International Journal of Education and Practice
2024 Vol. 12, No. 2, pp. 189-206
ISSN(e): 2310-3868
ISSN(p): 2311-6897
DOI: 10.18488/61.v12i2.3657

Development and validation of the inquiry-based nature of science and argumentation: A new instructional model on students' scientific argumentation ability

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Article History
Received: 20 June 2023
Revised: 14 September 2023
Accepted: 29 January 2024
Published: 26 February 2024

Keywords
Argumentation
IB-NOSA
Inquiry
Instructional model
NOS
Scientific argumentation ability.

ABSTRACT

One of the important goals of science education is to improve scientific argumentation ability which is part of the core practice of science. The main goals of this research are to develop and validate the inquiry-based nature of science and argumentation (IB-NOSA) instructional model which is designed to improve scientific argumentation ability. The research design in this study is Research and Development (R&D) using the steps proposed by Borg & Gall. The feasibility test of the IB-NOSA instructional model was assessed using the Focus Group Discussion (FGD) method, an assessment of the IB-NOSA model book, and an instrument test of scientific argumentation ability involving four experts. The practicality test was assessed by a lower secondary school science teacher. The data were analyzed using quantitative methods, and the validity and reliability indexes were calculated. The results of the study show that the IB-NOSA instructional model is feasible and practical. Meanwhile, the validation results of the scientific argumentation ability test instrument show that each item is in the range of 0.92 to 1. This indicates that each item is valid for further use. Therefore, it can be concluded that the IB-NOSA instructional model has feasibility and practicality for use in science learning and for developing the scientific argumentation ability of lower secondary school students.

Contribution/Originality: This research has the originality of integrating the inquiry instructional model with aspects of NOS and argument mapping. The study shows uniquely how IB-NOSA instructional model is designed to provide a stimulus for students' scientific argumentation ability in learning of science.

1. INTRODUCTION

Scientific argumentation ability is accepted by many educators as one of the main components of science education in terms of national science standards and training students to develop literacy in the context of science (Cetin, Dogan, & Kutluca, 2014). Students in the 21st century need to be scientifically literate so practicing argumentation needs to be emphasized (Archila, Molina, & Truscott, 2020). Scientific argumentation ability can improve students' understanding of the epistemic goals of science, which include an explanation or proof to find out the truth produced by science (Berland & Reiser, 2011). The importance of scientific argumentation ability is education must teach students how to make a strategy for good and correct scientific argumentation (Diković, 2021).

Although scientific argumentation ability has an important function in science education, it is rarely used together when learning science in class and when practicum in the laboratory, and students have not been trained to debate (Utomo, 2019) building an explanation, model, and theory on the concept being studied (Rahayu, Siswanto, Ramadhanty, & Subali, 2023). Based on Ginanjar, Utari, and Muslim (2015) the availability of good instructional models to equip students with argumentation ability is still limited. Sampson, Grooms, and Walker (2011) argue that one way to overcome the lack of scientific argumentation is to develop new learning models that can help students develop understanding and the ability required to be active in scientific argumentation activities. Argumentation in science learning will train students to be able to provide data or evidence, and valid theories that function to support claims on a problem (Robertshaw & Campbell, 2013).

The inquiry-based instructional model is an important innovation in science education (Eltanahy & Forawi, 2019). Researchers and teachers regard it as exciting for students' use of research ability, meaning the construction, and acquisition of scientific knowledge (Alake-Tuenter et al., 2012). Current standards place a premium on student participation in inquiry processes. However, implementing an inquiry-based instructional model can be difficult for teachers because they frequently lack examples for using and innovating inquiry-based teaching materials (Duncan, Pilitsis, & Piegaro, 2010).

The inquiry-based instructional model approved by science teachers that the right model for science education because students can construct their knowledge (Cairns, 2019). When students carry out practical activities in the laboratory directly, students must be able to write down their arguments as part of the scientific inquiry process (Choi, Klein, & Hershberger, 2015). Having more chances to experience inquiry-based learning at school is necessary for every student, whether or not they want to be a scientist in the future (Kang, 2022). Research by Choi et al. (2015) shows that incorporating writing and argumentation into science instruction can promote deeper understanding and engagement with scientific concepts. The inquiry-based instructional model either implicitly or explicitly has three advantages of science learning objectives simultaneously namely process, content, and nature of science (NOS) (Schuster, Cobern, Adams, Undreiu, & Pleasants, 2018).

Many researchers have raised inquiry in science as a means to improve the various abilities of students (Acar & Patton, 2012). However, there are still few researchers who reveal the achievement of inquiry in mastering concepts as well as students' ability in scientific argumentation (Noviyani, Kusairi, & Amin, 2016). In addition, the inquiry-based instructional model has a weakness that the activities and achievements of students are difficult to control, and students do not have the ability to learn actively. To resolve this weakness, students must learn analogically and have a strong memory when trying to learn on their own (Sugianto, Suryandari, & Age, 2020). Inquiry-based instructional model does not directly facilitate students to practice constructing scientific argumentation ability.

The inquiry-based instructional model should focus on teaching NOS (Saido, Siraj, DeWitt, & Al-Amedy, 2018). Understanding NOS guarantees that the assumptions about the nature of scientific knowledge are considered in science teaching and learning (Kinyota, 2020). Thus, it is very important to investigate whether the various levels of the curriculum have integrated inquiry-based learning models with NOS explicitly. When doing inquiry practice in a laboratory with a scientist, NOS must still be taught explicitly (Leblebicioglu et al., 2019). However , much of the research does not include explicit teaching about NOS. Capps and Crawford (2013) indicated that there are still many science teachers who do not understand the NOS-based inquiry instructional model.

Not only teaching about NOS, but science educators must also develop their knowledge of scientific argumentation as a way to structure argumentation learning and evaluate student arguments (Sengul, Enderle, & Schwartz, 2020). Science learning needs a classroom that allows students to collaborate in several ways to generate new viewpoints (Songsil, Pongsophon, Boonsoong, & Clarke, 2019). National Research Council (2011) recommended that components of inquiry-based instruction be added to argumentation activity. Argumentation is a discourse for someone to apply their knowledge. As scientists make propositions and provide evidence (such as observations, conclusions, and theories), that evidence is debated, reviewed, and criticized by the expert scientific community (Dawson & Venville, 2010).

Duschl (2008) states that to practice scientific argumentation, students must be given a series of information and instructions about the form or components of the argument builder. Many science education researchers suggest integrating arguments into learning. First, Schleigh, Bosse, and Lee (2011) show how students who are actively involved in argumentation activities as part of the inquiry process can increase their science knowledge. Second, Bell and Linn (2000) research has shown that students can increase their understanding of important content knowledge by engaging in argumentation. Third, a study shows that argumentation encourages students to improve ways of thinking that are different from usual. This is because students can have more opportunities to be actively involved in the discursive reasoning and practice of scientists. The three studies show that it is important to integrate argumentation into science education. However, the results of the study by Choi, Seung, and Kim (2021) show that a lack of experience and understanding is the reason for teachers not implementing argumentation-based science learning. Most of the research results from journal articles show that students' scientific argumentation ability in several countries is still low (Songsil et al., 2019).

Therefore, it is crucial to research how to change inquiry-based instructional models in science learning. Therefore, modifications are made by integrating inquiry-based learning with NOS and argumentation. The instructional model is "Inquiry-Based Nature of Science and Argumentation," (henceforth referred to as the IB-NOSA instructional model). The IB-NOSA instructional model has a novelty in the resulting syntax because it combines an inquiry-based instructional model, NOS, and argumentation. The components of the instructional model in this study refer to Joyce, Weil, and Calhoun (2015) namely their rational theory, syntax, principles of reaction, social systems, support systems, and instructional and nurturant effects. Each part of the IB-NOSA instructional model also has special characteristics that are different from other instructional models.

Therefore, the IB-NOSA instructional model becomes important to explain conceptually and pedagogically for science learning. As a new instructional model that intends to overcome the weaknesses of the old model (Inquiry-Based Instructional Model), IB-NOSA needs to examine its components, feasibility, and practicality. Therefore, the problems of this research included:

1. How can the components of the IB-NOSA instructional model increase Students' Scientific Argumentation Ability?
2. What is the feasibility of the IB-NOSA instructional model to increase Students' Scientific Argumentation Ability?
3. What is the practicality of the IB-NOSA instructional model to increase Students' Scientific Argumentation Ability?

2. LITERATURE REVIEW

2.1. Component of Instructional Models

The instructional model must be developed from the theory that underlies it (Arends, 2012). The instructional model must have the following components: (1) principles; (2) purpose; (3) learning content; (4) learning process; and (5) evaluation (Anchunda & Kaewurai, 2021). According to Arends (2012) the instructional model requirements must consist of four elements including (1) coherent rational theory, (2) learning outcomes achieved, (3) requiring certain teacher behaviors, and (4) requiring certain class structures. In addition, according to Joyce et al. (2015) the instructional model must have five main elements, namely: (1) rational theory; (2) syntax; (3) principles of reaction; (4) social system; (5) support system, and instructional and nurturant effects. Based on this explanation, the instructional model components in this study were adopted by Joyce et al. (2015).

2.2. Inquiry-Based Instructional Models

The inquiry-based learning has a characteristic, namely students answer research questions by applying the scientific method (Stender, Schwichow, Zimmerman, & Härtig, 2018). Students who actively participate during learning when taught with the inquiry model can increase their knowledge of academic content which includes an understanding of facts, principles, and concepts in the context of problem-solving (Kilbane & Milman, 2014). The inquiry-based learning model is more effective than traditional learning (Mello et al., 2019). The inquiry model has developed high-level thinking skills and students' positive attitudes toward learning science (Abaniel, 2021). The syntax of the instructional model in this study was adopted from Pedaste et al. (2015) namely: (1) orientation; (2) conceptualization which consists of asking questions and making hypotheses sub-phases; (3) the investigation consists of sub-phases of collecting data and analyzing data; (4) conclusion; (5) discussion consists of communication and reflection sub-phases.

2.3. Nature of Science (NOS)

Based on Aydin and Tortumlu (2015) model, teaching NOS to students can use three approaches, namely historical, implicit, and explicit-reflective. Research shows that the best approach to increase NOS is explicit-reflective (Khishfe & Abd-El-Khalick, 2002; Lederman, 2007). NOS characteristics consist of empirical basis, inferential nature, tentativeness, scientific theories/laws, human creativity/imagination, subjective nature, and social/cultural influences (Lederman, Lederman, & Antink, 2013; Liu & Lederman, 2007). NOS-oriented learning can help students to understand the inquiry process and can help students to know that science is a guide to logic and imagination can explain and predict facts that are not authoritarian (Hutauruk & Siregar, 2016). Michel and Neumann (2014) show that teaching NOS can increase the effectiveness of the science learning process because it helps students fulfill science class goals.

2.4. Argumentation

The argument referred to in this study is argument mapping (AM). Dwyer, Hogan, and Stewart (2010) define argument mapping as a method of representing arguments in the form of a diagram that is made to simplify and make it easier to read the core structure of arguments. Argument mapping is a visual depiction of an argument that shows how the main argument is supported by the premise/argument statement (Kaeppel, 2021). AM is also shown as a representation using a box graphic model and arrows of how to structure arguments (Metcalfe & Sastrowardoyo, 2013). The argumentation model or scheme or Toulmin Argumentation Pattern (TAP) (Toulmin, 2003) consists of six components, namely claims (C), data (D), warrants (W), backing (B), qualifiers (Q), and rebuttals (R) which are interrelated. The interrelationship between these components is based on Erduran, Simon, and Osborne (2004) and can be seen in Figure 1.

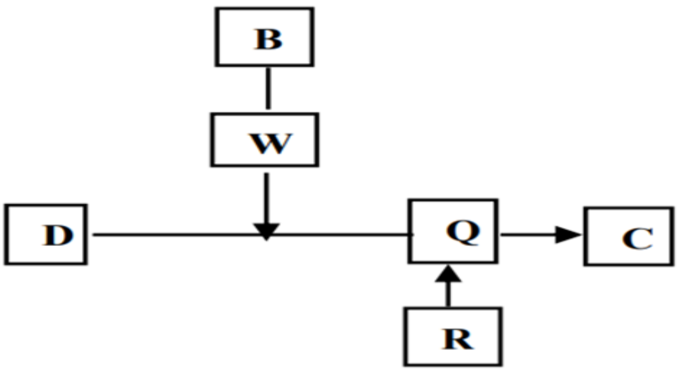

Figure 1. The interrelationship components of argumentation-mapping.
Source: Erduran et al. (2004).

2.5. Scientific Argumentation Ability

Scientific argumentation ability is important for students to be able to convey their arguments, make decisions, and solve problems in everyday life (Songsil et al., 2019). Anwar and Ali (2020) consider scientific argumentation ability as an important part of science education, where argumentation exemplifies how scientists talk to each other. The involvement of students in scientific argumentation ability, both individually and in groups, provides experience and awareness for the process of theoretical development (Heng, Surif, & Seng, 2015). Many researchers state that the classroom environment both in the classroom and in small groups greatly influences student participation in developing scientific argumentation ability (Chin & Osborne, 2010). The development of scientific argumentation ability cannot be obtained easily without continuous training. One effort to train argumentation ability is to provide argumentative content or substance in the learning process (Paramita, Dasna, & Yahmin, 2019). Scientific argumentation ability can also be improved by instructional models that can be collaborated with argumentation techniques (Widhi, Hakim, Wulansari, Solahuddin, & Admoko, 2021).

3. METHODOLOGY

3.1. Research Design

This research used the Educational Research and Development (R&D) model, following the steps proposed by Borg and Gall (1983). However, this study only reports the first five stages, which are as follows: (1) research and information collecting; (2) planning; (3) developing a preliminary form of product; (4) preliminary field testing; (5) main product revision. This research uses only five of the ten steps because it adapts to the research aims to evaluate the feasibility and practicality of product development. The research procedure can be seen in Figure 2.

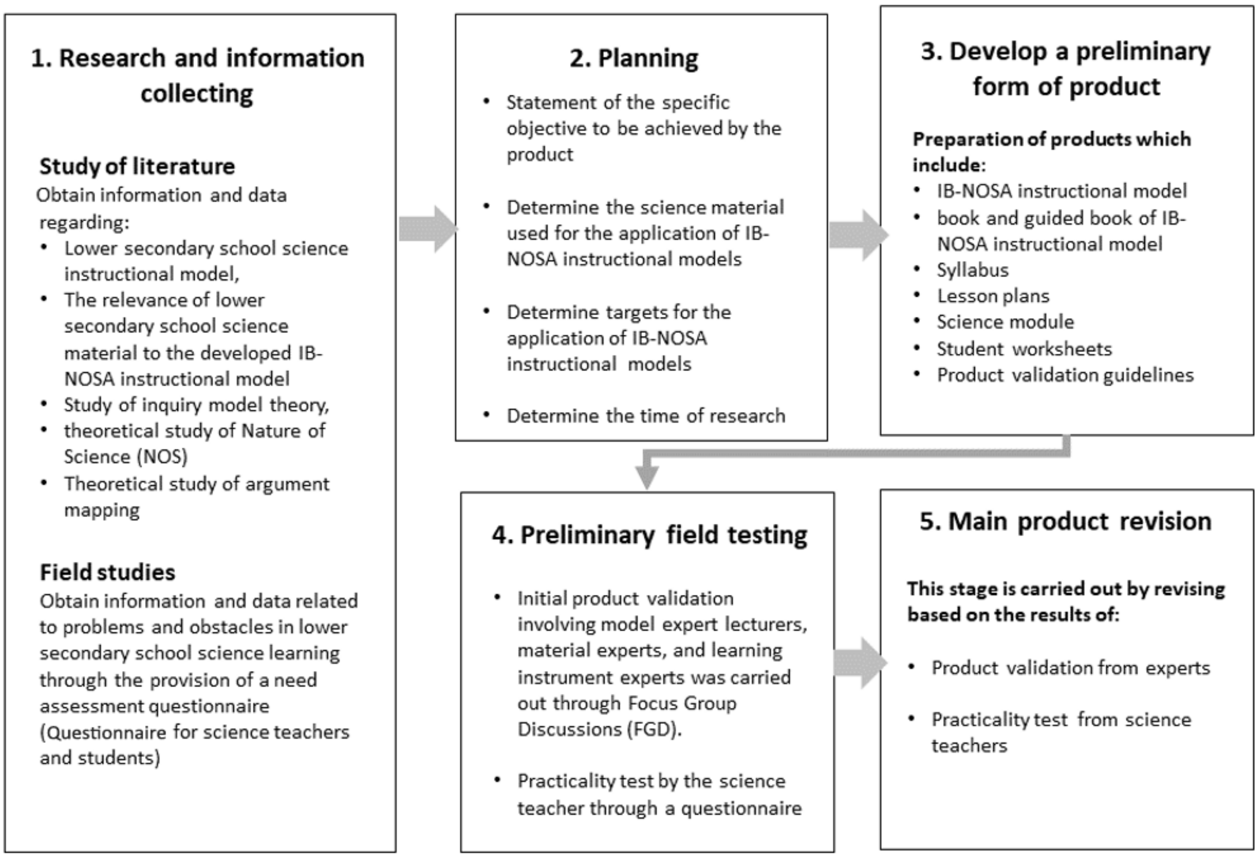

Figure 2. Stages of research development model.

3.2. Participants

The feasibility assessment of the IB-NOSA instructional model prototype involved by four experts or experienced lecturers from the field related to the model. The criteria for sampling experts were 10 years of teaching experience, a professor's position, a doctoral degree, and an expert in the fields of science, education, and learning theory. At the same time, science teachers took part in evaluating the practicality of the IB-NOSA instructional model with the criterion of 10 years of teaching experience in science learning. Table 1 presents a list of the experts involved in the Focus Group Discussion (FGD) and the assessments of the Inquiry-Based NOS Argumentation Instructional Model.

Table 1. Expert list: Validator of the IB-NOSA instructional model.

Expert's title	Teaching field	Expertise
E-1: Professor	Chemistry education	Science content material
E-2: Associate professor	Science education	Science instructional model
E-3: Associate professor	Physics education	Science instructional media
E-4: Associate professor	Educational philosophy	Instructional theory

3.3. Instruments

The instrument used in this research was the IB-NOSA instructional model product assessment sheet. This research involved four experts in the field of instructional model development who came from the internal environment of the research university. Expert judgment was used to assess the feasibility of the IB-NOSA instructional model. The practicality of the IB-NOSA instructional model was assessed by four lower secondary schools' science teachers. The feasibility and practicality assessment scale used is a five-point Likert scale with scores: very good (5); good (4); acceptable (3); poor (2); and very poor (1). The content validity of the scientific argumentation skills instrument was assessed by four expert lecturers. The evaluation forms of instruments test scientific argumentation ability using a four-point Likert scale with the following scores: without revision (4); minor revision (3); major revision (2); can not be used (1).

3.4. Data Analysis

The data analysis techniques used to process the results of feasibility and practicality tests refer to Widoyoko (2009) with the following steps:

1. Identify the average score for each instrument item.
2. Identify the average score of each component's total score.
3. Compare the overall average score of each component using the criteria listed in Table 2.

Table 2. Reference for changing the average score into categories.

No	Formula	Average score	Category
1	$X > \overline{X}_i + 1.8 \times sb_i$	>4.2	Very good
2	$\overline{X}_i + 0.6 \times sb_i < X \leq \overline{X}_i + 1.8 \times sb_i$	>3.4 – 4.2	Good
3	$\overline{X}_i - 0.6 \times sb_i < X \leq \overline{X}_i + 0.6 \times sb_i$	>2.6 – 3.4	Average
4	$\overline{X}_i - 1.8 \times sb_i < X \leq \overline{X}_i - 0.6 \times sb_i$	>1.8 – 2.6	Poor
5	$X \leq \overline{X}_i - 1.8 \times sb_i$	≤1.8	Very poor

Note: Information: $\overline{X}_i$ (Ideal mean) $= \frac{1}{2}$ (Ideal maximum score + ideal minimum score).
sb_i (Ideal standard deviation) $= \frac{1}{6}$ (Ideal maximum score - ideal minimum score).
X = Empirical score.

The instrument for assessing scientific argumentation ability consisted of 5 questions. Aspects of item validation included material, construction, and language. The results of content validity were analyzed according to Aiken's V. Due to the number of item 4 categories and rater 4, the item was said to be valid if the value of V ≥ 0.92

(Aiken, 1985). The Aikens' V index for each item was based on the validator's assessment with the following statistical formula:

$$V = \frac{\Sigma s}{[n(c-1)]}$$

Information:

V = Item validity index.

s = r-lo

lo = The lowest validity value.

c = The highest validity value.

r = The score given by the assessor.

n = Number of members.

4. RESULTS

4.1. Components of the IB-NOSA Instructional Model

The development results of the IB-NOSA instructional model can be seen in Figure 3. It consists of several components namely: rational theoretical model, syntax, principles of reaction, social system, support system, instructional and nurturant effects.

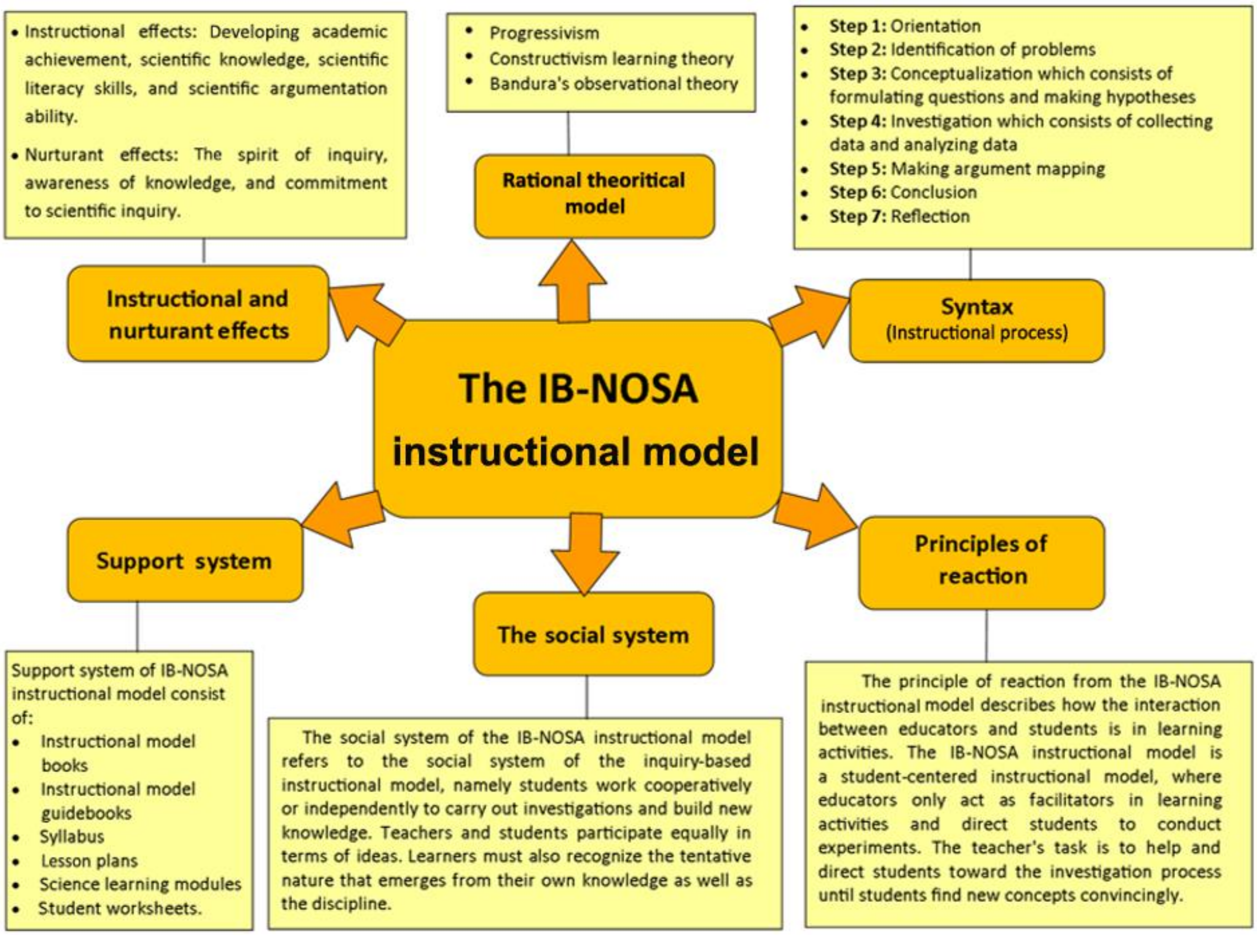

Figure 3. Components of the IB-NOSA instructional model.

4.1.1. Component 1: Rational Theory

The philosophical foundation underlying the development of the IB-NOSA instructional model is progressivism. Based on Wong and Pugh (2014) science education progressively seeks to contextualize meaningful problems in learning, involving students' previous experiences and interests in learning. A characteristic of the IB-NOSA instructional model is the teacher acting as a facilitator. This is in line with the flow of the progressivism philosophy where the teacher acts as a facilitator not as an authoritarian person.

The theoretical basis forms the basis for considering the design of the IB-NOSA instructional model which consists of Piaget's constructivist learning theory, Vygotsky, and Bandura's observational learning. Piaget stated that the learning process takes place through three stages, namely assimilation, accommodation, and equilibration/balancing. These three stages are a reference in developing syntax in the IB-NOSA instructional model, namely in the teacher-oriented syntax demonstrating unique events, discussing topics that interest students so that they can strengthen assimilation and accommodation, and encouraging learning activities.

The Zone of Proximal Development (ZPD) and scaffolding are two key concepts in Vygotsky's social constructivism theory (Schunk, 2012). The connection between ZPD and the application of the IB-NOSA instructional model is that teachers need to assist students if they experience difficulties during learning. When students' competence increases, the teacher gradually eliminates scaffolding with the aim that students can learn independently. The existence of interaction between students with other students, students, and teachers can encourage cognitive development.

According to Bandura, there are four learning phases from modeling, namely attention, retention, reproduction, and motivation (Santrock, 2011). The four learning phases of this model become a reference for developing the IB-NOSA instructional model. In Bandura's observational learning theory, the teacher plays an active role and ensures that the right role model is used to strengthen the stimulus-response mechanism. The teacher ensures that the learner pays attention and sees or hears about the consequences of the desired/unwanted behavior. The teacher gives appropriate chances and motivation for students to engage in desired behavior or refrain from engaging in undesirable behavior (Kay & Kibble, 2016).

4.1.2. Component 2: Syntax (Instructional Process)

The heart of the IB-NOSA instructional model is syntax or the instructional process.

Step 1: Orientation. The activity of this step is the teacher introduces topics related to everyday life problems. For the presentation of problem situations or events, it must be unclear which can arouse students' curiosity (Arends, 2012). In the orientation activity, students are invited to start reading the topic to be investigated. The orientation process can form students' awareness of the knowledge and attitudes that need to be built to overcome problems on a given topic (Wajdi, Jamaluddin, Bin, & Magfirah, 2022). In addition, according to Chen and Wang (2020) orientation activities can help students construct student knowledge.

Step 2: Identification of problems. This step is an important component of the thinking process for defining a structured and resolved problem (Bachtiar, Zubaidah, Corebima, & Indriwati, 2018). The problem will be the focus of investigation in the learning process. At this stage, the teacher also ensures students have the knowledge and skills prerequisites for inquiry assignments before introducing the inquiry process which aims to increase the potential for successful learning.

Step 3: Conceptualization. The conceptualization phase consists of two sub-phases, namely formulating questions and making hypotheses. In formulating questions, sub-phase students can develop their questions or engage in more targeted investigations (Arends, 2012). In the hypothesis sub-phase, students develop hypotheses based on their previous knowledge and experience. The teacher explains that in making a hypothesis there is an aspect of NOS: it involves human imagination and creativity.

Step 4: Investigation. This step consists of two sub-phases, namely collecting data and analyzing data. In the investigative phase students design and carry out their investigations to answer the questions that have been made by planning procedures and carrying out investigations. In the data analysis phase, students are focused on making meaning from the collected data and synthesizing new knowledge. This can help improve students' scientific literacy skills. This is supported by a study Pedaste et al. (2015) which argues that interpretation of data makes students return to the hypothesis and draw conclusions about what was hypothesized. The teacher explains that in the investigative phase, there are aspects of NOS: human imagination and creativity; observation and inference; and empirical basis.

Step 5: Create Argument Mapping. The argument mapping phase is a phase where students are trained to argue. The argument is considered a core practice of inquiry-based learning (Choi et al., 2021). Argument mapping activities train students to increase their knowledge so they can think and make decisions like scientists (Zhang & Browne, 2023). This relates to the work of scientists using patterns of problem investigators and establishing hypotheses and arguments that have a clear connection between claims, data, support, guarantees, evidence, counterclaims, and rebuttals about these problems or hypotheses (Yore, Pimm, & Tuan, 2007). The teacher explains that in the making argument mapping phase there are aspects of NOS: human imagination and creativity; observation and inference; and empirical basis.

Step 6: Conclusion. In the conclusion phase, it is used to synthesize the research that has been done (Pedaste et al., 2015). The last phase is reflection which is an important activity in learning science. Planning an action, justifying what is planned to be done or has been done, and contrasting the two activities are all examples of reflection (Holbrook & Rannikmae, 2007). The teacher explains that in the making argument mapping phase there are aspects of NoS: tentativeness and empirical basis.

Step 7: Reflection. This step is carried out through NOS aspects related to the material that has been taught previously. Aspects of NOS are made instructional explicit on student worksheets in the form of questions. Reflection plays a significant role in science learning. Reflection in learning is in the form of planning an action to be carried out, justifying what has been planned to be done or has been done, and then comparing the two actions (Holbrook & Rannikmae, 2007). The importance of including reflective elements in NOS aspects makes students learn more meaningfully and effectively (Yacoubian & BouJaoude, 2010). Students who have good reflection can improve their understanding of scientific knowledge related to scientific literacy (Santos, Maia, & Justi, 2020).

4.1.3. Component 3: Principles of Reaction

The principle of reaction relates to patterns that describe how interactions between educators and students should be in learning activities. The IB-NOSA instructional model is a student-centered learning model, where educators only act as facilitators in learning activities and direct students to conduct experiments. The teacher's task is to help and direct students toward the investigation process until students find new concepts convincingly.

4.1.4. Component 4: The Social System (Activities)

The social system of the IB-NOSA instructional model is that students work cooperatively or independently to conduct investigations and build new knowledge. Teachers and students participate equally in terms of ideas. Learners must also recognize the tentative nature that emerges from their knowledge as well as the discipline, thereby developing a certain humility for their well-developed approach to the discipline.

4.1.5. Component 5: Support System

The media, tools, and resources, as well as the facilities and infrastructures required to enable the greatest execution of learning activities in the application of learning models, are all part of the support system. The teacher provides a support system in the form of a science learning module and students' worksheet, which is used for students. Syllabus, lesson plans, and model manuals are used by teachers as a guide in implementing the IB-NOSA instructional model.

4.1.6. Component 6: Instructional and Nurturant Effects

Instructional effects are the direct impact of the learning process carried out using certain models on certain materials which can be in the form of learning outcomes obtained by students that are relevant to the learning goals that have been set. The instructional effect of the IB-NOSA learning model is developing academic achievement, scientific knowledge, scientific literacy skills, and scientific argumentation skills. The nurturant effect is the learning result that becomes a further influence because of the use of the applied instructional model. The nurturant effect of the IB-NOSA instructional model is the spirit of inquiry, awareness of knowledge, and commitment to scientific inquiry.

4.2. Expert Validation of the IB-NOSA Instructional Model

Validation by experts included validation of instructional model components, model books, model implementation manual books, and instruments of scientific argumentation ability. The four experts who assessed it gave a positive response about the feasibility of the IB-NOSA instructional model. This model can be effectively applied in science learning.

4.2.1. Validation Result of Components of the IB-NOSA Instructional Model

The main product of this study is the IB-NOSA instructional model. Evaluating the validity of the instructional model is done by expert judgment. Four experts assessed the validity of this model. The validity of the IB-NOSA instructional model is viewed from the components of the model, namely rational theoretical models, syntax, social systems, principles of reaction, support systems, instructional and nurturant effects. The result of the expert assessment can be seen in Table 3.

Table 3. Validation result of the components IB-NOSA instructional model.

Aspect	The average score of each aspect				Average	Category
	E1	E2	E3	E3		
Rational theoretical model	4.50	4.75	4.75	4.75	4.68	Very good
Syntax	4.83	4.67	4.67	4.33	4.62	Very good
Social system	4.75	4.75	4.50	4.75	4.68	Very good
Principles of reaction	5.00	4.67	5.00	4.67	4.83	Very good
Support system	4.20	4.40	4.00	4.00	4.15	Good
Instructional and nurturant effects	4.50	4.75	4.00	4.50	4.43	Very good
Average					4.56	Very good

Note: E= Expert.

Table 3 shows a summary of the validation results of the IB-NOSA instructional model. These results show that the average overall score is 4.56 which indicates a very good category, so it can be concluded that the IB-NOSA instructional model is feasible to use and is ready to be used in learning.

4.2.2. Validation Result of the IB-NOSA Instructional Model Book

The IB-NOSA instructional book is used by science practitioners/teachers in implementing the IB-NOSA instructional model. This model book has sections namely the introduction, the basic concepts of the IB-NOSA instructional model, the philosophical basis and theory of the IB-NOSA instructional model, the components of the IB-NOSA instructional model, and the closing. The following result of the expert assessment can be seen in Table 4.

Table 4. Validation result of the IB-NOSA instructional model book.

Aspect	The average score of each aspect				Average	Category
	E1	E2	E3	E3		
Presentation	5.00	4.50	4.75	5.00	4.81	Very good
Design	4.50	4.33	4.33	4.50	4.12	Good
Language	4.00	4.67	5.00	4.33	4.50	Very good
Material/Substance	4.50	5.00	4.00	5.00	4.62	Very good
Average					4.51	Very good

Note: E= Expert.

Table 4 shows a summary of the validation results of the IB-NOSA instructional model book. These results show that the average overall score is 4.51 which indicates a very good category. As a result, it can be found that the IB-NOSA instructional model book is feasible to use. A sample of the book cover of the IB-NOSA instructional model can be seen in Figure 4.

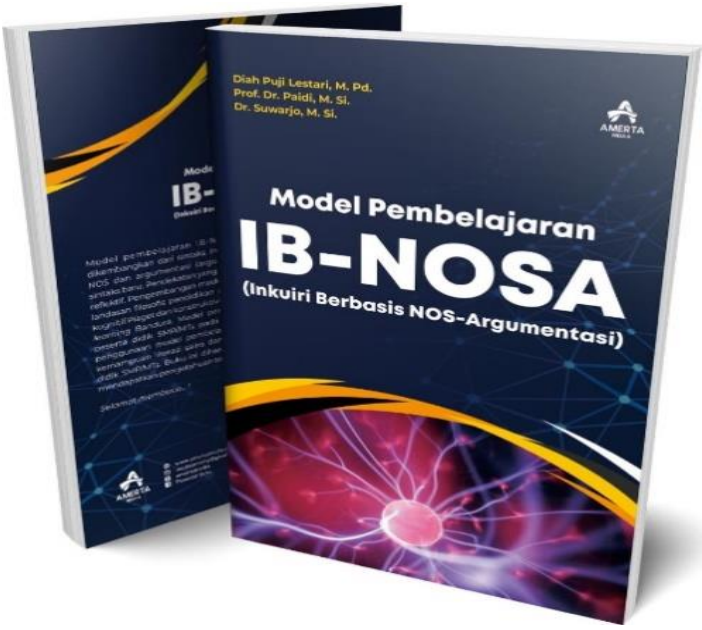

Figure 4. Cover book of the IB-NOSA instructional model.

4.2.3. Validation Result of the IB-NOSA Instructional Model Guidebook

The IB-NOSA instructional model guidebook is used as a guide for science practitioners/teachers in implementing the IB-NOSA instructional model in the classroom. The IB-NOSA instructional model guidebook has the main sections, namely the introduction, components of the IB-NOSA instructional model, and instructional model tools. The following result of the expert assessment can be seen in Table 5.

Table 5. Validation result of the IB-NOSA instructional model guidebook.

Aspect	The average score of each aspect				Average	Category
	E1	E2	E3	E3		
Material/Substance	4.67	4.67	4.33	5.00	4.67	Very good
Construction	4.50	5.00	4.50	5.00	4.75	Good
Presentation	4.00	4.00	4.00	4.50	4.13	Very good
Language	4.00	4.67	4.67	4.33	4.42	Very good
Feasibility	4.50	4.50	4.50	5.00	4.63	Very good
Design	4.50	4.33	4.50	4.67	4.50	Very good
Average					4.51	Very good

Note: E= Expert.

Table 5 shows a summary of the results of the validation of the guidebook for the implementation of the IB-NOSA instructional model. These results show that the average overall score is 4.51 which indicates a very good category, so it can be concluded that the guidebook for the implementation of the IB-NOSA instructional model is feasible to use.

4.2.4. Validation Result of Scientific Argumentation Ability Test

Students' Scientific Argumentation Ability is measured using essay questions through pretest (before learning begins) and posttest (after learning using the IB-NOSA instructional model). The number of items used is five. Table 6 shows the results of the validation of the scientific argumentation ability instruments test.

Table 6. Validation result of scientific argumentation ability test.

Items	Raters				s1	s2	s3	s4	∑s	Validity coef. (V)	Category
	1	2	3	4							
1	4	4	3	4	3	3	2	3	11	0.92	Valid
2	4	4	4	3	3	3	3	2	11	0.92	Valid
3	4	4	4	4	3	3	3	3	12	1	Valid
4	4	3	4	4	3	2	3	3	11	0.92	Valid
5	3	4	4	4	2	3	3	3	11	0.92	Valid

Based on Table 6 it is known that the validity coefficient value of Aiken's V for each item is in the range of 0.92 to 1. This indicates that each item is valid for further use.

4.3. Practicality Test Results of the IB-NOSA Instructional Model

The practicality of the IB-NOSA instructional model was assessed based on the model's practicality questionnaire. The practicality of the model sheet was assessed by four science practitioners/teachers. The following results of practical assessments by science teachers can be seen in Table 7.

Table 7. Practicality test results of the IB-NOSA instructional model.

Aspect	The average score of each aspect				Average	Category
	P1	P2	P3	P4		
Syntax	4.50	4.75	4.75	4.75	4.69	Very practical
Social system	4.67	4.67	4.67	5.00	4.75	Very practical
Principles of reaction	4.67	5.00	4.67	4.67	4.75	Very practical
Support system	4.67	4.89	4.67	4.89	4.78	Very practical
Instructional and nurturant effects	5.00	4.50	4.50	5.00	4.75	Very practical
Average					4.74	Very practical

Note: P= Practitioners.

Table 7 shows a summary of the results of the practicality assessment of the IB-NOSA instructional model. These results show that the average overall score is 4.74 which shows a very practical category, as a result, the IB-NOSA instructional model can be inferred to be very useful in science learning.

5. DISCUSSION

The goal of this research was to develop the IB-NOSA instructional model through a literature review which then produces seven syntaxes, that have been validated by four expert lecturers and four lower secondary school science teachers. The results of the validation test, the IB-NOSA instructional model, were declared "very good". Based on practicality tests assessed by lower secondary school science teachers, the IB-NOSA instructional model is "very practical" to apply in learning. The contribution of this research compared to the existing research is that it aims to overcome the problem of low argumentation ability among lower secondary school students in Indonesia based on the results of research from Amielia, Suciati, and Maridi (2018); Jumadi, Perdana, and Rosana (2021); Widodo, Waldrip, and Herawati (2016) and Wikara, Sutarno, Suranto, and Sajidan (2022).

The "very good" assessment by experts of the IB-NOSA instructional model can be explained by the fact that experts understand the needs, objectives, and uses of the IB-NOSA instructional model and feel that the model will be appropriate for improving scientific argumentation ability. The components of the IB-NOSA instructional model are also considered to be the components of the instructional model based on Joyce et al. (2015). In addition, according to the assessment of the science teachers, the syntax of the IB-NOSA instructional model can be easily used, and they are interested in using the IB-NOSA instructional model.

One of the advantages of the IB-NOSA instructional model is that it focuses on students, where the teacher acts as a facilitator. This is by constructivist instructional theory, where students are active in building their knowledge. In addition, the syntax of the IB-NOSA learning model was developed into an interesting activity that aims to foster students' scientific argumentation skills. During the lesson, students' study in groups to discuss with each other. Group members consider counterarguments before they agree on a unanimous conclusion.

Teaching NOS explicitly inquiry learning models can also facilitate meaningful discussions and achieve learning objectives that focus on epistemological understanding, which will affect the level of content knowledge (Abd-El-Khalick, 2013; Kutluca & Aydın, 2017). Through the syntax of the IB-NOSA instructional model which explicitly teaches aspects of NOS, students can understand creativity can create scientific knowledge, empirical data or evidence can become scientific knowledge obtained from experiments with scientific methods, scientific knowledge is tentative based on new evidence, personal subjectivity can affect scientific knowledge, social and cultural society can affect scientific knowledge in the form of law or theory.

Argumentation is a core practice of scientific inquiry, where arguments supported by evidence have a role in explaining the process of occurrence of natural phenomena (Choi et al., 2021). The IB-NOSA instructional model taught students' basic knowledge of science-related contexts and how scientists make evaluations of their claims. Where the process can create quality scientific argumentation ability and make effective decisions. Students who are taught argumentation explicitly can significantly improve the quality of their scientific argumentation ability (Khishfe, 2014). Argumentative learning becomes constructivist learning because it teaches students to evaluate their knowledge claims (Yilmaz, Cakiroglu, Ertepinar, & Erduran, 2017). Through a combination of argumentation activities in the syntax of the IB-NOSA instructional model, we believe that students can improve the skills needed to argue properly and precisely, understand how to compose good and correct scientific arguments and learn content that is important as part of the process. Developing a new instructional model, like the IB-NOSA instructional model, can help teachers understand how to increase student learning interest, some of the barriers that science educators must consider, and the process of learning science in the years to come.

6. CONCLUSION

The conclusion of this research is the IB-NOSA instructional model is an innovative inquiry-based instructional model that integrates NOS explicitly reflective and argumentative activity. This instructional model was developed for use by lower secondary school science teachers. The components of the IB-NOSA instructional model consist of rational theory, syntax, principles of reaction, social systems, support systems, and instructional and nurturant effects. Each component of the IB-NOSA instructional model has special characteristics that are different from other learning models.

The philosophical basis for developing the IB-NOSA instructional model is progressivism, and the instructional theory used is constructivism and Bandura's observational theory. The syntax of the IB-NOSA instructional model consists of orientation, identification of problems, conceptualization consists of formulating questions and making hypotheses, the investigation which consists of collecting data and analyzing data, making argument mapping, conclusion, and reflection. The principle of the reaction of the IB-NOSA instructional model is that the teacher acts as a facilitator in learning. The social system of the IB-NOSA instructional model is students work cooperatively or independently to conduct investigations and build new knowledge. The support system for the IB-NOSA instructional model, namely the teacher provides a support system in the form of a science learning module and students' worksheet, which is used for students. Syllabus, lesson plans, and model manuals are used by teachers as a guide in implementing the model. The instructional effect of the IB-NOSA learning model is developing academic achievement, scientific knowledge, scientific literacy ability, and scientific argumentation ability. The nurturant effect of the IB-NOSA instructional model is the spirit of inquiry, awareness of knowledge, and commitment to scientific inquiry.'

The components of the IB-NOSA instructional model and its tools are validated by expert judgments and science teachers. The results of the component validation of the IB-NOSA instructional model and its tools show that all are in the very good category. The validation results show that the IB-NOSA instructional model is feasible and practical. Meanwhile, the validation results of the argumentation ability test instrument show that each item is in the range of 0.92 to 1. This indicates that each item is valid for further use.

Suggestions for further research for lower secondary school science teachers who will apply the IB-NOSA instructional model must understand each component of the IB-NOSA instructional model. In addition, this IB-NOSA instructional model needs to be tested in extensive trials, especially in lower secondary school science learning, to find out its effectiveness in improving scientific argumentation ability. This IB-NOSA instructional model can also be used as material for further research studies.

Funding: This research is supported by the Ministry of Education and Culture of Indonesia, Indonesia (Grant number: T/6.3.14/UN34.9/PT.01.03/2023).
Institutional Review Board Statement: The Ethical Committee of the Yogyakarta State University, Indonesia has granted approval for this study on 8 September 2022 (Ref. No. 1312/UN34.17/LT/2022).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Abaniel, A. (2021). Enhanced conceptual understanding, 21st century skills and learning attitudes through an open inquiry learning model in Physics. *Journal of Technology and Science Education, 11*(1), 30-43. https://doi.org/10.3926/jotse.1004

Abd-El-Khalick, F. (2013). Teaching with and about nature of science, and science teacher knowledge domains. *Science & Education, 22*(9), 2087-2107. https://doi.org/10.1007/s11191-012-9520-2

Acar, O., & Patton, B. R. (2012). Argumentation and formal reasoning skillsin an argumentation-based guided inquiry course. *Procedia-Social and Behavioral Sciences, 46*, 4756-4760. https://doi.org/10.1016/j.sbspro.2012.06.331

Aiken, L. (1985). Three coefficients for analysing reliability and validity of rating. *Educational and Psychological Measurement, 45*, 131–142.

Alake-Tuenter, E., Biemans, H. J., Tobi, H., Wals, A. E., Oosterheert, I., & Mulder, M. (2012). Inquiry-based science education competencies of primary school teachers: A literature study and critical review of the American national science education standards. *International Journal of Science Education, 34*(17), 2609-2640. https://doi.org/10.1080/09500693.2012.669076

Amielia, S. D., Suciati, S., & Maridi, M. (2018). Enhancing students' argumentation skill using an argument driven inquiry-based module. *Journal of Education and Learning (EduLearn), 12*(3), 464-471. https://doi.org/10.11591/edulearn.v12i3.8042

Anchunda, H. Y., & Kaewurai, W. (2021). Instructional model development based on collaborative and communicative approaches to enhance lower secondary students' English-speaking skills in Thailand. *Kasetsart Journal of Social Sciences, 42*(2), 287-292. https://doi.org/10.34044/j.kjss.2021.42.2.11

Anwar, N. P., & Ali, M. A. (2020). The effect of socio-scientific issue (SSI) based discussion: A student-centred approach to the teaching of argumentation. *Scholarship of Teaching and Learning in the South*, *4*(2), 35-62. https://doi.org/10.36615/sotls.v4i2.76

Archila, P. A., Molina, J., & Truscott, D. M. A.-M. (2020). Using historical scientific controversies to promote undergraduates' argumentation. *Science & Education*, *29*(3), 647-671. https://doi.org/10.1007/s11191-020-00126-6

Arends, R. (2012). *Learning to teach*. New York: The McGraw-Hill Companies, Inc.

Aydin, S., & Tortumlu, S. (2015). The analysis of the changes in integration of nature of science into Turkish high school chemistry textbooks: Is there any development? *Chemistry Education Research and Practice*, *16*(4), 786-796. https://doi.org/10.1039/c5rp00073d

Bachtiar, S., Zubaidah, S., Corebima, A. D., & Indriwati, S. E. (2018). The spiritual and social attitudes of students towards integrated problem based learning models. *Issues in Educational Research*, *28*(2), 254-270.

Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: Designing for learning from the web with KIE. *International Journal of Science Education*, *22*(8), 797-817. https://doi.org/10.1080/095006900412284

Berland, L. K., & Reiser, B. J. (2011). Classroom communities' adaptations of the practice of scientific argumentation. *Science Education*, *95*(2), 191-216. https://doi.org/10.1002/sce.20420

Borg, W. R., & Gall, M. D. (1983). *Educational research: An introduction*. New York: Longman.

Cairns, D. (2019). Investigating the relationship between instructional practices and science achievement in an inquiry-based learning environment. *International Journal of Science Education*, *41*(15), 2113-2135. https://doi.org/10.1080/09500693.2019.1660927

Capps, D. K., & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education*, *24*(3), 497-526. https://doi.org/10.1007/s10972-012-9314-z

Cetin, P. S., Dogan, N., & Kutluca, A. Y. (2014). The quality of pre-service science teachers' argumentation: Influence of content knowledge. *Journal of Science Teacher Education*, *25*(3), 309-331. https://doi.org/10.1007/s10972-014-9378-z

Chen, C.-M., & Wang, W.-F. (2020). Mining effective learning behaviors in a web-based inquiry science environment. *Journal of Science Education and Technology*, *29*(4), 519-535. https://doi.org/10.1007/s10956-020-09833-9

Chin, C., & Osborne, J. (2010). Students' questions and discursive interaction: Their impact on argumentation during collaborative group discussions in science. *Journal of Research in Science Teaching*, *47*(7), 883-908. https://doi.org/10.1002/tea.20385

Choi, A., Klein, V., & Hershberger, S. (2015). Success, difficulty, and instructional strategy to enact an argument-based inquiry approach: Experiences of elementary teachers. *International Journal of Science and Mathematics Education*, *13*(5), 991-1011. https://doi.org/10.1007/s10763-014-9525-1

Choi, A., Seung, E., & Kim, D. (2021). Science teachers' views of argument in scientific inquiry and argument-based science instruction. *Research in Science Education*, *51*(S1), 251-268. https://doi.org/10.1007/s11165-019-9861-9

Dawson, V. M., & Venville, G. (2010). Teaching strategies for developing students' argumentation skills about socioscientific issues in high school genetics. *Research in Science Education*, *40*(2), 133-148. https://doi.org/10.1007/s11165-008-9104-y

Diković, M. (2021). Students' assessment on dialogue and argumentation in society and school. *Informatologia*, *54*(1-2), 77-87. https://doi.org/10.32914/i.54.1-2.7

Duncan, R. G., Pilitsis, V., & Piegaro, M. (2010). Development of preservice teachers' ability to critique and adapt inquiry-based instructional materials. *Journal of Science Teacher Education*, *21*(1), 81-102. https://doi.org/10.1007/s10972-009-9153-8

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education*, *32*(1), 268-291. https://doi.org/10.3102/0091732x07309371

Dwyer, C. P., Hogan, M. J., & Stewart, I. (2010). The evaluation of argument mapping as a learning tool: Comparing the effects of map reading versus text reading on comprehension and recall of arguments. *Thinking Skills and Creativity*, *5*(1), 16-22. https://doi.org/10.1016/j.tsc.2009.05.001

Eltanahy, M., & Forawi, S. (2019). Science teachers' and students' perceptions of the implementation of inquiry-based learning instruction in a middle school in Dubai. *Journal of Education, 199*(1), 13-23. https://doi.org/10.1177/0022057419835791

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education, 88*(6), 915-933. https://doi.org/10.1002/sce.20012

Ginanjar, W. S., Utari, S., & Muslim, M. (2015). Application of the argument-driven inquiry model in science learning to improve junior high school students' scientific argumentation abilities. *Jurnal Pengajaran MIPA, 20*(1), 32-37.

Heng, L. L., Surif, J., & Seng, C. H. (2015). Malaysian students' scientific argumentation: Do groups perform better than individuals? *International Journal of Science Education, 37*(3), 505-528. https://doi.org/10.1080/09500693.2014.995147

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education, 29*(11), 1347-1362. https://doi.org/10.1080/09500690601007549

Hutauruk, A., & Siregar, G. N. (2016). Nature of science learning model innovation to improve research data analysis capabilities through statistics courses. *Jurnal Suluh Pendidikan FKIP-UHN, 3*(1), 67-76.

Joyce, B., Weil, M., & Calhoun, E. (2015). *Models of teaching* (9th ed.). New Jersey: Pearson Education, Inc.

Jumadi, J., Perdana, R., & Rosana, D. (2021). The impact of problem-based learning with argument mapping and online laboratory on scientific argumentation skill. *International Journal of Evaluation and Research in Education, 10*(1), 16-23. https://doi.org/10.11591/ijere.v10i1.20593

Kaeppel, K. (2021). The influence of collaborative argument mapping on college students' critical thinking about contentious arguments. *Thinking Skills and Creativity, 40*, 100809. https://doi.org/10.1016/j.tsc.2021.100809

Kang, J. (2022). Interrelationship between inquiry-based learning and instructional quality in predicting science literacy. *Research in Science Education, 52*(1), 339-355. https://doi.org/10.1007/s11165-020-09946-6

Kay, D., & Kibble, J. (2016). Learning theories 101: Application to everyday teaching and scholarship. *Advances in Physiology Education, 40*(1), 17-25. https://doi.org/10.1152/advan.00132.2015

Khishfe, R. (2014). Explicit nature of science and argumentation instruction in the context of socioscientific issues: An effect on student learning and transfer. *International Journal of Science Education, 36*(6), 974-1016. https://doi.org/10.1080/09500693.2013.832004

Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching, 39*(7), 551–578. https://doi.org/10.1002/tea.10036

Kilbane, C. R., & Milman, N. B. (2014). *Teaching models: Designing instruction for 21st century learners.* Boston, MA: Pearson Education Inc.

Kinyota, M. (2020). The status of and challenges facing secondary science teaching in Tanzania: A focus on inquiry-based science teaching and the nature of science. *International Journal of Science Education, 42*(13), 2126–2144. https://doi.org/10.1080/09500693.2020.1813348

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. https://doi.org/10.1007/s11191-017-9919-x

Leblebicioglu, G., Abik, N. M., Capkinoglu, E., Metin, D., Dogan, E. E., Çetin, P. S., & Schwartz, R. (2019). Science camps for introducing nature of scientific inquiry through student inquiries in nature: Two applications with retention study. *Research in Science Education, 49*(5), 1231-1255. https://doi.org/10.1007/s11165-017-9652-0

Lederman, N. G. (2007). Nature of science : past, present, and future. In Handbook of research on science education. In (pp. 831–879). Mahwah, NJ: Routledge.

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.

Liu, S. Y., & Lederman, N. G. (2007). Exploring prospective teachers' worldviews and conceptions of nature of science. *International Journal of Science Education, 29*(10), 1281-1307. https://doi.org/10.1080/09500690601140019

Mello, P., Natale, C., Trivelato, S., Marzin-Janvier, P., Vieira, L., & Manzoni-de-Almeida, D. (2019). Exploring the inquiry-based learning structure to promote scientific culture in the classrooms of higher education sciences. *Biochemistry and Molecular Biology Education, 47*(6), 672-680. https://doi.org/10.1002/bmb.21301

Metcalfe, M., & Sastrowardoyo, S. (2013). Complex project conceptualisation and argument mapping. *International Journal of Project Management, 31*(8), 1129-1138. https://doi.org/10.1016/j.ijproman.2013.01.004

Michel, H., & Neumann, I. (2014). Nature of science and science content learning: Can NOS instruction help students develop a better understanding of the energy concept? In (pp. 1–10). Pittsburgh, Pennsylvania: National Association of Research in Science Teaching (NARST).

National Research Council, N. (2011). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. In Social Sciences*. Washington, DC: The National Academies Press.

Noviyani, M., Kusairi, S., & Amin, M. (2016). Concept mastery and argumentation abilities of junior high school students in science learning with argument-based inquiry. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan, 2*(7), 974-978.

Paramita, A. K., Dasna, I. W., & Yahmin, Y. (2019). Literature review: Stem integration for argumentation skills in science learning. *Jurnal Pembelajaran Kimia, 4*(2), 92-99. https://doi.org/10.17977/um026v4i22019p092

Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., . . . Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47-61. https://doi.org/10.1016/j.edurev.2015.02.003

Rahayu, R., Siswanto, S., Ramadhanty, C. A., & Subali, B. (2023). Guided inquiry learning model using scientific argumentation activities to improve concept understanding on optical and light. *Jurnal Pendidikan Fisika Indonesia, 19*(1), 55–64. https://doi.org/10.15294/jpfi.v19i1.36626

Robertshaw, B., & Campbell, T. (2013). Constructing arguments: Investigating pre-service science teachers' argumentation skills in a socio-scientific context. *Science Education International, 24*(2), 195-211.

Saido, G., Siraj, S., DeWitt, D., & Al-Amedy, O. S. (2018). Development of an instructional model for higher order thinking in science among secondary school students: A fuzzy Delphi approach. *International Journal of Science Education, 40*(8), 847-866. https://doi.org/10.1080/09500693.2018.1452307

Sampson, V., Grooms, J., & Walker, J. P. (2011). Argument-Driven Inquiry as a way to help students learn how to participate in scientific argumentation and craft written arguments: An exploratory study. *Science Education, 95*(2), 217-257. https://doi.org/10.1002/sce.20421

Santos, M., Maia, P., & Justi, R. (2020). A model of science to base the introduction of aspects of nature of science in teaching contexts and to analyse such contexts. *Revista Brasileira De Pesquisa Em Educação Em Ciências, 20*(u), 617-651. https://doi.org/10.28976/1984-2686rbpec2020u617651

Santrock, J. W. (2011). *Educational psychology* (6th ed.). New York: MC Graw Hill Education.

Schleigh, S. P., Bosse, M., & Lee, T. (2011). Redefining curriculum integration and professional development: In-service teachers as agents of change. *Current Issues in Education, 14*(3), 1–14.

Schunk, D. H. (2012). *Learning theorie: An educational perspective* (6th ed.). Boston, MA: Pearson.

Schuster, D., Cobern, W. W., Adams, B. A., Undreiu, A., & Pleasants, B. (2018). Learning of core disciplinary ideas: Efficacy comparison of two contrasting modes of science instruction. *Research in Science Education, 48*(2), 389-435. https://doi.org/10.1007/s11165-016-9573-3

Sengul, O., Enderle, P. J., & Schwartz, R. S. (2020). Science teachers' use of argumentation instructional model: Linking PCK of argumentation, epistemological beliefs, and practice. *International Journal of Science Education, 42*(7), 1068-1086. https://doi.org/10.1080/09500693.2020.1748250

Songsil, W., Pongsophon, P., Boonsoong, B., & Clarke, A. (2019). Developing scientific argumentation strategies using revised argument-driven inquiry (rADI) in science classrooms in Thailand. *Asia-Pacific Science Education*, *5*(1), 1-22. https://doi.org/10.1186/s41029-019-0035-x

Stender, A., Schwichow, M., Zimmerman, C., & Härtig, H. (2018). Making inquiry-based science learning visible: The influence of CVS and cognitive skills on content knowledge learning in guided inquiry. *International Journal of Science Education*, *40*(15), 1812-1831. https://doi.org/10.1080/09500693.2018.1504346

Sugianto, I., Suryandari, S., & Age, L. D. (2020). The effectiveness of the inquiry learning model on student learning independence at home. *Jurnal Inovasi Penelitian*, *1*(3), 159-170. https://doi.org/10.47492/jip.v1i3.63

Toulmin, S. (2003). *The uses of argument*. Cambridge: Cambridge University Press.

Utomo, Y. S. (2019). *Argumentation skills profile on 8th grade students using Toulmin's argument pattern on controversial topic*. Paper presented at the Journal of Physics: Conference Series.

Wajdi, M., Jamaluddin, A., Bin, N. N., & Magfirah, N. (2022). The effectiveness of problem-based learning with environmental-based comic in enhancing students environmental literacy. *International Journal of Evaluation and Research in Education*, *11*(3), 1049-1057.

Widhi, W., Hakim, A. R., Wulansari, N. I., Solahuddin, M. I., & Admoko, S. (2021). Analysis of students' scientific argumentation skills in the learning model based on Toulmin's Argumentation Pattern (TAP) in understanding physics concepts using the library research method. *PENDIPA Journal of Science Education*, *5*(1), 79–91. https://doi.org/10.33369/pendipa.5.1.79-91

Widodo, A., Waldrip, B., & Herawati, D. (2016). Students argumentation in science lessons: A story of two research projects. *Jurnal Pendidikan IPA Indonesia*, *5*(2), 199-208.

Widoyoko, E. P. (2009). *Evaluation of learning programs: A practical guide for educators and prospective educators* (4th ed.). Yogyakarta: Pustaka Pelajar.

Wikara, B., Sutarno, S., Suranto, S., & Sajidan, S. (2022). Implementation of 5E plus learning model on energy subject matter to improve students' argumentation skills. *Jurnal Pendidikan IPA Indonesia*, *11*(2), 237–245. https://doi.org/10.15294/jpii.v11i2.30567

Wong, D., & Pugh, K. (2014). *Dewey and the learning of science. In: Gunstone, R. (Eds.), Encyclopedia of Science Education*. Dordrecht: Springer.

Yacoubian, H. A., & BouJaoude, S. (2010). The effect of reflective discussions following inquiry-based laboratory activities on students' views of nature of science. *Journal of Research in Science Teaching*, *47*(10), 1229-1252. https://doi.org/10.1002/tea.20380

Yilmaz, Y. Ö., Cakiroglu, J., Ertepinar, H., & Erduran, S. (2017). The pedagogy of argumentation in science education: Science teachers' instructional practices. *International Journal of Science Education*, *39*(11), 1443–1464. https://doi.org/10.1080/09500693.2017.1336807

Yore, L. D., Pimm, D., & Tuan, H.-L. (2007). The literacy component of mathematical and scientific literacy. *International Journal of Science and Mathematics Education*, *5*(4), 559-589. https://doi.org/10.1007/s10763-007-9089-4

Zhang, J., & Browne, W. J. (2023). Exploring Chinese high school students' performance and perceptions of scientific argumentation by understanding it as a three-component progression of competencies. *Journal of Research in Science Teaching*, *60*(4), 847-884. https://doi.org/10.1002/tea.21819