www.ijses.net

Pre-service Primary Teachers' Views about Scientific Inquiry

Georgios Stylos
University of Ioannina, Greece

Antonios Christonasis
University of Ioannina, Greece

Konstantinos T. Kotsis
University of Ioannina, Greece

To cite this article:

Stylos, G., Christonasis, A., & Kotsis, K.T. (2023). Pre-service primary teachers' views about scientific inquiry. *International Journal of Studies in Education and Science (IJSES), 4*(2), 100-112. https://doi.org/10.46328/ijres.66

IJSES
International Journal of Studies in Education and Science
2023, Vol. 4, No. 2, 100-112 https://doi.org/10.46328/ijres.66

Pre-service Primary Teachers' Views about Scientific Inquiry

Georgios Stylos, Antonios Christonasis, Konstantinos T. Kotsis

Article Info

Article History

Received:
27 February 2023
Accepted:
04 June 2023

Keywords

Primary teachers
Scientific inquiry
VASI

Abstract

While scientific inquiry is a critical goal in science education reform, worldwide research indicates that students and educators misunderstand it. The present study investigates the scientific inquiry views of 170 senior-year pre-service primary school teachers using the VASI (Views About Scientific Inquiry) questionnaire. This standardized tool assesses learners' understanding of scientific inquiry. The analysis of student responses demonstrates that the sampled pre-service primary education teachers hold naïve views on several aspects of scientific inquiry. Findings show that participants seem to have difficulty understanding that scientific inquiry begins with a question and are unclear on whether a single procedure generates the same results or if scientific data is equivalent to scientific evidence. The inability of pre-service teachers to understand scientific inquiry confirms a lack of general consideration of its process, raising doubt over the opportunities for learners to adopt and engage in scientific inquiry. Consequently, the implications of curriculum reform are discussed.

Introduction

It is currently widely agreed that educators should strive beyond teaching science as a body of knowledge toward developing scientific literacy for themselves and their students. There is international consensus on scientific literacy development requiring a meaningful understanding of scientific inquiry (SI) (Lederman et al., 2013; Lederman et al., 2019; Ramnarain, 2016; Crawford, 2014), which explains why the latter has become a focal point in many reform documents and science assessment studies (e.g., Australian Curriculum Assessment and Reporting Authority [ACARA], 2011; National Research Council [NRC], 2000, 2012; Organization for Economic Co-operation and Development, 2006). Considering that 'science,' according to Zimmermann (2000, p.101), is a body of knowledge and the activities that gave rise to that knowledge, scientific inquiry relates to the process by which scientific knowledge is developed and how this resulting knowledge is generated and accepted (Lederman et al., 2014, p. 66).

Shifting specifically to educational objectives, inquiry-based science learning consists of students progressively developing key scientific ideas via understanding how to investigate and build their knowledge of the world around them (Harlen & Allende, 2009). In essence, they use skills employed by scientists: raising questions, collecting data, reasoning, reviewing the evidence in light of what is already known, drawing conclusions, and discussing results. Besides impacting students' learning of science concepts and principles, teaching inquiry-based science enhances their understanding of the core nature of scientific inquiry (Crawford, 2014). Practically speaking, teaching scientific inquiry requires specific skills on the teacher's part (Garritz, 2012), and teachers often show little confidence in teaching science (García-Carmona & Cruz-Guzmán, 2016). Encouraging teachers to incorporate the inquiry-based approach and accept it as an ideal way to teach science is undoubtedly a considerable challenge (Kim & Tan, 2011). Even if an intervention is broken down into carefully specified curriculum-based materials (Blumenfeld et al., 1991; Singer et al., 2000), the teacher plays a central role in delivering those materials. McNeill's (2009) study highlighted that teachers carry out reform-based curricula in different ways, so it is critical that research sheds light on the extent educators' understanding is accurate. Science teachers encourage SI in science education, so it is essential for them first to understand its processes and second to help students understand them. This paper aims to answer the extent to which teachers understand scientific inquiry to carry out inquiry-based instruction in their classrooms.

Literature Review

Much emphasis has been placed on teachers' inquiry skills instead of their understanding of SI. Adding to this limitation is the previous use of insufficient tools to measure their views, justifying our limited insight on the matter. Teachers and pre-service teachers' understanding of the nature of science, i.e., assumptions, characteristics, and methods of scientific inquiry (Rutledge, 2005), is critical because, in turn, serves as an influential factor to students' understanding of its relevant aspects (Akerson et al., 2017; Khishfe, 2017). In other words, teachers' conceptions enhance students' learning. An informed understanding of scientific inquiry requires awareness of the following aspects: (1) all scientific investigations begin with a question but do not necessarily test a hypothesis; (2) there is no single set of steps followed in all investigations (i.e., there is no single scientific method); (3) inquiry procedures are guided by the question asked; (4) all scientists performing the same procedures may not get the same results; (5) inquiry procedures can influence the results; (6) research conclusions must be consistent with the data collected; (7) scientific data are not the same as scientific evidence; and (8) explanations are developed from a combination of collected data and what is already known (NRC, 2000).

Typically, teachers are more likely to promote inquiry-based approaches in their science classes if they have already acquired the necessary skills during their initial teacher training (García-Carmona et al., 2016b; Yakar & Baykara, 2014). Even as a student, passive listening to inquiry processes does not signify any fundamental understanding of scientific inquiry (Wong & Hodson, 2010). Previous research has clarified that the individuals responsible for providing inquiry-based learning to students have mixed or even naive views about scientific inquiry: Pre-service science teachers (Baykara & Yakar, 2020; Baykara et al., 2018; Güngören & Öztürk, 2021; Karışan et al., 2017; Lederman et al., 2019; Liu et al., 2017; Özer & Sarıbaş, 2022), in-service science teachers (Adisendjaja et al., 2017; Mesci & Kartal, 2021; Muntholib et al., 2019) pre-service primary education teachers (Ozturk, 2021; Akalamkam, 2020) and pre-service pre-school teachers (Aydemir et al., 2017), all commonly share inadequate views. Being asked to provide an appropriate learning context that allows reflection related to knowledge of the inquiry. At the same time, they, as educators, have not developed a sound understanding of the aspects of SI, which creates a situation that raises many questions.

The current study, therefore, aims to determine pre-service primary school teachers' views about scientific inquiry, seeking to specify which aspects of SI they struggle to grasp in an attempt to establish an internationally recognized baseline of pre-service primary school teachers' understanding of SI. This paper aims to empirically investigate pre-service teachers' SI views about scientific inquiry with the VASI instrument.

Method

Participants

Convenience sampling (Dornyei, 2007) was used to select participants for the study because senior undergraduate students were easily accessible to the research team. The sample consisted of 170 (148 women-22 men) fourth-year students of the Department of Primary Education of the University of Ioannina. At the end of their academic year, the senior students consented to participate and completed the questionnaire in approximately 30 minutes. All participants had successfully passed the compulsory course "Fundamental Physics I," and several had passed additional elective courses, such as "Physics in Everyday Life" and "Teaching Concepts of Physics in Laboratory."

Instrument

A translated version of the VASI questionnaire, developed and implemented by Lederman et al. (2014), was used as the research tool. The instrument consisted of seven items (see Table 1) containing one or two sub-questions associated with the eight aspects of SI, as previously described. For a more detailed description of these eight aspects, we recommend the original article by Lederman et al. (2014).

Aspect 1: No single set or sequence of steps is followed in all investigations (i.e., there is no single scientific method).

Aspect 2: Scientific investigations begin with a question and do not necessarily test a hypothesis.

Aspect 3: All scientists performing the same procedures may get different results.

Aspect 4: Inquiry procedures can influence results.

Aspect 5: Scientific data are not the same as scientific evidence.

Aspect 6: Inquiry procedures are guided by the question asked.

Aspect 7: Research conclusions must be consistent with the data collected.

Aspect 8: Explanations are developed from a combination of collected data and what is already known.

The VASI questionnaire was initially translated into Greek by two researchers and then back-translated into English by another researcher of the Greek team, proficient in English, to check if the meaning was kept unaltered. A single difficulty emerged in question 4a, as the terms 'proof' and 'evidence' were initially expressed by the same Greek word. Based on this misunderstanding of the different connotations between the terms 'evidence' and 'proof,' as observed in the pilot study, the research team decided to use the terms 'scientific data' and 'scientific evidence', respectively.

Additionally, 34 students were interviewed by the first author to ensure that the coding of the VASI questionnaire was accurate and to obtain a deeper qualitative understanding of students' views on scientific inquiry. The interviews lasted approximately 20 minutes and were audio recorded to be re-examined by the Greek team.

Scoring Students' Responses

US-based researchers trained the Greek research team on the study's methodology. After administering the VASI, five completed questionnaires were sent to the US team and scored separately by the US and Greek teams. A virtual meeting via Skype was conducted between the two groups to compare scores and discuss the quality of the answers and reliability and inter-rater agreement.

Students' responses were coded independently by two members of the team and classified as informed (I), mixed (M), or naïve (N) for each aspect. If a student responded congruent with the target response for a given aspect of scientific inquiry, it was labeled as "informed." A mixed label was given if a response was partially explained, or a contradiction was evident. A response contradictory to accepted views of an aspect of scientific inquiry was labeled as "naïve." For a more detailed description of the interpretation and coding of students' answers, we refer the reader to the original article by Lederman et al. (2014) on the VASI instrument.

Results

The results of the analysis of the total sample of 170 questionnaires are shown in Table 1. The first element that immediately stands out is that pre-service teachers have low understanding of scientific inquiry, as they hold naïve views on six aspects and mixed and informed views on a single aspect.

Table 1. The Distribution of VASI Scores in Percentages (%) for Each Aspect

Aspect	Naïve	Mixed	Informed
1. Multiple Methods	**68.2**	20.6	11.2
2. Starts with a Question	25.3	25.9	**48.8**
3. Same Procedures May not Yield the Same Results	**72.9**	12.9	14.1
4. Procedures Influence Results	**40.6**	23.5	35.9
5. Data and Evidence are not the Same	**77.2**	13.7	9.1
6. Procedures are Guided by the Question Asked	**56.5**	11.2	32.4
7. Conclusions Must be Consistent with Data Collected	**54.7**	14.1	31.2
8. Conclusions are Developed from Data and Prior Knowledge	16.5	**50.0**	33.5

To get an overview of the characteristics within the sample, the aspects were listed from least informed to most informed. The three most naïve views are found in aspect 5, i.e., that data and evidence are not the same (77.2%), in aspect 3, the same procedures may not yield the same results (72.9%), and in aspect 1, multiple methods (68.2%). The following four aspects revealed a relatively similar trend. In aspect 6, procedures are guided by the question asked, and in aspect 7, conclusions must be consistent with data collected and exhibited naïve views of understanding (56.5% and 54.7%) again. Aspect 8, conclusions are developed from data, and prior knowledge was labeled as mixed (50%). Interestingly, the aspect of an inquiry starts with a question was the only one demonstrating informed understanding however exhibited by less than half of the sample. Aspect 4, procedures influence results, was another case that generated naïve primarily (40.6%) views in understanding SI.

Aspect 1: Multiple Methods

The first aspect consists of three questions that assess the understanding that no single set or sequence of steps is followed in every investigation. The scenario of observing birds' beaks and eating habits is provided.

Question 1a explores students' scientific understanding of the scenario presented. More than half the students (55.9%) considered a personal investigation as scientific as they considered that observations and data collection is part of the scientific investigation procedure (formulation of cases, outcome of conclusions, and exploration of question). The absence of an experiment, the non-use of scientific instruments in data collection, the single-person observer instead of a methodical laboratory research team, etc., led the other half to conclude that the presented scenario is not scientific. Below is one student's comment:

> "I think the only method that produces scientific data is the experiment, i.e., experimentation and verification lead you to valid scientific data."

Question 1b examines students' understanding of the presented scenario and whether it defines an experiment. Students who responded that the study about birds was experimental (40.6%) supported the argument that observation was performed and data was collected. The remaining sample (59.4%) was able to distinguish between experimentation and investigation, arguing that the performed observations and data collected do not constitute on their own an experimental procedure. For instance, one student notes:

> "No, they are not conducting an experiment to test hypotheses."

Here is an example of a mixed view:

> "No, he's only observing birds. He isn't manipulating variables."

Finally, question 1c explored students' ideas of whether science follows more than one method. Most students responded that there is more than one way to conduct a scientific investigation. Still, only one-third justified it sufficiently, reporting experimentation and observation as examples of scientific studies. For example:

> "A scientific investigation may follow the method of observation. Darwin observed and studied the diversity of species, so he developed his theory on the mechanism of natural selection. However, to prove a theory in physics, we can run an experiment."

Aspect 2: Starts with a Question

Question 2 probes the understanding that scientific investigations all begin with a question but do not necessarily test a hypothesis. Most students demonstrated informed (48,8%) or mixed understandings (25.9%) of this SI aspect. Half the students explained that the question determines the approach or method of scientific investigation, as commented by one student who wrote that "scientific questions identify and delimit the subject of the research." Students who held mixed views could have rationally explained the role of the question as an essential starting point. The naïve count (25.3%) mainly indicated that daily life phenomena, interests, and curiosity can start scientific investigations.

Aspects 3 and 4: How Procedures May Influence the Results

Because of the close association of how aspects 3 and 4 are tested in the VASI, we present students' answers to these in tandem. The students were asked if scientists seeking to answer the same question and use the same (Question 3a) or different (Question 3b) methods to collect data will necessarily arrive at the same conclusions.

Question 3a assesses the understanding that scientists may ask similar questions and follow similar procedures; however, they may reach different conclusions. The views here were labeled as naïve (72.9%) as students responded that the same findings would result or if their responses' argumentation was insufficient in explaining how conclusions could be different. Only 14.1% of students had informed views supporting that other findings could be obtained due to the role of human interpretation (scientists' perceptions, experimental errors). Below is the formulation of one accurate response:

> "I do not think they will necessarily come to the same conclusions because while the question or the procedure may be the same, we are not sure that the data they collected is the same, nor will they process or interpret this data in the same way, to reach to the same conclusion."

Question 3b evaluates the understanding that inquiry procedures can influence results. The naïve count here was the highest (40.6%) among all aspects. These students supported that the same question always leads to the same results regardless of the procedure. About one-third of students (35.9%) demonstrated informed views responding that the different procedures of a scientific investigation can influence its outcome, e.g., due to the different ways scientists interpret data. An example of a student's valid argument follows:

> "No, since data collection procedures are different, the variables are likely to be different, and therefore the results may differ."

Aspect 5: Data and Evidence are not the same

Question 4 of the instrument examines the understanding that scientific data are not the same as scientific evidence. We had been aware from the pilot study that the question about data and evidence would raise a semantic issue as the translation of these terms in the Greek language needs to be clarified, as stated above. For this reason, we chose to include the word "proof" in parenthesis next to the term "evidence" to remind the reader of this difference in connotation.

Most students' responses (77.2%) were coded as naive. They failed to adequately define the above concepts indicating several times that scientific data and evidence are one of the same or provided incorrect definitions. 13.7% of student responses were classified as mixed because they did not sufficiently explain the difference between scientific data and evidence. Few pre-service teachers demonstrated that data are quantitative and incontestable observations as they arise from research methodologies, while evidence is what you obtain from said data that shows whether your theory is right or wrong, as quoted by one student:

> "Data is the information we already have or collect from an experiment, and based on this information we are led to evidence (proof)."

Aspect 6: Procedures are guided by the Question Asked

Question 5 tested aspect 6, which is the understanding of inquiry. Aspect 6 introduces respondents to a scenario about several brands of tires and those most likely to rupture. Respondents are then prompted to provide two recommended investigations to conclude. More than half the students (56.5%) held naïve views because they did not choose the appropriate experimental procedure to answer the question. Most consider that tires' durability depends on road surfaces. For example:

> "The second is because it ran the experiment on 3 different types of road surfaces. Therefore the results of this experiment are considered more reliable."

On the contrary, a student rightfully answered that:

> "The first is best because it tests several types of tires on the same road surface to determine which tire is of the best quality, which is the purpose of the research study."

About one-third of student responses (32.4%) were classified as informed, indicating that the procedure should involve testing multiple tire brands on a single road surface.

Aspect 7: Conclusions must be Consistent with the Data Collected

Question 6 assesses the understanding that research conclusions must be consistent with the data collected. A table is presented showing the relationship between plant growth in cm per week and the number of minutes of light received each day. More than half of student responses (54.7%) were coded as naïve since their biased thinking influenced them, i.e., photosynthesis to explain their answer, or misinterpreted the data given. The mixed count (14,1%) mainly considered specific data on the table, and 31.2% of students held informed views. This student holds one such informed view:

> "According to the table, the more time a plant is exposed to the sun, the less it grows over a week."

Aspect 8: Conclusions are developed from Data and Prior Knowledge

Question 7 (testing aspect 8) targets the understanding that explanations are developed from a combination of collected data and what is already known. The item on the VASI questionnaire shows the fossilized bones of a dinosaur as found by a group of scientists, then reassembled in two different ways. The question is the following: (a) why most scientists would argue that figure 1 is the best arrangement, and (b) what information did the scientists use to reach their conclusions? Most responses were coded as mixed (50%), while 33.5% were classified as informed. Specifically, students with mixed views should have acknowledged the combination of data and previous investigations and accepted scientific knowledge only. Students' responses were determined as naïve (16.5%) if they raised such issues as the center of gravity, balance, survival, strong legs and forelimbs, the anatomy or bone structure of other animals, or hunting. Informed views were formulated as follows:

> "The scientists had information about the dinosaurs' body structure, and with the discovery of their bones, understood that this structure was more practical for their lives."

Discussion and Conclusion

The results of the study confirm that it is not only middle school (Eliyahu et al., 2020; Yang et al., 2017) or high school students (Anggraeni et al., 2017; Cetin, 2021; Concannon et al., 2020; (Bologna Soares de Andrade & Levoratob, 2017; Gaigher et al., 2014; Gaigher et al., 2022; Gyllenpalma, et al., 2022; Lederman et al., 2021; Penn & Ramnarain, 2022; Hamed et al., 2017) that have a crucial misunderstanding of SI, but educators as well. It is safe to assume that low levels of SI understanding are linked to (1) a lack of standards to define one's understanding of SI, (2) teaching styles that do not support the understanding of SI, (3) science teaching that emphasizes doing science only, and (4) teaching practices that do not focus on the inquiry approach (Lederman et al., 2019). It has been previously and consistently revealed that pre-service and in-service schoolteachers have low understanding of scientific inquiry. This is also the case for the Greek pre-service primary education teachers who participated in this study.

While the participants seemed to be aware of introducing a research question (aspect 2) prior to an investigation, only a few managed to successfully present their views using real scientific content (Aspect 6). Additionally, many students needed to distinguish between experiment and investigation because they misunderstood the meaning of these two words, a result also found in other studies (Yang et al., 2017). Similarly, according to respondents, failing to experiment with a study directly implies a non-scientific procedure. However, as Lederman (2009, p. 2) explains, scientific inquiry "can take several forms: Experimental, Correlational, and Descriptive." Although most students rightly indicated that there is more than one way to investigate a case, they didn't manage to clarify more than one scientific method. As McComas (2000, p.64) states, 'throughout their school science careers, students are encouraged to associate science with experimentation,' which is exactly the case in Greek. School science textbooks promote a specific model of a scientific method for every case, be it an observation or a scientific question. The interest lies in discovering an answer; thus, students/scientists formulate hypotheses and conduct experiments to confirm these hypotheses (Akerson & Hanuscin, 2007).

Regarding question 5, and as such, the distinction between "data" and "evidence," most pre-service teachers could not draw a fine line between the two. We must clarify that the term "evidence" is not used in the Greek curriculum. Therefore, it is not used in a real classroom environment. It's worth considering that general translation issues that may arise, and the absence of context behind a specific questionnaire item may explain this misunderstanding (Gyllenpalm et al., 2022). Regarding aspect 3, few students acknowledged human interpretation as a factor that may affect the whole procedure, e.g., methods of data collection, operationalization, measurement, and analysis of variables may have influenced the researchers' conclusions.

For the final two aspects, most students still need to conclude the data presented, which shows a limited ability in critical interpretation (Question 6) or to blend collected data and existing knowledge in an explanation (Question 7). Students instead tended to focus on what they generally know rather than the objective data (Gaigher et al., 2014; Hamed et al., 2017). Although the direct inquiry is the proposed teaching model in Greek Primary schools, science is limited to the traditional way of transmitting knowledge (Stylos, 2014). Students of all grades are substantially abstaining from hands-on activities or situations that demand formulating questions, testing a hypothesis, interpreting results, and drawing conclusions.

In Greek secondary schools especially, the pressure to cover the content in the curriculum and prepare students for the national university entrance examinations are the dominant preoccupations (Siorenta & Jimogiannis, 2008). Additionally, Greek school science textbooks present scientific knowledge academically and focus mostly on scientific knowledge content (Hatzinikita et al., 2008). In another Greek context, 100 high school students questioned were knowledgeable about aspects such as starting and guiding a research project, that explanations are developed from data, and what is already known. Still, they expressed naïve views over the practical procedures of a research study, which again sheds light on their curriculum's theoretical/academic focus, a lack of experimental work, and the low levels of inquiry in science classrooms (Lederman et al., 2021). This perennial failure of the education system to appropriate the process of scientific inquiry, which needs to be addressed at the university level, too, leads pre-service primary school teachers to be at a similar level of SI understanding to that of younger-aged students.

Implications

The low SI scores highlight the need for teachers' training to focus on inquiry and to develop an accurate understanding of SI during their studies in higher education and well-planned professional development programs that include microteaching sessions that target both the content and pedagogical knowledge of SI. Therefore, while 'doing' inquiry, it is equally important that science teaching is based on appropriate approaches that encompass the nature of scientific inquiry and reflective discussions on its several aspects.

Limitations and Future Research

One limitation which emerged from the current study is that participants were from a single Department of Primary Education, and therefore findings are only representative of some of the country. In the future, a larger sample selected from more than one institution is recommended to ensure the robustness of this paper's study results. To complement this research study, an assessment of in-service primary school and science teachers' understanding of the NOSI would expand the baseline data, allowing stakeholders and educators to design and apply programs to promote scientific inquiry and its aspects effectively in real settings.

Acknowledgements

The authors are grateful to Professors Judith Lederman and †Norman Lederman of Illinois Institute of Technology, Chicago, for their assistance and dedicate this paper to the memory of Professor †Norman Lederman.

References

ACARA. (2011). T*he Australian Curriculum: Science* (Version 5.2). Sydney: Australian Curriculum Assessment and Reporting Authority.

Adisendjaja, Y. H., Rustaman, N. Y., Redjeki, S., & Satori, D. (2017). Science Teachers' Understanding of Scientific Inquiry in Teacher Professional Development. Journal of Physics: Conference Series, 812. https://doi.org/10.1088/1742-6596/812/1/012054

Akalamkam, K., (2020). Primary school teachers' understanding about scientific inquiry. *International Journal of Research in Applied, Natural and Social Sciences, 8*(1), 17–22. https://www.impactjournals.us/archives/international-journals/international-journal-of-research-in-applied-natural-and-social-sciences?page=49

Akerson, V. L., & Hanuscin, D. L. (2007). Teaching nature of science through inquiry: Results of a 3-year professional development program. *Journal of Research in Science Teaching, 44*(5), 653-680. https://doi.org/10.1002/tea.20159

Akerson, V. L., Pongsanon, K., Park Rogers, M. A., Carter, I., & Galindo, E. (2015). Exploring the Use of Lesson Study to Develop Elementary Preservice Teachers' Pedagogical Content Knowledge for Teaching Nature of Science. *International Journal of Science and Mathematics Education*, *15*(2), 293–312. https://doi.org/10.1007/s10763-015-9690-x

Anggraeni, N., Adisendjaja, Y. H. and Amprasto, A. (2017). Profile of High School Students' Understanding of Scientific Inquiry. Journal of Physics: Conference Series 895. https://doi.org/10.1088/1742-6596/895/1/012138

Aydemir, S., Ugras, M., Cambay, O., & Kilic, A. (2017). Prospective Pre-School Teachers' Views on the Nature of Science and Scientific Inquiry. *Üniversitepark Bülten, 6*(2), 74-87. http://dx.doi.org/10.22521/unibulletin.2017.62.6

Baykara, H., & Yakar, Z., (2020). Preservice Science Teachers' Views about Scientific Inquiry: The Case of Turkey and Taiwan. *Turkish Online Journal of Qualitative Inquiry (TOJQI), 11*(2), 161-192. https://doi.org/10.17569/tojqi.618950

Baykara, H., Yakar, Z., & Liu S. Y. (2018). Preservice science teachers' views about scientific inquiry. *European Journal of Education Studies, 4*(10), 128-143. https://doi.org/10.5281/zenodo.1311801

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist, 26*(3–4), 369–398. https://doi.org/10.1080/00461520.1991.9653139

de Andrade, M. A., & Levoratob, C. C. A. (2017). Brazilian learners' understanding about Scientific Inquiry. X. Congreso Internacıonal Sobre Investıgacıón En Dıdáctıca De Las Cıencıas, Sevilla, Spain.

Cetin, P. S. (2021). Effectiveness of inquiry-based laboratory instruction on developing secondary students' views on scientific inquiry. *Journal of Chemical Education*, *98*(3), 756–762. https://doi.org/10.1007/s11191-022-00325-3

Concannon, J. P., Brown, P. L., Lederman, N. G., & Lederman, J. S. (2020). Investigating the development of secondary students' views about scientific inquiry. *International Journal of Science Education*, *42*(6), 906-933. https://doi.org/10.1080/09500693.2020.1742399

Crawford, B. (2014). From Inquiry to Scientific Practices in the Science Classroom. Lederman, N. G., & Abell, S. K. (Eds.). *Handbook of Research on Science Education* (Vol. 2). Routledge. (pp. 515–542).

Gaigher, E., Lederman, N., & Lederman, J. (2014). Knowledge about Inquiry: A study in South African high schools. *International Journal of Science Education, 36*(18), 3125-3147, 13-23. https://doi.org/10.1080/09500693.2014.954156

Gaigher, E., Hattingh, A., Lederman, J., & Lederman, N. (2022). Understandings About Scientific Inquiry in a South African School Prioritizing STEM. *African Journal of Research in Mathematics, Science and Technology Education, 26*(1), 13-23. https://doi.org/10.1080/18117295.2022.2056373

García-Carmona, A., & Cruz-Guzmán, M. (2016). ¿Con qué vivencias, potencialidades y predisposiciones inician los futuros docentes de Educación Primaria su formación en la enseñanza de la ciencia? *Revista Eureka Sobre Enseñanza Y Divulgación De Las Ciencias., 13*(2), 440–458. https://doi.org/10.25267/rev_eureka_ensen_divulg_cienc.2016.v13.i2.15

Garritz, A. (2012). Proyectos educativos recientes basados en la indagación de la química. *Educación Química, 23*(4), 458–464. https://doi.org/10.1016/s0187-893x(17)30133-7

Güngören, S. C., Öztürk, E., (2018). What Do Pre-service Science Teachers Views about the Nature of Scientific Inquiry? *International Journal of Progressive Education, 17*(1), 421-438. https://doi.org/10.29329/ijpe.2020.329.27

Gyllenpalm, J., Rundgren, C. J., Lederman, J., & Lederman N. (2022). Views About Scientific Inquiry: A Study of Students' Understanding of Scientific Inquiry in Grade 7 and 12 in Sweden. *Scandinavian Journal of Educational Research, 66*(2), 336-354. https://doi.org/10.1080/00313831.2020.1869080

Hamed, S., Rivero, A. & Jiménez, J. (2017). Views about Scientific inquıry (VASI): The case of Spain and Sweden. X. Congreso Internacıonal Sobre Investıgacıón En Dıdáctıca De Las Cıencıas, Sevilla, Spain.

Harlen, W., & Allende, J. (2009). *Report of the Working Group on teacher professional development in Pre-Secondary School Inquiry-Based Science Education* (Santiago, Chile: IAP).

Hatzinikita, V., Dimopoulos, K., & Christidou, V. (2008). PISA test items and school textbooks related to science: A textual comparison. *Science Education, 92*(4), 664-687. https://doi.org/10.1002/sce.20256

Hodson, D., & Wong, S. L. (2014). From the Horse's Mouth: Why scientists' views are crucial to nature of science understanding. *International Journal of Science Education, 36*(16), 2639–2665. https://doi.org/10.1080/09500693.2014.927936

Khishfe, R. (2017). Consistency of nature of science views across scientific and socio-scientific contexts. International *Journal of Science Education, 39*(4), 403–432. https://doi.org/10.1080/09500693.2017.1287976

Karışan, D., Bilican, K., & Şenler, B. (2017). The Adaptation of the Views about Scientific Inquiry Questionnaire: A Validity and Reliability Study. *Journal of the Faculty of Education, 18*(1), 326-343. https://doi.org/10.17679/inuefd.307053

Kim, M., & Tan, A. (2010). Rethinking Difficulties of Teaching Inquiry-Based Practical Work: Stories from elementary pre-service teachers. *International Journal of Science Education, 33*(4), 465–486. https://doi.org/10.1080/09500691003639913

Lederman, J. S. (2009). Teaching scientific inquiry: Exploration, directed, guided, and opened-ended levels. In National geographic science: Best practices and research base (pp. 8–20). Hapton-Brown Publishers.

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), 138-147.

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.

Lederman, N. G., & Lederman, J. S. (2019). Teaching and Learning of Nature of Scientific Knowledge and Scientific Inquiry: Building Capacity through Systematic Research-Based Professional Development. *Journal of Science Teacher Education, 30*(7), 737-762. https://doi.org/10.1080/1046560X.2019.1625572

Lederman, J., Lederman, N., Bartels, S., and Jimenez, J. (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. https://doi.org/10.1002/tea.21512

Lederman, J. S., Lederman, N. G., Bartels, S., Jimenez, J., Acosta, K., Akubo, M., Aly, S., Andrade, M. A. B. S. D., Atanasova, M., Blanquet, E., Blonder, R., Brown, P., Cardoso, R., Castillo-Urueta, P., Chaipidech, P., Concannon, J., Dogan, O. K., El-Deghaidy, H., Elzorkani, A., … Wishart, J. (2021). International collaborative follow-up investigation of graduating high school students' understandings of the nature of scientific inquiry: Is progress being made? *International Journal of Science Education, 43*(7), 991– 1016. https://doi.org/10.1080/09500693.2021.189450

Liu, C., Liu, E., & Guo, S. (2017). 7th grade VASI study: The case of Beijing. X. Congreso Internacıonal Sobre Investıgacıón En Dıdáctıca De Las Cıencıas, Sevilla, Spain.

Mccomas, W. F. (2000). The principal elements of the nature of science: dispelling the myths. In W. F. McComas (Ed.), The Nature of Science in Science Education. Rationales and Strategies. Dordrecht, The Netherlands: Kluwer Academic.

McNeill, K. L. (2009). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. *Science Education, 93*(2), 233–268. https://doi.org/10.1002/sce.20294

Mesci, G., & Kartal, E. E. (2021). Science teachers' views on nature of scientific inquiry. *Bartın University Journal of Faculty of Education*, 10(1), 69–84. https://doi.org/10.14686/buefad.797246

Muntholib, Pratiwi, Y. N., Yahmin, & Parlan (2019). Journal of Physics: Conf. Series 1227. https://doi.org/10.1088/1742-6596/1227/1/012007

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academies Press.

National Research Council. (2012). *A framework for K-12 science*. Washington, DC: National Academies Press

Penn, M. & Ramnarain, U.D. (2022). South African grade 12 science students' understandings of scientific inquiry. *Science and Education, 31*, 635–656. https://doi.org/10.1007/s11191-021-00259-2

Organization for Economic Co-operation and Development. (2006). Assessing scientific, reading and mathematical literacy. Paris: Author

Özer, F., & Sarıbaş, D., (2022). Exploring Pre-service Science Teachers' Understanding of Scientific Inquiry and Scientific Practices Through a Laboratory Course. *Science & Education*. https://doi.org/10.1007/s11191-022-00325-3

Ozturk, E. (2021). The effect of STEM activities on the scientific inquiry skills of pre-service primary school teachers. *Journal of Education in Science, Environment and Health (JESEH),7*(4), 296-308. https://doi.org/10.21891/jeseh.987215

Ramnarain, U. (2016). Understanding the Influence of Intrinsic and Extrinsic Factors on Inquiry-Based Science Education at Township Schools in South Africa. *Journal of Research in Science Teaching, 53*(4), 598–619. https://doi.org/10.1002/tea.21315

Rutledge, M. L. (2005). Making the Nature of Science RELEVANT: Effectiveness of an Activity That Stresses Critical Thinking Skills. *American Biology Teacher, 67*(6), 329–333. https://doi.org/10.1662/0002-7685(2005)067

Siorenta, A., & Jimoyiannis, A. (2008). Physics instruction in secondary schools: An investigation of teachers' beliefs towards physics laboratory and ICT. *Research in Science & Technological Education, 26*(2), 185-202. https://doi.org/10.1080/02635140802037328

Singer, J., Marx, R. W., Krajcik, J., & Clay Chambers, J. (2000). Constructing Extended Inquiry Projects: Curriculum Materials for Science Education Reform. *Educational Psychologist, 35*(3), 165–178. https://doi.org/10.1207/s15326985ep3503_3

Stylos, G. (2014). P*rimary education teachers' attitudes and practices regarding the teaching of physics education*. [Doctoral thesis, University of Ioannina]. National Archive of PhD Theses. https://www.didaktorika.gr/eadd/handle/10442/36692

Yang, I., Park, S., Shin, J., & Lim, S. (2017). Exploring Korean Middle School Students' View about Scientific Inquiry. *Eurasia Journal of Mathematics, Science and Technology Education, 13*(7), 3935-3958. https://doi.org/10.12973/eurasia.2017.00765a

Yakar, Z., & Baykara, H. (2014). Inquiry-Based Laboratory Practices in a Science Teacher Training Program. *Eurasia Journal of Mathematics, Science and Technology Education, 10*(2). https://doi.org/10.12973/eurasia.2014.1058a

Zimmermann, C. (2000). The development of scientific reasoning skills. *Developmental Review, 20*, 99–149. https://doi.org/10.1006/drev.1999.0497

Author Information

Georgios Stylos

https://orcid.org/0000-0001-8036-8427

University of Ioannina

Greece

Contact e-mail: *gstylos@uoi.gr*

Antonios Christonasis

https://orcid.org/0000-0001-9675-3696

University of Ioannina

Greece

Konstantinos T. Kotsis

https://orcid.org/ 0000-0003-1548-0134

University of Ioannina

Greece