, S., Bernholt, S., & Ropohl, M. (2016). Searching for a common ground - A literature review of empirical research on scientific inquiry activities. Studies in Science Education, 52(2), 161–197. DOI: https://doi.org/10.1080/03057267.2016.1206351
Salas, D. J., Baldiris, S., Fabregat, R., & Graf, S. (2016). Supporting the acquisition of scientific skills by the use of learning analytics. In Advances in Web-Based Learning–ICWL 2016: 15th International Conference, Rome, Italy, October 26–29, 2016, Proceedings 15 (pp. 281-293). Springer International Publishing. DOI: https://org.tr/10.1007/978-3-319-47440-3_32
Slavin, R. E. (2002). Evidence-based education policies: Transforming educational practice and research. Educational researcher, 31(7), 15-21. DOI: https://doi.org/10.3102/0013189X031007015
Stone, E. M. (2014). Guiding students to develop an understanding of scientific inquiry: A science skills approach to instruction and assessment. CBE—Life

Sciences Education, 13(1), 90-101. DOI: https://doi.org/10.1187/cbe-12-11-0198

Sutiani, A., Situmorang, M., & Silalahi, A. (2021). Implementation of an inquiry learning model with science literacy to improve student critical thinking skills. International Journal of Instruction, 14(2), 117-138. DOI: https://doi.org/10.29333/iji.2021.1428

Taggart, G. L., & Wilson, A. P. (2005). Promoting reflective thinking in teachers: 50 action strategies. Corwin Press. ISBN: 1412909643, 9781412909648

Tang, X., Coffey, J. E., Elby, A., & Levin, D. M. (2010). The scientific method and scientific inquiry: Tensions in teaching and learning. Science education, 94(1), 29-47. DOI: https://doi.org/10.1002/sce.20366

Teig, N. (2021). Inquiry in science education. In International handbook of comparative large-scale studies in education: Perspectives, methods and findings (pp. 1135-1165). Cham: Springer International Publishing. DOI: https://doi.org/0.1007/978-3-030-38298-8-62-1

Teig, N. (2024). Uncovering Student Strategies for Solving Scientific Inquiry Tasks: Insights from Student Process Data in PISA. Research in Science Education, 54(2), 205-224. DOI: https://doi.org/10.1007/s11165-023-10134-5

Tekin, D., & Kabapınar, F. (2023). Ters Yüz Sınıf Modeli ile Mol Kavramı ve Kimyasal Hesaplamalar Ünitelerinin Öğretimi. Fen Bilimleri Öğretimi Dergisi, 11(1), 1-40. DOI: https://doi.org/10.56423/fbod.1200304

Tekin, D. (2020). Kimyanın temel kanunları, kimyasal hesaplamalar ve mol kavramı ünitelerinin yapılandırmacılık temelli ters yüz edilmiş sınıf modeli ile öğretimi [Unpublished Master's thesis]. Marmara University, İstanbul.

Tekin, D. (2024). Kimya öğretmen adaylarının çoklu öğrenme ortamı oluşturma sürecine yönelik yansıtma becerilerinin incelenmesi (Investigation of Reflective Skills Pre-Service Chemistry Teachers for Process of Creating Multiple Learning Environments) [Unpublished doctoral dissertation]. Marmara University, İstanbul.

Thanh, N. C., & Thanh, T. T. (2015). The interconnection between interpretivist paradigm and qualitative methods in education. American journal of educational science, 1(2), 24-27.

Timperley, H. (2010, February). Using evidence in the classroom for professional learning. In Étude présentée lors du Colloque ontarien sur la recherche en éducation. Available at: https://cdn.auckland.ac.nz/assets/education/about/schools/tchldv/docs/Using%20Evidence%20in%20the%20Classroom%20for%20Professional%20Learning.pdf

Treagust, D. F., & Won, M. (2023). Paradigms in science education research. In the Handbook of research on science education (pp. 3-27). Routledge. DOI: https://doi.org/10.4324/9780367855758-2

Watts, H. (1985). When Teachers Are Researchers Teaching Improves. Journal of Staff Development. Retrieved from https://eric.ed.gov/?id=EJ328842

Willis, J. W. (2007). Foundations of qualitative research: interpretive and critical approaches. London: Sage. DOI: https://doi.org/10.4135/9781452230108

Yıldırım, A., & Şimşek, H. (2013). Sosyal Bilimlerde Nitel Araştırma Yöntemleri [Qualitative Research Methods in Social Sciences]. (9. Ed.). Seçkin. ISBN: 9789750239991.

Received: January 28, 2025
Revised: March 11, 2025
Accepted: May 10, 2025

Appendix 1. Open-Ended Questionnaires

1. How would you define scientific inquiry skills? Have you ever done scientific inquiry before, showing evidence from your previous experiences?
2. Which other skills do you think scientific inquiry skills are related to? Explain this association by showing evidence.
3. What do you think are the roles of students and teachers in a teaching based on scientific inquiry skills? Explain your reason for giving these roles.
   Teacher role:
   Student role:
4. Do you think data and evidence used in the scientific enquiry process are the same phenomenon? Are there similar or different aspects of these two phenomena, if possible, explain by showing evidence.
5. Design an activity to develop students' scientific inquiry skills in chemistry education. Specify all the processes of your activity in detail. Make your teaching process clear by adding tables/figures etc. where necessary.

Appendix 2. Scientific Inquiry Skill Sub-Components Rubric (MoNE, 2023a)

Level of Scientific Inquiry Skill Sub-Components (MoNE, 2023a).

Criteria	High (3)	Medium (2)	Low (1)
Defining the question or problem	Identifies a researchable question based on observation or experience	Partially identifies an investigable question based on observation or experience	Does not identify an investigable question based on observation or experience
Developing a model to answer the question/problem/find a solution	Develops a model to represent an object or phenomenon	Develops a partial model to represent an object or phenomenon.	Does not develop a model to represent an object or phenomenon.
Planning and realizing the research	Identifies the variables related to the solution of the problem.	Partially identify the variables related to the solution of the problem	Does not identify the variables related to the solution of the problem
Analyzing and interpreting data	Uses appropriate graphical tools and mathematical calculations in data analysis.	Partially uses appropriate graphical tools and mathematical calculations in data analysis.	Does not use appropriate graphical tools and mathematical calculations in data analysis
Making evidence-based explanations and producing solutions	Makes evidence-based explanations about the results obtained from the data.	Makes evidence-based partial explanations about the results obtained from the data.	Does not make evidence-based statements about the conclusions drawn from the data
Evaluating and sharing knowledge	Associates scientific knowledge with the evidence obtained in the solution process.	Partially associates scientific knowledge with the evidence obtained in the solution process.	Does not associate scientific knowledge with the evidence obtained in the solution process