



## Scientific Argumentation in Chemistry Education: A Literature Review of Practices, Challenges, And Solutions

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### Abstract:

This study presents a systematic literature review (SLR) on students' scientific argumentation skills in chemistry education, focusing on practices, challenges, and potential solutions. Articles selected were sourced from the Scopus database using Publish or Perish (PoP) and published within the period of 2015-2024. Some of the notable issues identified in this review relate specifically to limited teacher preparation and low student engagement, which hinder the development of argumentation skills. Effective instructional models, strategies, and media that promote argument-driven learning are crucial according to these findings. Also, enhancing these specific skills requires targeted teacher training, curriculum integration of argumentative practices, and supportive classroom environments that cultivate inquiry-based learning and critical thinking. Generally, it sheds light on the importance of valid assessment tools to evaluate students' argumentation skills. Thus, strengthening these skills is essential for classroom members. Not only for acquiring a better understanding of chemical concepts but also for promoting scientific literacy as well as informed decision-making in broader societal contexts.

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## Introduction

Education is a process that continues to develop and evolve. When this shift occurs in today's learning, it means that students have been directed and prepared to live in the 21st century. This era demands a set of critical skills from students - critical thinking, problem-solving, communication, collaboration, creativity and innovation. On top of that, other skills also need to be mastered, such as skills in expressing opinions or arguing (AACTE, 2010).

Scientific argumentation is portrayed as a preparation that incorporates a few skills, including distinguishing proof, the mental capacity to recognize counterarguments, and the capacity to invalidate them sensibly (Songsil, Pongsophon, Boonsoong, & Clarke, 2019). Argumentation skills refer to a person's capability to logically construct and present opinions, using persuasive techniques to influence others' beliefs or actions (Ekanara, Adisendjaja, & Hamdiyati, 2018). The Partnership for 21st Century Skills (P21) also emphasizes that argumentation enhances a person's ability to communicate, think analytically and creatively, as well as tackle challenges, all of which are integral to 21st-century skills (Nakano & Wechsler, 2018).

Notably, constructing scientific arguments is closely tied to critical thinking and communication skills, both of which are key components of the 21st-century skills that students must develop. Thus, it means that scientific argumentation skills are also part of the core competencies of 21st-century skills (Hasnunidah et al., 2020; Karadeniz & Universitesi, 2016; Roviati & Widodo, 2019). Argumentation will prepare students with the capacity to defend their information, claims, and concepts and secure them from fallacious considerations. Songsil et al. (2019) contend that scientific argumentation abilities can equip students with the capacity to use reasoning to resolve socio-cognitive clashes. In other words, argumentation is crucial for advancing, assessing and evaluating logical information and it is a fundamental skill that creates science distinctive from other ways of knowing (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Hogan & Maglienti, 2001; Sandoval, 2003).

According to the NGSS Lead States (2013), engaging in arguments supported by evidence is a crucial practice in both science and engineering. In this manner, the System for K-12 Science Education serves as a platform for emphasizing that students learn to argue from evidence. Argumentation and examination, which interface proof and hypothesis, are fundamental aspects of science. At this point, researchers must be able to examine, audit, and assess their claim information and concepts, as well as critique the claims and concepts of others.

Extending this idea to chemistry learning, which is frequently referred to as a central science due to its ability to link different fields of study. In educational settings, chemistry teaching instruction requires students to acquire chemical concepts in a systematic order. It aims to develop a scientific mindset, which includes a critical perspective on scientific claims that should not be readily accepted without observational evidence. For instance, understanding chemical concepts and applying these to solve problems in everyday life. Likewise, skills in argumentation are crucial for learning chemistry as they help students convey and defend their opinions based on scientific evidence. With these skills, students can understand concepts more

deeply and are better prepared to face real-world challenges that require logical and scientific problem-solving (F. Gazali, Rahayu, Munzil, & Wonorahardjo, 2024).

Essentially, argumentation skills can be improved and mastered by students if they are regularly practiced during the learning process (Inkomara & Suyono, 2023). However, in fact, many students still lack an understanding of these skills and are rarely trained. The reason why students' argumentation skills are not optimal is that they have not implemented student-centered learning (Hardini & Alberida, 2022). Training in this area is necessary to meet the needs of the 21st century, which calls for a student-centered learning process, allowing students to analyze problems in learning according to relevant facts and evidence (Farida, Rosidin, Herlina, & Hasnunidah, 2018).

As a result, argumentation skill is quite necessary in chemistry education since it fosters students' critical thinking, scientific reasoning, and understanding of complex chemical concepts. They also learn how to construct and evaluate arguments logically through structured discussions and debates, which will later support their academic progress and everyday success. This particular skill also encourages collaborative learning, where students share ideas and challenge each other's viewpoints, as well as model real-world scientific practices (Loureço, Ferreira, & Queiroz, 2016).

However, poor argumentation skills can create issues in real-life situations, particularly when making decisions about the use of chemical products. To illustrate, a person who lacks strong argumentation skills is not able to critically assess the risks of pesticide use, thereby ignoring their impact on the environment and health. Similarly, consumers are misinformed by misleading advertisements about chemicals in food or household cleaners if they neglect the aforementioned skills. Indeed, teachers play a vital role in the skill application within the classroom, yet many feel unprepared due to a lack of resources and training. Therefore, strengthening argumentation skill in this field, coupled with professional support for teachers, is an important step in equipping students to face real-world chemistry challenges (Bambut & Rahayu, 2020; Do Vale, Batinga, & Do Nascimento Firme, 2023).

After all, incorporating argumentation into chemistry learning requires more than just a natural process, as it demands careful organization and design. Teachers need to help students learn how to construct and substantiate arguments, as well as critically evaluate or respond to others' arguments using suitable teaching models. Moreover, teachers should develop learning activities that encourage students to discuss and articulate their opinions in problem-solving contexts. The learning environment within the classroom is outlined to empower students to communicate with each other by debating to justify or invalidate explanations based on science (F. Gazali et al., 2024).

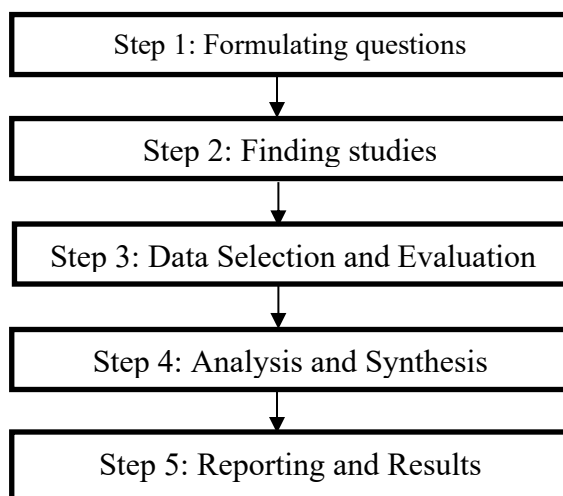
To show novelty in research and provide solutions in chemistry learning, this study was conducted to examine the importance of scientific argumentation skills, identify obstacles, and explore potential solutions for developing such skills in chemistry education. The findings are expected to provide practical and theoretical implications for improving teaching strategies, enhancing teacher competences, and promoting students' critical thinking and scientific literacy. This study also implies the

need for assessment tools that can validly measure students' argumentation skills, as well as classroom environments that promote inquiry, dialogue, and critical thinking.

Prominently, improving students' scientific argumentation skills enables them to gain a profound understanding of chemical concepts and make informed decisions in scientific and societal contexts. To maintain the relevance of this study and its reflection on recent trends in curriculum reform, digital learning integration, and 21st-century skills, only studies published within a ten-year literature range (2015-2024) and methodologically thorough studies were included. This time frame allows the review to capture sustained patterns and emerging innovation in the discussion above, providing a comprehensive basis for addressing current challenges and serving as a stepping stone for future studies.

### Research Method

This study employed the Systematic Literature Review (SLR) method to examine and identify effective practices in teaching scientific argumentation skills in chemistry classes. Moreover, to analyze the primary challenges faced by teachers and students in developing these skills and propose solutions. The data sources comprised scholarly articles from numerous journals spanning over 10 years. Given these points, the scope of the review is presented in Table 1 and the steps involved in conducting the SLR method are illustrated in Figure 1.



**Figure 1. Five Steps of the Systematic Literature Review (SLR)**

**Table 1. Parameters Studied**

Parameter	Definition
Identify key challenges	Looking at the main challenges in developing scientific argumentation skills
Models, approaches, methods and media in chemistry learning	To see the practices carried out as a solution in developing scientific argumentation skills

Step 1: Formulating questions

Identifying the scope in order to establish a distinct study topic is the first step that needs to be taken. The research questions in this study were designed to match the topic's needs:

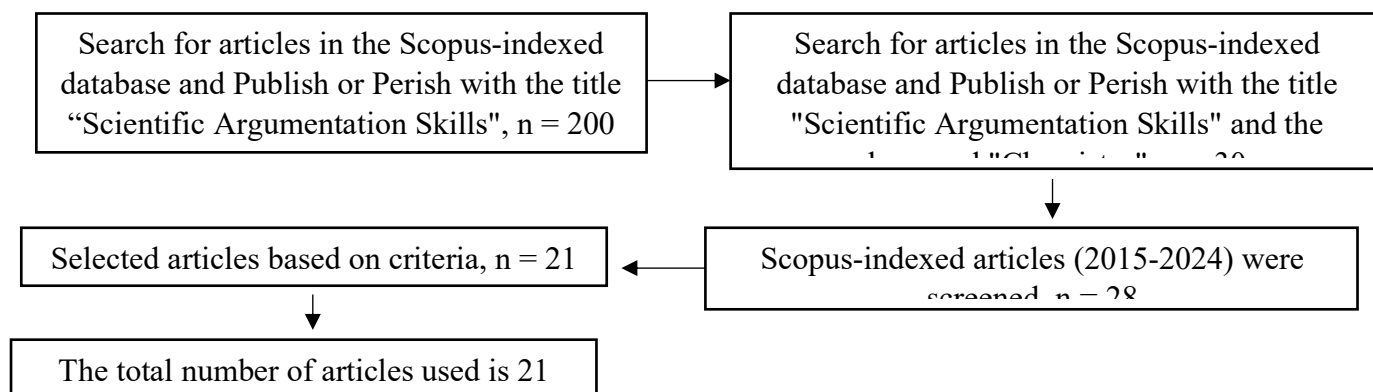
- What are the challenges faced by the teachers in developing scientific argumentation skills?
- How are the practices of applying models, approaches, methods, and media as solutions to develop scientific argumentation skills in chemistry learning?

### Step 2: Finding studies

This study focuses on the development of scientific argumentation skills in chemistry learning in terms of identifying challenges and solutions. The selected keywords were used to retrieve SCOPUS-indexed articles published between 2015 and 2024. This publication window reflects the emerging trends in learning approaches, educational technology, and curriculum policies in the past 10 years. In addition, this particular discussion on scientific argumentation in chemistry education has significantly evolved in the last decade, integrating with STEM, digital tools, and argument-driven inquiry (ADI) approaches. It is a common standard in the Systematic Literature Review (SLR) to cover a period of 5-10 years in study selection for ensuring data quality and avoiding excessive or outdated data processes. With this in mind, the search process was conducted on November 2<sup>nd</sup>, 2024 through the SCOPUS database with the assistance of Publish or Perish, which the articles were then saved and synchronized with Mendeley.

### Step 3: Data Selection and Evaluation

This stage is intended to assess whether the data obtained is suitable and relevant for inclusion in the SLR study. To align with this research objectives, several inclusion criteria are applied to the article selection phase: (1) papers exploring scientific argumentation skills within chemistry learning experience; (2) several papers published from 2015-2024; (3) SCOPUS-indexed journal articles; (4) full-text articles available through open access. Then, this type of systematic literature review was conducted using the PRISMA approach. The flowchart of the PRISMA method is depicted in Figure 2 (Primadianningsih, Sumarni, & Sudarmin, 2023).



**Figure 2. Article Screening Process based on Inclusion Criteria**

#### Step 4: Analysis and Synthesis

Following the selection of articles, the next step involves synthesizing the information by analyzing and assessing the research results from different studies based on the established parameters. The data synthesis is visualized in graphical form. In this research, the synthesis was carried out by analyzing studies that satisfied the quality assessment along with the inclusion and exclusion criteria. The aim of this synthesis is to map research topics related to scientific argumentation skills in chemistry learning.

#### Step 5: Reporting and Results

The reporting stage is the final stage in a systematic literature review which includes presenting and explaining the results.

### Results and Discussion

The research results were obtained from several journals reviewed, resulting in several interrelated discussions. The results and discussions include challenges in developing scientific argumentation skills and looking at practices carried out as solutions in developing scientific argumentation skills.

#### *Challenges in developing scientific argumentation skills*

The low level of students' argumentation skills is caused by the fact that it is still difficult for students to construct good arguments (Driver, Newton, & Osborne, 2000). Specifically, students' scientific argumentation skills are still limited to providing correct claims, while they have not yet mastered the ability to present sound arguments and explanations (Sulistina, Rahayu, Dasna, & Yahmin, 2024). By all means, scientific argumentation skills are central to advanced cognitive processes and logical reasoning, essential for both personal thought and for grappling with scientific problems that affect society (Al-Ajm & Ambusaidi, 2022). However, the development of scientific argumentation skills still faces many challenges. Students often have difficulty connecting evidence to claims logically, so that the arguments they construct are less strong. The challenges faced in the process of developing scientific argumentation skills are presented in Table 2.

**Table 2. Challenges in Developing Scientific Argumentation Skills**

Author (year)	Article title	Information
Sulistina et al. (2024)	Enhancing the Scientific Argumentation Skills of Prospective Chemistry Teachers Using Integrated Chemical Literacy Strategies.	In its development, the challenges faced include the need for teacher training in delivering logical argumentation skills and the necessity of integrating these skills into explicit instructions. Moreover, only around 10% of science teachers present science as a discipline that requires evaluating ideas for their validity.
Al-Ajm & Ambusaidi (2022)	The Level of Scientific Argumentation Skills in Chemistry Subject among Grade 11th Students: The Role of Logical Thinking	Scientific argumentation skills remain challenging to develop due to the lack of attention and opportunities for learning. Chemistry learning that is often performed is still not aligned with the teaching objectives, which have a broad scope. This is what prevents students' argumentation skills from developing.
A. Gazali et al. (2015)	Profile of The First Year Student's Argumentation Skills on General	Argumentation skills in chemistry learning do not occur naturally. In fact, the challenges in



	Chemistry Courses at a Public University in West Sumatra: A Preliminary Study	fostering these skills often stem from the teachers themselves. As educators, teachers must be able to create pedagogical contexts that are able to promote and support knowledge construction through argumentation by applying certain learning models.
Duhita et al. (2021)	The Validity of the Internalized Argumentation Skills Test for Chemistry Students	The development of argumentation skills faces a number of challenges, including the need for a structured teaching approach, so that these skills can be effectively integrated into students' cognitive schemas.
Laily et al. (2020)	Learning Buffer Solution through Modified POGIL Justified by Student's Scientific Argumentation Skills.	A key challenge in developing scientific argumentation skills is the difficulty in adopting an approach that integrates investigation. Additionally, the lack of administrative support, teacher expertise, and differences in teachers' perceptions of students further complicates this process.
Hosbein et al. (2021)	Tracking Student Argumentation Skills across General Chemistry through Argument-Driven Inquiry Using the Assessment of Scientific Argumentation in the Classroom Observation Protocol	The challenge of developing scientific argumentation skills can come from the students themselves. Students often fail to focus on three aspects, namely cognitive, epistemic and social. This prevents the scientific argumentation skills of the students from fully developing.

The development of scientific argumentation skills encounters significant challenges. One of the main challenges is the lack of teacher preparation for teaching this skill, as well as the lack of explicit integration of argumentation skills in the learning process. Although chemistry should be taught as knowledge that requires proof of truth, only about 10% of teachers implement this approach (Sulistina et al., 2024). In addition, limited administrative support and insufficient teacher knowledge, as well as teacher perceptions of students also hinder the development of these skills.

From the student's perspective, difficulties in focusing on cognitive, epistemic, and social aspects are factors that hinder the development of optimal scientific argumentation skills (Hosbein et al., 2021). Therefore, a structured teaching approach, learning model, strategy, or appropriate media are necessary to establish an environment conducive to fostering scientific argumentation skills in chemistry education.

### *Models, approaches, strategies and media in chemistry learning*

To develop scientific argumentation skills, students and teachers must engage in two-way interactions, rather than just relying on teacher-centered instruction. In this regard, argumentation skill allows students to develop the ability to analyze, advocate, dispute and critique ideas during the scientific discussion process, which in turn deepens their understanding of scientific concepts, such as the concept of acids and bases in the context of this study (Karpudewan, Michael Roth, & Sinniah, 2016).

Argumentation activities driven by inquiry will further enhance conceptual understanding and skills needed to build a more comprehensive understanding of chemical concepts. Each student is expected to be able to make claims based on the

knowledge they have learned, support them with evidence, and provide logical explanations (Laily et al., 2020). This set of activities will also provide students with the ability to refine the information they receive or encounter while interacting with peers or within social media (Aldahmash & Omar, 2021). It is indeed possible to sustain this increase level of activity by student-centered learning. It can be achieved by utilizing learning models, approaches, strategies or learning media that support argumentation activities.

Then, learning models are used to describe imagination and conceptualization of certain phenomena. In scientific practice, models are utilized to explain and represent systems or phenomena, gather evidence, develop claims, answer inquiries, make predictions, and engage in argumentation with peers (Chen, 2020). The application of learning models that can help develop scientific argumentation skills is presented in Table 3.

**Table 3. Learning Models that Can Improve Scientific Argumentation Skills**

Author (year)	Article title	Information
Hosbein et al. (2021)	Tracking Student Argumentation Skills across General Chemistry through Argument-Driven Inquiry Using the Assessment of Scientific Argumentation in the Classroom Observation Protocol	The implementation of the Argument-Driven Inquiry (ADI) learning model has demonstrated a clear improvement in argumentation skills after continuous exposure to the argumentation process. Significant advancements were observed in all three subcategories of the ASAC observation protocol: cognitive, epistemic, and social.
Arslan et al. (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.	The application of the Argument-Driven Inquiry (ADI) learning model has been proven to promote the understanding of examination and argumentation, as well as to make positive impacts on the implementation of science instruction and examination, and leading to intended improvements in future science classes.
Putri, Munzil, & Sumari (2021)	Developing Multiple Representation's Teaching Materials Assisted by Blended Learning to Enhance Students' Scientific Argumentation Skills.	Multiple representations combined with the blended learning model have been proven to improve scientific argumentation skills. This increase is due to the fact that in the online session, students are given a phenomenon, while in the offline session, students' arguments will be tested. This type of learning has been shown to build students' knowledge of the concepts being studied.

The learning model is used to develop arguments for debating, defending, and refuting ideas in within their community. Various studies have demonstrated that Argument-Driven Inquiry (ADI)-based learning models and blended learning are effective in enhancing students' scientific argumentation skills. Research by Arslan et al. (2023) and Hosbein et al. (2021) revealed that repeated application of the ADI significantly improved students' argumentation skills in cognitive, epistemic, and



social aspects. Additionally, the ADI helped deepen their understanding of the scientific inquiry process and foster a positive attitude towards argumentation-based teaching methods that can be applied in future science classes. Meanwhile, the study by Putri et al. (2021) showed that the use of multiple representation-based teaching materials combined with blended learning can strengthen students' scientific argumentation skills. Thus, the ADI and blended learning approaches not only improve scientific argumentation skills, but also help students and prospective teachers to understand the scientific process and build positive attitudes towards the application of argumentation-based learning.

The role of learning approaches in developing scientific argumentation skills is also no less important than the role of learning models. In current reality, more teachers apply learning approaches than learning models. This is due to the fact that learning approaches are based on philosophical concepts and didactic methods in teaching (Aflalo & Gabay, 2013). This represents the learning goals and approaches that focus on knowledge development, iterative processes, application, understanding, perspective-taking, and the cultivation of thinking skills. Learning approaches that can help develop scientific argumentation skills are shown below in Table 4.

**Table 4. Learning Approaches that Can Improve Scientific Argumentation Skills**

Author (year)	Article title	Information
Nurdiyanti et al. (2020)	Learning Electrochemistry with A Modified Writing to Teach Approach to Enhance Student's Argumentation Skills	The implementation of the Writing to Teach (WtT) approach can help students to ace the concepts since they will obtain information that can reinforce or idealize their information through composing and peer learning exercises. This study findings indicated that students utilized the learning stages of the WtT approach to assist them in enhancing their argumentation skills.
Bambut & Rahayu (2020)	The Patterns of Discussion in Teaching Argumentation Skills in Chemistry Learning	Chemistry learning, when applied through the Socio-Scientific Issues (SSI) approach has been proven effective in improving students' argumentation skills. The SSI approach encourages students to participate in scientific dialogues regarding important social topics, enabling them to sharpen their critical thinking skills as well as their abilities to logically formulate and support arguments.
Effendi-Hasibuan et al. (2020)	Skills to Argue: Using Argument-based Learning (AbL) and Socio-Scientific Issues to Promote University Students' Argumentation Skills in Chemistry	Applying the Argument-Based Learning approach alongside SSI topics revealed that ABL students have a notably superior argumentation scale, significantly outperforming students in other classes.
Uzuntiryaki-Kondakci et al. (2021)	The Role of the Argumentation-Based Laboratory on the Development of Pre-service	The approach used in this study is the Science Writing Heuristic (SWH). This approach is used as an argument-based

	Chemistry Argumentation Skills	Teachers'	approach in the laboratory and has been shown to significantly improve the teachers' argumentation skills over the course of one semester.
Fitria et al. (2023)	Analysis of Students' Argumentation Skills towards Socio-Scientific Issues in Chemistry Learning		The application of the SSI approach can specifically trigger or impact argumentation skills. So, this is a consideration point for investigating students' argumentation skills towards SSI. The results of this study showed that the students' argumentation skills are at levels 3 and 4.

Argumentation-based approaches, such as Writing to Teach (WtT), Socio-Scientific Issues (SSI), Argument-Based Learning (AbL), and Science Writing Heuristic (SWH) are effective in improving students' argumentation skills, especially in chemistry learning. Chemistry learning that integrates local SSI will seem more relevant to students' lives, hence making it easier for them to convey accurate scientific arguments. The application of SSI allows students to engage in discussions about relevant social issues, refining their critical thinking skills and argumentative logic. (Fitria et al., 2023). The SSI can also be combined with other learning approaches, such as Argument-Based Learning (AbL) and Science Writing Heuristic (SWH) and has also been shown to be effective in improving 21st century skills.

Improving argumentation skills is not only through learning that uses learning models and approaches. The use of suitable and ideal learning strategies can also improve scientific argumentation skills. In general, learning strategies can be a person's approach to learning and using data. Students utilize learning strategies to assist them in obtaining data and understanding complex issues. Therefore, learning strategies are applied in the learning process with the aim of helping students to become more active learners by teaching them how to memorize and how to apply what they have learned to succeed (University of Kansas, 2009). The application of learning strategies that can help develop scientific argumentation skills is depicted in Table 5.

**Table 5. Learning Strategies to Improve Scientific Argumentation Skills**

Author (year)	Article title	Information
Rusmini et al. (2024)	Effectiveness of the Connected Learning Cycle (CLC) for Training Scientific Literacy Skills and Argumentation Skills in Prospective Chemistry Teacher Students	The application of the Connected Learning Cycle (CLC) strategy combined with the 5E cycle has been proven effective in training students' scientific argumentation skills.
Sulistina et al. (2024)	Enhancing the Scientific Argumentation Skills of Prospective Chemistry Teachers Using Integrated Chemical Literacy Strategies	The use of the Integrated Chemical Literacy Strategy (ICLS) offers a significant contribution to the improvement of students' scientific argumentation skills.
Effendi-Hsb et al. (2019)	Promoting Indonesian Secondary School Students'	The implementation of learning using cooperative strategies, such as the jigsaw

	Argumentation Skills in The Concept of Chemistry Reaction-Rate: A Comparative Effect Of Three Cooperative Learning Strategies	and two-stay-two-stray (TSTS), has been proven to provide students with valuable openings to lock in in-depth discussions. It is highly recommended to foster students' skills progress in logical argumentation.
Masbakhah et al. (2019)	Analysis of Students' Argumentation Skills in Chemistry Class of Grade XI through Product Life-Cycle Analysis Assessment on Colloid Lesson	The application of the Life-Cycle Analysis (LCA) strategies in chemistry education has been demonstrated to boost students' scientific argumentation skills, with particular emphasis on ecological and socio-economic factors.
Septyastuti et al. (2021)	The Effectiveness of Inquiry-Based Learning with OE3R Strategy for Scientific Argumentation Skills	The OE3R (Orientation-Exploration-Explanation-Elaboration-Reflection) strategy yielded results in the quality of scientific argumentation, indicating that students in the experimental class demonstrated a higher increase in scientific argumentation skill scores due to its application.
Saija et al. (2023)	The Effect of Chemistry Instruction Strategy Contextualized by Local SSI-OE3C on the High School Students' Argumentation Skills	Learning strategies can also be integrated with science-related issues such as SSI. The use of the SSI-OE3C learning strategy has a considerable impact on students' proficiency in scientific argumentation, with a high effect size.

Learning strategies, particularly those based on inquiry and cooperative learning, have proven effective in enhancing students' scientific argumentation skills. The Connected Learning Cycle (CLC) strategy which is integrated with the 5E cycle, and the strategies of ICLS, has proven to have a significant influence in training scientific argumentation skills. In addition, the Life-Cycle Analysis (LCA) approach and cooperative strategies, such as jigsaw and two-stay-two-stray help students to engage in intense debate and improve argumentation, especially on ecological and socio-economic aspects.

Notably, cooperative learning is a term used to describe a series of learning strategies designed to foster cooperation and group interaction among students. This strategy highlights social engagement as a means to facilitate cognitive growth (Ilmi, Janah, & Subroto, 2019). While cooperative learning strategies can enhance students' abilities in argumentation, few are aware of which specific cooperative learning strategies are the most effective in developing these skills.

Inquiry learning emphasizes the activities students engage in to discover their own experiences and understanding. Majid (2013) suggests that learning activities should guide students in seeking and identifying their own solutions to pose questions or problems, which is expected to enhance their self-confidence. The combination of learning with cooperative and inquiry-based strategies can strengthen students' learning processes by involving them actively and collaboratively in investigations and problem-solving. Certainly, in this strategy, students work in small teams with different roles to investigate a problem or question in-depth, ensuring the involvement of all students in every stage of the investigation. This approach allows students to ask

questions, share ideas, discuss solutions, and compare their findings, thereby deepening understanding through positive social interactions.

Similarly, learning media also plays an important role in developing scientific argumentation skills. In this regard, by providing sources of information and real-world phenomena that can be used as materials to train critical thinking and argumentation skills (Duhita et al., 2021). Likewise, media serves as a stimulus for discussion, encouraging students to formulate claims and evidence based on the information presented. Through exposure to various claims, media trains students to conduct critical analysis to evaluate the truth of the information they receive.

Suyono et al. (2021) in their research, have proven that the use of teaching media, such as videos can boost students' argumentation skills. The researchers selected viral videos from social media containing chemical content and analyzed the claim statements in these videos. The assertions were subsequently used to create a tool for evaluating students' skills in argumentation. These videos were chosen as the learning medium since it seemed more interesting and relevant to everyday phenomena, which encourage students to argue based on scientific evidence. Videos allow students to practice identifying, supporting, or rejecting claims through the construction of arguments and counterarguments.

The use of viral videos as a learning medium involves examining chemical claims that are either true or false, which are then analyzed to determine the validity of the claims. Then, students are asked to evaluate the claims by accepting or rejecting them, collecting supporting data, and providing explanations for their decisions. In this activity, learners work on utilizing scientific data to back up their claims, while also enhancing their critical thinking skills and argumentation capabilities (Duhita et al., 2021).

Based on the literature review conducted in this study, the direction of future research in scientific argumentation in chemistry education should shift from simply identifying problems to designing and implementing sustainable and integrated pedagogical solutions. This review revealed that the primary barriers to developing students' argumentation skills are teachers' lack of preparation and low student engagement. What is even more challenging is the issue of limited integration of argumentation practices into regular classroom instruction. Thus, future research should move beyond descriptive analyses, but towards intervention-based studies that develop, test, and refine learning models, such as Argument-Driven Inquiry (ADI), Socio-Scientific Issues (SSI), and blended learning in actual classroom settings.

Furthermore, there is an increasing demand to explore how instructional media, particularly digital tools and phenomenon-based videos, can be used to contextualize argumentation within students' everyday experiences. Prospective research should also investigate teacher training models that focus specifically on argumentation facilitation skills. Moreover, it is expected to develop and validate assessment instruments that measure not only students' claims, but also the epistemic and social dimensions of their arguments. In the phase of synthesizing the literature, this study provided a roadmap: from understanding barriers to actively building a classroom ecosystem that fosters in-depth, evidence-based scientific discourse.

## Conclusion

Scientific argumentation skills are processes that include several skills, such as identifying evidence, the mental ability to recognize counterarguments, and the ability to refute them reasonably. Overall, this study outlined the challenges in developing students' argumentation skills, namely the lack of teacher preparation in teaching these skills and students who are less focused on learning. For these reasons, proper learning media, strategies, approaches, and models are needed in chemistry learning. It is suggested that by implementing suitable learning approaches and models, the students' scientific argumentation skills can be fostered even better. However, this systematic review is subject to several drawbacks, including a limited focus on contexts and populations, variations in teacher competencies, and potential bias in the data used. As a result, future studies are recommended to address the long-term effects of various learning models in a broader context, establish more comprehensive teacher training programs, and utilize interactive technology to increase student focus and engagement in the classroom. A mixed research approach is also recommended to gain a deeper understanding of the process of developing scientific argumentation skills in chemistry learning.

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