Attractive : Innovative Education Journal
Vol. 8 No. 1, March 2026

Enhancing Evidence-Based Decision-Making through the Study of the Philosophy of Science Based on Ontology, Epistemology, and Axiology in the Education of Prospective Science Teachers

Yulianti Yusal [1] *, Rifda Nur Hikmahwati Arif [1], Banu Kisworo [1], Nurazmi [2]
[1] *Universitas Negeri Makassar, Indonesia*
[2] *Universitas Muhammadiyah Makassar, Indonesia*

Yulianti.yusal@unm.ac.id*

ARTICLE INFO
Article history:
Received
January 06, 2026
Revised
February 24, 2026
Accepted
March 30, 2026

ABSTRACT

This study aims to examine the effectiveness of ontology-epistemology-axiology-based philosophy of science instruction (OEA) in improving evidence-based decision-making skills through a case study on electricity conservation at home. The study employed a pre-experimental quantitative approach with a single-group pretest-posttest design. The research subjects were 31 fourth-semester students in the Science Education Program. The intervention was conducted over four sessions, including an OEA orientation and a pretest; analysis of electricity consumption using OEA worksheets and a framework Claim-Evidence-Reasoning (CER); evaluation of new evidence and decision revision; and a posttest accompanied by OEA reflection. The main instrument consists of a pretest-posttest package based on electricity conservation case studies with five assessment dimensions: problem formulation, energy calculation, evidence-based decision making, identification of limitations and the need for additional data, and OEA reflection. The maximum score of 20 on the rubric is converted to a scale of 0–100. Data were analyzed using normality tests, paired t-tests, N-gain, and Cohen's d; the results of the worksheets and reflections were used as supporting data to trace the learning process. The results showed that the average score increased from 42.06 on the pretest to 90.90 on the posttest, with an N-gain of 0.84, which is categorized high. The difference in scores was significant ($t = -44.03$; $p < 0.001$) with a very ($d = 7.90$). OEA-based learning using energy conservation case studies has the potential to strengthen students' ability to calculate and use revise decisions when evidence changes, and weigh trade-offs between cost savings and convenience.

Keywords: Evidence-based Decision-Making; Ontology-Epistemology-Axiology (OEA); Electricity Conservation

Journal Homepage https://attractivejournal.com/index.php/aj/

Published by CV. Creative Tugu Pena

INTRODUCTION

The education of prospective science teachers must go beyond mere conceptual mastery; it must also foster evidence-based decision-making skills—namely, the ability to formulate problems, evaluate claims, use relevant evidence, recognize uncertainty, and consider the consequences of a decision. These competencies are essential because prospective teachers will encounter scientific issues that require accountable reasoning, both in the classroom and in daily life. This approach aligns with contemporary science literacy, which positions decision-making, evidence-based reasoning, and ethical-social responsibility as integral parts of science education (Ceyhan et al., 2021; Leung, 2020, 2022; Mesci et al., 2025; Sjöström, 2025; Sultan et al., 2021).

In the study of the philosophy of science, the ontology-epistemology-axiology (OEA) framework can be used to integrate aspects that are often taught separately. Ontology guides students to examine relevant objects, phenomena, and concepts; epistemology helps students question the origin, quality, and limitations of evidence; while axiology directs consideration of the values, benefits, risks, and consequences of a decision. The integration of these three dimensions is necessary so that students not only obtain numerical answers but are also able to explain the scientific reasoning and value considerations underlying their decisions. The need to link evidence evaluation with epistemic reasoning in pre-service teacher education is also underscored by research on online information seeking, the use of research evidence, and changes in pre-service teachers' evidence evaluation profiles (Bellocchi et al., 2025; Guilfoyle et al., 2020; Reuter & Leuchter, 2023).

A number of international empirical studies indicate that learning that involves argumentation, inquiry, evaluation of information sources, and problem-solving can enhance students' understanding of the nature of science, their argumentation skills, and their orientation toward evaluating evidence. In the education of prospective science teachers, argumentation-driven inquiry and argumentation-based learning approaches have been reported to strengthen science process skills, argumentation skills, and understanding of the nature of science and inquiry (Altun & Özsevgeç, 2025; Arslan et al., 2023; Erenler et al., 2025; Eymur et al., 2024; Kalyon & Yılmaz, 2025; Kutluca & Aydın, 2017; Mesci et al., 2023; Özer & Sarıbaş, 2023; Palma-Jiménez et al., 2025; Peten, 2022). Studies on problem-based learning also highlight the importance of structured problem-solving experiences for prospective science teachers (Magaji et al., 2024). On the other hand, research on evidence-based practice in teacher education highlights the need for systematic support to enable pre-service teachers and teacher educators to interpret and use research findings when making professional decisions (Diery et al., 2021; Georgiou et al., 2023; McFadden & Williams, 2020; Weyers et al., 2024). However, many interventions still emphasize only one dimension—such as argumentation, the nature of science, socioscientific issues, or information evaluation—without explicitly linking the analysis of phenomena, the evaluation of evidence, and value considerations within a single operational learning pathway.

The case of household electricity conservation was chosen as the learning context because it is relevant to students' experiences and allows for the use of clear quantitative evidence, such as appliance power, duration of use, electricity consumption in kWh, and costs. This context also involves scientific uncertainty—for example, variations in the actual power consumption of appliances operating automatically—as well as axiological trade-offs between cost savings and residents' comfort. Research on energy education indicates that learning that connects knowledge, consumption calculations, and daily actions can increase awareness and encourage more responsible energy-use behaviors (Dias et al., 2021; Gill & Lang, 2018; Merritt et al., 2019; Wang & Wang, 2023). Furthermore, teacher education for sustainability emphasizes the importance of the interconnectedness of knowledge, context, collaboration, and reflective action (Brandt et al., 2021; Linhares & Reis, 2023). Thus, this context is suitable for training students to connect electrical concepts with OEA-based philosophical thinking.

This study implemented philosophy of science learning over four sessions. The first session consisted of an OEA orientation and a pretest. The second session used worksheets to calculate electricity consumption, identify the largest sources of consumption, select energy-saving alternatives, and construct Claim-Evidence-Reasoning (CER) arguments. The third session presented new evidence in the form of the average power of an AC inverter and the "warm" mode on a rice cooker, prompting students to recalculate, test the correspondence and coherence of their decisions, and revise their choices. The fourth session was dedicated to a posttest and individual OEA reflection. This sequence was designed to demonstrate that scientific decisions can change when more accurate evidence becomes available. This activity design is also consistent with research indicating that material-based planning tasks and tracking the development of professional knowledge can support pre-service teachers' reasoning in a more focused manner (Koberstein-Schwarz & Meisert, 2022; Mahler et al., 2024).

Based on the above discussion, this study aims to examine the effectiveness of OEA-based philosophy of science instruction in the context of household electricity conservation on prospective science teachers' evidence-based decision-making skills. Specifically, this study examines changes in students' abilities to formulate problems, calculate electricity consumption, select evidence-based conservation strategies, recognize data limitations, and connect ontological, epistemological, and axiological aspects in the decisions they make.

METHOD

This study employed a quantitative pre-experimental approach with a single-group pretest-posttest design. This design was used to compare students' evidence-based decision-making abilities before and after participating in OEA-based philosophy of science instruction. Schematically, the research design is illustrated as :

$$O_1 - X - O_2$$

where O_1 represents the pretest, X represents OEA-based instruction using a case study on electricity conservation, and O_2 represents the posttest. The study was conducted during the even semester of the 2025/2026 academic year in the Science Education Program at a public university in South Sulawesi, Indonesia. The intervention took place over four consecutive sessions, each lasting approximately 100 minutes. The sample was selected purposively, consisting of one class of fourth-semester students enrolled in the Philosophy of Science course. The study included 31 participants.

Learning Design and Procedures

The sequence of instruction was organized based on the course materials and OEA worksheets themed "Saving Electricity at Home" in the electricity module. The flow of each session is presented in Table 1.

Table 1. Sequence of OEA-Based Philosophy of Science Instruction

Session	Activity Focus	Activities and learning Outcomes
1	OEA Orientation and Pretest	Apperception of the concepts of power, energy, kWh, and electricity rates; introduction to OEA: ontology (equipment, power, energy, behavior), epistemology (formulas, measurements, uncertainty), and axiology (efficiency, comfort, environment). Students take the pretest individually.
2	OEA and CER Worksheet	Groups calculate the daily kWh consumption of several devices, identify the three largest sources of consumption, calculate the savings for options A–E, develop an OEA framework, and formulate Claim-Evidence-Reasoning (CER) for two energy-saving options.
3	New Evidence and Decision Revision	The students used new measurement data: average power of 0.32 kW for the air conditioner and 0.30 kW for the rice cooker while cooking, and 0.08 kW in keep-warm mode. The students recalculated the energy consumption, tested the consistency and coherence of the decision, and then revised the decision.
4	Posttest and OEA Reflection	Students took an individual posttest using an equivalent case with different data for Family B, then wrote a reflection comparing the from the pretest and posttest, the evidence, the limitations, and the prioritized values.

Research Instruments

The main instrument consists of a set of pretest and posttest assessments on evidence-based decision-making based on a case study of home electricity conservation. Both tests have the same question structure but use different case data to ensure comparability and prevent students from simply repeating their answers. Five tasks in the test ask students to: (1) identify the main problem and three stakeholders; (2) calculate daily electricity consumption for air conditioners, televisions, rice cookers, and irons; (3) select two energy-saving options based on kWh per day and monthly cost; (4) explain two data limitations and one piece of additional data needed; and (5) formulate a decision within the OEA framework. Pretest and posttest answers were assessed using a 1–4-point OEA rubric across five dimensions. The maximum rubric score was 20, which was then converted to a 0–100 scale using the formula: final score = (score obtained / 20) × 100. With this conversion, the pretest and posttest results could be compared using statistical analysis. Student worksheets (LKM) from Sessions 2–3, group CERs, and individual reflections from Sessions 3–4 were used as supporting data to illustrate the process of students' use of evidence and revision of their decisions.

Table 2. Dimensions of the Pretest and Posttest Assessment Rubric

Dimension	Assessment Focus	Range Score
D1. Problem Formulation	Clarity of the problem, relevance to stakeholders, and identification of potentially conflicting objectives: cost efficiency and convenience.	1-4
D2. Energy Calculation (kWh)	Accuracy in converting W to kW, use of formulas, and energy calculation results.	1-4
D3. Decision Making Evidence Based	Select two options based on evidence of kWh per day and monthly cost, and compare priorities.	1-4
D4. Limitations and Additional Data	Understanding variations in power/usage time and the need for specific data, such as a wattmeter or kWh meters.	1-4
D5. Reflection Philosophy Science (OEA)	The interconnection of problems, evidence, and uncertainty, as well as the exchange of values in decision-making.	1-4

Data Analysis

Quantitative data from pretest and posttest scores were analyzed using descriptive statistics, including the number of participants, mean, standard deviation, and standard error of the mean. A normality test was conducted first. Since the data met the assumption of normality, differences in pretest and posttest scores were analyzed using a paired t-test. Improvements in ability were calculated using N-gain, while the effect size of learning was analyzed using Cohen's d. Data from the learning management system (LMS) and reflections were analyzed descriptively to trace students' thought processes. The analysis focused on the alignment of decisions with kWh and cost data, acknowledgment of data limitations, the ability to revise decisions after receiving new evidence, and the trade-off between savings and convenience.

RESULT AND DISCUSSION

The learning process over four sessions facilitated students' gradual use of data. In Session 2, students used initial data to calculate daily energy consumption and select energy-saving alternatives. In Session 3, students were presented with new evidence. This process directly reinforced the understanding that scientific decisions are tentative and need to be revised when better evidence becomes available. Pretest and posttest scores are presented on a 0–100 scale based on the OEA rubric conversion. As shown in Table 3, the average posttest score is higher than the pretest score. These findings indicate that after engaging in calculation activities, evaluating new evidence, developing a CER, and reflecting on the OEA, students demonstrated improved ability to make evidence-based decisions.

Table 3. Descriptive Statistics of Pretest and Posttest Scores

Variable	N	Mean	Standard Deviation	Standard Error of the Mean
Pretest	31	42,06	5,30	0,95
Posttest	31	90,90	5,01	0,90

An improvement in ability was also evident in the N-gain score of 0.84, which falls into the high category (Table 4). The N-gain range of 0.70–0.93 indicates that all participants showed improvement in the high category based on the criteria used.

Table 4. N-gain for Evidence-Based Decision-Making Skills

Variable	N	Average N-gain	Minimum	Maximum	Category
N-gain	31	0,84	0,70	0,93	High

Before testing for differences, the normality of the scores was tested using the Shapiro-Wilk test. The significance values were 0.087 for the pretest and 0.112 for the posttest, both of which were greater than 0.05. Thus, the data met the assumption of normality and could be analyzed using a paired t-test (Table 5).

Table 5. Results of the Shapiro-Wilk Normality Test

Variable	Statistic	df	Sig.
Pretest	0,956	31	0,087
Posttest	0,962	31	0,112

Table 6. Results of the Paired t-Test

Pair	Difference in Means	Standard Deviation	Standard Error of the Mean Average	t	df	Sig. (2-tailed)
Pretest - Posttest	-48,84	6,20	1,11	-44,03	30	<0,001

The results of the paired t-test indicate a significant difference between the pretest and posttest scores, $t(30) = -44.03$; $p < 0.001$. Thus, in this research sample, OEA-based philosophy of science learning through case studies on electricity conservation is associated with an improvement in students' evidence-based decision-making skills. The effect size of the learning was also very large, as indicated by a Cohen's d value of 7.90 (Table 7).

Table 7. Effect Size of Learning

Comparison	Pretest Mean	Posttest Mean	Diffenrence	SD	Cohen's d	Interpretation
Pretest vs Posttest	42,06	90,90	48,84	6,18	7,90	Very Big

The novelty of this study lies in the operationalization of the ontology-epistemology-axiology (OEA) framework as an integrated learning pathway, rather than merely as conceptual material in the philosophy of science. Students sequentially identify phenomena and stakeholders, evaluate quantitative evidence, formulate decisions through CER, assess data limitations, incorporate new evidence, and then revise their decisions by considering values and their consequences. Unlike courses on argumentation or the nature of science—which primarily emphasize the development of arguments and an understanding of the Nature of Science (NOS)—this design integrates ontological, epistemological, and axiological elements into a single case study on electricity conservation that is relevant to students' daily lives (Arslan et al., 2023; Erenler et al., 2025; Mesci et al., 2023, 2025).

The main findings indicate a very strong improvement in evidence-based decision-making skills after students participated in OEA-based learning. The average score increased from 42.06 on the pretest to 90.90 on the posttest, accompanied by an N-gain of 0.84 in the high category, a significant difference in the paired t-test, and a Cohen's d effect size of 7.90. Substantively, students became increasingly capable of framing problems and stakeholders, calculating kWh and costs, selecting conservation strategies based on data, identifying information limitations, and linking evidence and values when formulating decisions. These results are relevant to the education of prospective science teachers because they demonstrate that the philosophy of science can be taught through contextual and practical analytical experiences.

The results of this study are consistent with previous studies showing that learning based on argumentation, inquiry, and evidence evaluation can strengthen prospective teachers' scientific reasoning. (Altun & Özsevgeç, 2025; Arslan et al., 2023; Kalyon & Yılmaz, 2025; Mesci et al., 2023, 2025; Palma-Jiménez et al., 2025) reported improvements in argumentation competence or understanding of the nature of science through argumentative learning. These findings are also consistent with studies that explicitly integrate inquiry and the nature of science for prospective science teachers, including research by (Erenler et al., 2025; Eymur et al., 2024; Kutluca & Aydın, 2017; Özer & Sarıbaş, 2023; Peten, 2022). Regarding evidence evaluation, these results align with those of (Bellocchi et al., 2025; Ceyhan et al., 2021; Leung, 2020; Reuter & Leuchter, 2023), who emphasize the importance of assessing the quality of information and the justification of claims. Furthermore, the consideration of values and consequences in students' decisions aligns with studies on socioscientific decision-making and epistemic practices (Fang et al., 2019; Ha et al., 2023; Han-Tosunoglu & Ozer, 2022; Şen & Kaplan, 2025; Silva & Sasseron, 2025; Smit et al., 2025).

The consistency of these findings with previous research likely stems from the fact that students did not simply accept energy-saving solutions as ready-made information but were actively engaged in identifying electrical devices and usage habits, calculating data, discussing alternatives, testing new evidence, and reflecting on the consequences of their decisions. This step-by-step process allows students to connect claims with data and reasoning—a condition also considered crucial for developing prospective teachers' use of evidence and professional reasoning (Guilfoyle et al., 2020; Koberstein-Schwarz & Meisert, 2022; Mahler et al., 2024; Weyers et al., 2024). However, the magnitude of the improvement observed in this study should be interpreted with caution. Differences in results compared to previous studies may be influenced by the single-group design without a control group, the relatively small sample size, the four-session intervention duration, the use of a highly structured energy context, and the direct alignment between learning activities and test indicators. These factors may make changes in scores easier to detect compared to studies with different contexts, populations, or experimental designs.

This study's contribution to the field of science education is that it offers an operational philosophy of science learning design to train evidence-based decision-making. This design positions OEA as a thinking tool that students can use to map phenomena, examine the basis of evidence, recognize data limitations, and weigh values in decision-making. Thus, this study addresses the need for philosophy of science instruction that goes beyond merely mastering definitions, instead bridging the understanding of the nature of science, science literacy, problem-solving, and epistemic practices. This contribution complements research on the understanding of the nature of science, instructional planning, and the development of teacher education programs based on technology and sustainability (Cullinane & Erduran, 2023; Khaokhajorn & Srisawasdi, 2024; Magaji et al., 2024; McFadden & Williams, 2020; Sultan et al., 2021).

In practical terms, the research findings imply that the Philosophy of Science course can be designed using contextual case studies, real-world data, computational activities, argumentation assignments, and value-based reflection so that students can directly experience how scientific decisions are formulated and revised. The context of energy conservation can also be linked to education for sustainability and energy literacy, particularly when learning activities address energy use at home, economic impacts, comfort, and environmental responsibility (Brandt et al., 2021; Dias et al., 2021; Gill & Lang, 2018; Linhares & Reis, 2023; Merritt et al., 2019; Wang & Wang, 2023). At the academic and policy levels, strengthening evidence-based learning in teacher education requires curriculum support, professional development for teacher educators, and access to research resources that students can use when making decisions (Diery et al., 2021; Georgiou et al., 2023). Future research should include control groups, involve more diverse samples, compare multiple socio-scientific contexts, and examine the sustainability of students' ability to apply evidence in real-world teaching practice.

CONCLUSION

Ontology-epistemology-axiology (OEA)-based philosophy of science learning through the context of electricity conservation at home has the potential to enhance prospective science teachers' evidence-based decision-making skills. The four-session intervention integrated an orientation to OEA concepts, a pretest, worksheets for calculating energy consumption and

CERs, the presentation of new evidence to revise decisions, a posttest, and OEA reflection. This sequence provided students with the opportunity to understand the problem, use quantitative evidence, acknowledge uncertainty, and weigh values in the decisions they made.

The improvement in performance was demonstrated by an increase in the average score from 42.06 on the pretest to 90.90 on the posttest, an N-gain of 0.84 in the high category, a significant difference in the paired t-test, and a Cohen's d effect size of 7.90. Substantively, the learning experience helped students understand that decisions regarding electricity conservation cannot be based solely on intuition. Decisions must be supported by calculations of kWh and costs, be open to revision when actual power data changes, and consider the balance between cost savings and convenience.

The OEA framework can be used as an operational and contextual philosophy of science learning design to foster evidence-based decision-making. However, since this study used a single-group pretest-posttest design without a control group and involved only one class, the results should be interpreted with caution. Future research should include a comparison group, a more diverse sample, measures of skill retention, and other problem contexts so that the effectiveness and applicability of this approach can be more robustly tested.

REFERENCES

Altun, E., & Özsevgeç, T. (2025). Making Argumentation-Based Learning and Teaching Happen: Exploring the Development of Pre-Service Science Teachers' Argumentation Competencies. *Science & Education*, *34*, 4057–4106.

Arslan, H. O., Genc, M., & Durak, B. (2023). Exploring the effect of argument-driven inquiry on pre-service science teachers' achievement, science process, and argumentation skills and their views on the ADI model. *Teaching and Teacher Education*, *121*, 103905.

Bellocchi, A., Mills, R., Arthars, N., Tomas, L., Appanna, S., Davis, J., & Campos, P. R. de. (2025). Preservice Science Teachers' Epistemic Cognition during Online Searching. *Research in Science Education*, *55*(4), 1063–1083.

Brandt, J. O., Barth, M., Merritt, E., & Hale, A. (2021). A matter of connection: The 4 Cs of learning in pre-service teacher education for sustainability. *Journal of Cleaner Production*, *279*, 123749.

Ceyhan, G. D., Lombardi, D., & Saribas, D. (2021). Probing into Pre-Service Science Teachers' Practices of Scientific Evaluation and Decision-Making on Socio-scientific Issues. *Journal of Science Teacher Education, 32*(8), 865–889.

Cullinane, A., & Erduran, S. (2023). Nature of Science in Preservice Science Teacher Education–Case Studies of Irish Pre-service Science Teachers. *Journal of Science Teacher Education*, *34*(2), 201–223.

Dias, R. A., Paula, M. R. de, Rizol, P. M. S. R., Matelli, J. A., Mattos, C. R. de, & Balestieri, J. A. P. (2021). Energy education: Reflections over the last fifteen years. *Renewable and Sustainable Energy Reviews*, *141*, 110845.

Diery, A., Knogler, M., & Seidel, T. (2021). Supporting evidence-based practice through teacher education: A profile analysis of teacher educators' perceived challenges and possible solutions. *International Journal of Educational Research Open*, *2*, 10056.

Erenler, S., Çetin, P. S., & Eymur, G. (2025). Impact of Argument-Driven Inquiry Activities on Pre-service Science Teachers' Views of the Nature of Scientific Inquiry in the Context of Climate Change Education. *Science & Education*.

Eymur, G., Hasançebi, F. Y., & Çetin, P. S. (2024). The influence of the nature of science embedded in the argument-driven inquiry instructional method on promoting content knowledge and self-efficacy among pre-service science teachers in evolution. *Journal of Biological Education*, *58*(3), 552–569.

Fang, S. C., Hsu, Y. S., & Lin, S. S. (2019). Conceptualizing socioscientific decision making from a review of research in science education. *International Journal of Science and Mathematics Education*, *17*(3), 427–448.

Georgiou, D., Diery, A., Mok, S. Y., Fischer, F., & Seidel, T. (2023). Turning research evidence into teaching action: Teacher educators' attitudes toward evidence-based teaching. *Journal of Educational Research Open*, *4*, 100240.

Gill, C., & Lang, C. (2018). The effects of in-school energy education on at-home electricity consumption. *Energy Policy*, *118*, 88–96.

Guilfoyle, L., McCormack, O., & Erduran, S. (2020). The "tipping point" for educational research: The role of pre-service science teachers' epistemic beliefs in evaluating the professional utility of educational research. *Teaching and Teacher Education*, *90*, 103033.

Ha, H., Park, W., & Song, J. (2023). Preservice Elementary Teachers' Socioscientific Reasoning During a Decision-Making Activity in the Context of COVID-19. *Science & Education*, *32*, 1869–1886.

Han-Tosunoglu, C., & Ozer, F. (2022). Exploring Pre-service Biology Te4achers' Informal Reasoning and Decision-Making About COVID-19. *Science & Education*, *31*(2), 325–355.

Kalyon, D. Ş., & Yılmaz, Y. Ö. (2025). The Development of Pre-service Primary Teachers' Understanding and Skills of Argumentation through Argument Driven Inquiry. *Science & Education*, *34*, 557–584.

Khaokhajorn, W., & Srisawasdi, N. (2024). Assessing pre-service science teachers' understanding of the nature of scientific inquiry to develop a sustainable technology-infused pedagogical program in teacher education. *Cogent Education*, *11*(1), 1–22.

Koberstein-Schwarz, M., & Meisert, A. (2022). Pedagogical content knowledge in material-based lesson planning of pre-service biology teachers. *Teaching and Teacher Education*, *116*, 103745.

Kutluca, A. Y., & Aydın, A. (2017). Changes in pre-service science teachers' understandings after being involved in explicit nature of science and socioscientific argumentation processes. *Science & Education*, *26*(6), 637–668.

Leung, J. S. C. (2020). Students' adherence to epistemic understanding in evaluating scientific claims. *Science Education*, *104*(2), 164–192.

Leung, J. S. C. (2022). Shifting the Teaching Beliefs of Preservice Science Teachers About Socioscientific Issues in a Teacher Education Course. *International Journal of Science and Mathematics Education*, *20*, 659–682.

Linhares, E., & Reis, P. (2023). Education for Environmental Citizenship in Pre-Service Teachers: Potentialities and Limitations of a Pedagogical Approach Applied at a Distance. *Sustainability*, *15*(21), 15411.

Magaji, A., M. Adjani, M., & Coombes, S. (2024). A Systematic Review of Preservice Science Teachers' Experience of Problem-Based Learning and Implementing It in the Classroom. *Education Sciences*, *14*(3), 301.

Mahler, D., Bock, D., Schauber, S., & Harms, U. (2024). Using longitudinal models to describe pre-service science teachers' development of content knowledge and pedagogical content knowledge. *Teaching and Teacher Education*, *144*, 104583.

McFadden, A., & Williams, K. E. (2020). Teachers as evaluators: Results from a systematic literature review. *Studies in Educational Evaluation*, *64*, 100830.

Merritt, E. G., Bowers, N., & Rimm-Kaufman, S. E. (2019). Making connections: Elementary students' ideas about electricity and energy resources. *Renewable*

Energy, *138*, 1078–1086.
Mesci, G., Erdas-Kartal, E., & Yeşildağ-Hasançebi, F. (2025). The effect of argumentation-based inquiry on preservice teachers' understanding of the nature of science, inquiry, and scientific literacy. *Teaching and Teacher Education*, 162.
Mesci, G., Yeşildağ-Hasançebi, F., & Tuncay-Yüksel, B. (2023). Argumentation based nature of science instruction: Influence on pre-service science teachers' NOS views and practicing. *Teaching and Teacher Education*.
Özer, F., & Sarıbaş, D. (2023). Exploring pre-service science teachers' understanding of scientific inquiry and scientific practices through a laboratory course. *Science & Education*, *32*, 787–820.
Palma-Jiménez, M., Cebrián-Robles, D., & Blanco-López, A. (2025). Impact of Instruction Based on a Validated Learning Progression on the Argumentation Competence of Preservice Elementary Science Teachers. *Science & Education*, *34*, 423–455.
Peten, D. M. (2022). Influence of the argument-driven inquiry with explicit-reflective nature of scientific inquiry intervention on pre-service science teachers' understandings about the nature of scientific inquiry. *International Journal of Science and Mathematics Education*, *20*(5), 921–941.
Reuter, T., & Leuchter, M. (2023). Pre-service teachers' latent profile transitions in the evaluation of evidence. *Teaching and Teacher Education*, *132*, 104248.
Şen, A., & Kaplan, A. Ö. (2025). Reflections of Pre-Service Science Teachers' Understanding of the Nature of Science on a Socioscientific Issue. *Science & Education*, *34*, 4405–4431.
Silva, F. C., & Sasseron, L. H. (2025). Mobilization of Scientific Knowledge Domains to Build Epistemic Practices Among Pre-service Chemistry Teachers. *Science & Education*, *34*, 3915–3958.
Sjöström, J. (2025). Vision III of scientific literacy and science education: an alternative vision for science education emphasising the ethico-socio-political and relational-existential. *Studies in Science Education*.
Smit, R., Rietz, F., & Büchel, D. (2025). Using the socioscientific issue approach to foster secondary students' argumentation skills, science self-efficacy beliefs and science interest. *International Journal of Science Education*, 1–17.
Sultan, A. Al, Henson, H. J., & Lickteig, D. (2021). Assessing preservice elementary teachers' conceptual understanding of scientific literacy. *Teaching and Teacher Education*, *102*, 103327.
Wang, J. C., & Wang, T. H. (2023). Learning effectiveness of energy education in junior high schools: Implementation of action research and the predict–observe–explain model in a STEM course. *Heliyon*, *9*(3), 14058.
Weyers, J., Kramer, C., Kaspar, K., & König, J. (2024). Measuring pre-service teachers' decision-making in classroom management: A video-based assessment approach. *Teaching and Teacher Education*, *138*, 104426.