



The Design Thinking to Improving on Scientific Argumentation Skills: A Systematic Literature Review

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Abstract: Students scientific argumentation skills remain relatively low, posing both global and national educational challenges that require innovative solutions. Effective learning methods to foster these skills are still limited and not yet optimal. This study aimed to identify research trends in the application of design thinking in learning, the learning outcomes achieved, the subjects most frequently using design thinking, and its contribution to developing scientific argumentation skills. The method used in this study is the Systematic Literature Review (SLR) with PRISMA analysis of 20 relevant articles. The articles were obtained from two databases, namely Google Scholar and PubMed with a publication range between 2020 - 2025. The article selection process was carried out to collect, analyze and compile findings on the application of the design thinking method in learning. The findings of the Systematic Literature Review show that the most dominant research trend uses quantitative methods. Design thinking has a positive impact on creativity, critical thinking skills, learning outcomes, numeracy, learning interest, motivation, and scientific attitudes. Design thinking tends to be applied more in the context of science learning, especially in science and biology subjects. In addition, design thinking not only increases student engagement and creativity, but also significantly trains and strengthens scientific argumentation skills which are essential in science learning.

Keywords: Design thinking; PRISMA; Science education; Scientific argumentation skills; Systematic literature review

Introduction

Scientific argumentation skills are the key to unlocking critical thinking and evidence-based decision-making. Psychologists view argumentation as involving high-level thinking skills, so critical thinking needs to be developed (Giri & Paily, 2020). Scientific argumentation skills are skills needed by students in the modern era to achieve success in academics, careers, and personal lives (Haug & Mork, 2021; Noviyanti et al., 2019; Lobczowski et al., 2020; Noroozi et al., 2020). A Scientific argumentation skill play an important role in shaping scientific thinking and supporting active participation in

the science learning process. In addition, argumentation skills are considered to have an important role in developing students' knowledge and an important step for the nature of science (Wahyunan Widhi et al., 2021; Allchin & Zemplén, 2020; Henderson et al., 2017; Ho et al., 2019). In line with that, scientific argumentation skills also help students develop critical thinking skills in examining information and reasons in depth, and become important provisions for students in making wise decisions regarding issues that develop in society (Öztürk & Doğanay, 2019; Songsil et al., 2019). PISA has three competencies that are much more process-oriented: (1) identifying scientific issues, (2) explaining

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phenomena scientifically, and (3) using scientific evidence (Ho et al., 2019). PISA identifies argument from evidence as a key cognitive technique that serves as the basis for developing scientific understanding and forming holistic knowledge in science (Henderson et al., 2017; OECD, 2022). Furthermore, the ability to construct statements based on evidence or as scientific argumentation skills is considered essential because it allows theories and findings to be retested, increases the level of scientific literacy, and encourages effective problem solving. Through this skill, the progress and development of science can be achieved. Therefore, it is important for students to be facilitated in developing this skill through classroom learning (Hendratmoko et al., 2023; Ping et al., 2020).

Theoretically, scientific argumentation skills are closely related to critical thinking. In line with what has been stated (Christodoulou & Diakidoy, 2020) scientific argumentation skills are strongly related to critical thinking because they require students to construct arguments logically and strengthen them with relevant evidence. Scientific argumentation skills are formed by two components of critical thinking. The first component of critical thinking is an evaluation of evidence-based knowledge using epistemic standards to assess claims. The second component is finding reasons for claims and rejecting authority as the only basis for truth. (Aleixandre & Blanca, 2012; Sinatra & Lombardi, 2020). In Toulmin's framework, constructing an argument is not just about making statements and providing reasons but there are six important elements that are interrelated, namely claims are statements that you want to convey, claims need to be supported by data, namely relevant evidence, or facts, so that the relationship between data and claims becomes clear, justification is needed to provide logical reasons that connect the two. Justification can be strengthened with support for justification in the form of a theoretical basis or principle that makes the justification. In addition, Toulmin suggests a modal qualification to show the extent to which a claim can apply and finally a good argument needs to consider rebuttals. This is what helps to form arguments that are logical, strong and open to discussion (Yang, 2022; Zarębski, 2024).

One of the skills that plays an important role in the field of science is scientific argumentation skills, but it is still rarely applied in the science learning process. Research conducted by Al-Ajmi and Ambusaidi (2022) showed that the scientific argumentation skills of grade 11 students in Oman were classified as moderate. This is due to the lack of implementation of scientific argumentation-based learning and the limitations of teachers in developing scientific argumentation skills. Meanwhile, the results of research on the Assessment of Scientific Argumentation Competence (SAC) in some

areas in China showed that scientific argumentation skills were still relatively low. This is due to the lack of clear instructions, not integrated into learning, and minimal practice and discussion opportunities (Zhang & Browne, 2022). In line with this, the results of an experimental study conducted by Demircioğlu (2016) in Turkey revealed that scientific argumentation skills were still low before being given treatment. This is due to the lack of access to information obtained and the lack of individual knowledge. The low scientific argumentation skills in various countries such as Oman, China, and Turkey reflect that this problem is global. Similar problems are also experienced by students in Indonesia.

The reality in Indonesian shows that scientific argumentation skills are still low. This is supported by several reports of scientific argumentation skills that have been conducted, stating that the argumentation skills of class VII of SMP Negeri 62 Surabaya on the subject of global warming are still low at levels 1 and 2 (Zairina & Hidayati, 2022). In line with that, SMA Negeri Sukabumi Regency in class XI showed that the quality of students' arguments was still low. Most students are still at level 1 with the highest percentage being 38% (Rahayu et al., 2020). Furthermore, the results of a study conducted at the high school level in Subang explained that students' scientific argumentation skills were still low. This is evidenced by the average claim score of 54%, data 38%, warrant 29%, backing 35% and rebuttal 35% (Syerliana et al., 2018). In addition, the results of research at MAN 1 Yogyakarta showed that scientific argumentation skills were still low with the largest category at level 1 at 38.9% (Perdana et al., 2020). The low scientific argumentation skills were caused by learning methods and models that did not support the development of skills, difficulty understanding elements of scientific argumentation skills such as claims, data, justification, backing and rebuttal, and lack of understanding of the concepts of the material being taught so that students tended to only put forward claims, and were not yet accustomed to solving questions that measured scientific argumentation skills.

Based on the research results that have been presented, it shows that students scientific argumentation skills need to be improved by designing learning that builds critical thinking skills, formulates evidence-based claims and skills in conveying and responding to arguments scientifically through design thinking learning. One promising approach is Design Thinking (DT). The opinion of Dunne and Martin in Al-Muqbil (2023) describe design thinking as a problem solving framework that encourages the exploration of multiple possible solutions based on real world evidence rather than relying solely on deductive on inductive logic. This aligns with the contrutivist learning theory,

which posits those students actively construct knowledge through experience, collaboration, and reflection. Design thinking also supports the principles of inquiry-based learning, where students investigate problems, gather evidence and test hypotheses to construct knowledge scientifically. Design Thinking is an important foundation that makes a significant contribution to 21st century education in various scientific fields, thus encouraging students to hone their critical thinking skills, reason logically and solve problems systematically and innovatively (Razzouk & Shute, 2012). Students can develop soft skills through design thinking. Design Thinking contributes to developing students' creativity by encouraging unlimited exploration of ideas (Mosely et al., 2018). In addition, Design Thinking also increases active involvement of students and fosters higher motivation to learn independently (Tu et al., 2018). Not only that, Design thinking can develop problem-solving and creative thinking skills (Guaman Quintanilla et al., 2023; Man et al., 2022).

A few articles on design thinking have been widely conducted, as explained in the previous article. However, research on design thinking to train scientific argumentation skills has never been conducted by previous researchers. In fact, this research is important to be conducted considering that design thinking has great potential in encouraging the improvement of scientific argumentation skills.

Based on the description above, the formulation of the problem to be answered through the research is as follows: 1. What are the research trends on the use of design thinking in science learning? 2. What are the learning outcomes achieved by using design thinking? 3. What subjects often use design thinking? 4. How is the application of design thinking to support the development of scientific argumentation skills?

Method

This Systematic Literature Review (SLR) process uses the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method to evaluate and filter relevant articles on design thinking. The details are shown in Figure 1. The first step is to identify research needs and formulate clear objectives, namely to examine the application of design thinking in training scientific argumentation skills in science learning. The main keywords used in the article search include design thinking, design thinking in education, "design thinking in science education," scientific argumentation skills" to obtain more comprehensive search results.

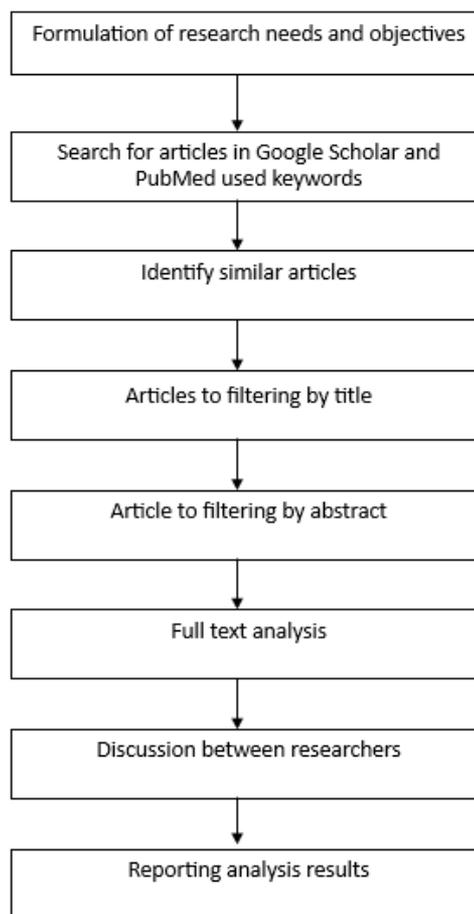


Figure 1. Data collection, analysis, and reporting

The help of the Publish or Perish search engine, data was collected from two databases, Google Scholar, and PubMed. With a publication deadline between 2020 and 2025. The next stage is the identification stage, which aims to filter duplicate articles. The same article will be removed from the analysis list. Next, the title screening stage, which is based on the following criteria: the article title includes design thinking in science learning in Indonesian or English. The article comes from an international or national journal accredited with at least Sinta 3 and is not a literature study. The next screening stage is carried out by reading the article abstract. The articles included are based on the following criteria: the research results explain the application of design thinking in science learning, the research uses qualitative, quantitative, and research and development methods, and is carried out at elementary and secondary education levels. Articles that pass this stage are then reviewed thoroughly with fellow researchers to ensure that the article meets all the inclusion criteria that have been set. The final stage is reporting the results of the analysis of the number of articles relevant to the research topic.

The data obtained are presented systematically in the form of tables or graphs to facilitate interpretation

and report preparation. The article selection process is described in a PRISMA diagram that describes the number of articles found in the initial stage, the number of articles eliminated during screening, and the number of articles that were completely analyzed and finally used in the study. The result of this process is a comprehensive report on the application of design thinking to train scientific argumentation skills in science learning. The SLR process is carried out systematically, transparently, and accountably.

Results and Discussion

This Literature Review aims to provide information related to research trends that apply design thinking in science learning, learning outcomes achieved by using design thinking, subjects that often use design thinking, and the application of design thinking to train scientific skills development. Articles were searched from the Google Scholar and PubMed databases. This search resulted in 1096 articles consisting of Google Scholar 994 articles and PubMed 200 articles. Then identification was carried out to find similar articles and resulted in 98 articles. Furthermore, filtering based on the titles found, as many as 482 articles were not related to design thinking to improve scientific argumentation skills, as many as 98 articles were marked as unworthy articles by

automation tools, as many as 186 articles were in the form of books, and as many as 122 articles used the literature study method. After the filtering process, it was continued to the analysis of the remaining articles to be processed, which were 213 articles, but there were 182 articles that did not show the influence of design thinking and 11 articles that were not qualitative, quantitative, research and development. The final result obtained from this PRISMA analysis diagram is as many as 20 relevant research articles used in this study. The following is a diagram analysis based on the PRISMA provisions shown in Figure 2.

A total of 20 articles selected in the initial stage of the selection process were reviewed in depth by researchers simultaneously. This review process was carried out carefully to ensure that each article met the predetermined inclusion criteria and was relevant to the focus of the research. If there were differences of opinion or review results between researchers, intensive discussions were conducted to align perceptions and reach a standard agreement. This collaborative approach aims to minimize subjectivity, increase the validity of the review results, and ensure that each selected article makes a significant contribution to the analysis and findings of the research. Thus, this review process prioritizes not only accuracy but also academic integrity in the preparation of the SLR.

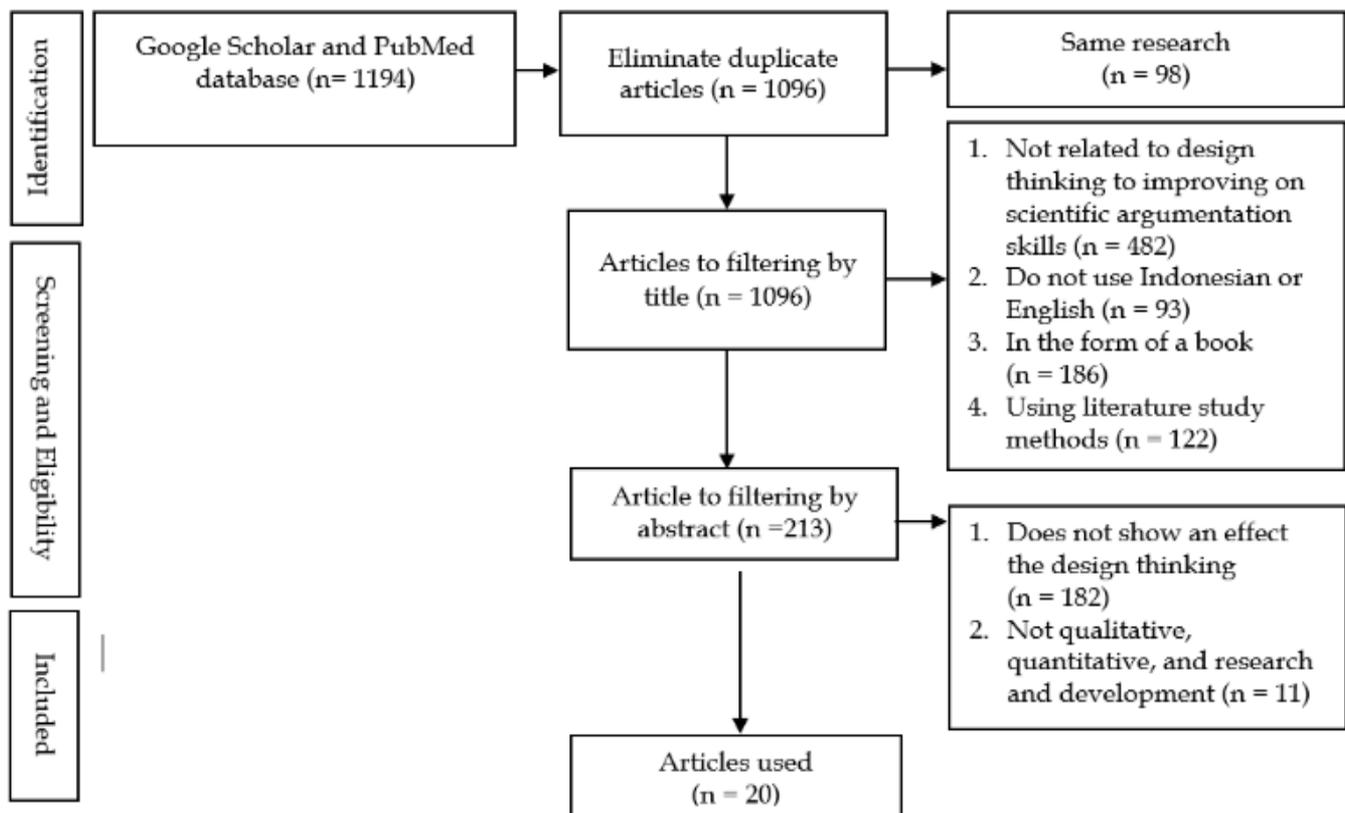


Figure 2. Diagram PRISMA

In the application of design thinking, students are trained to go through systematic stages such as: 1) Identifying problems and collecting information from various sources (resource-based learning), which encourages students to seek scientific evidence and relevant data. 2) Brainstorming and developing creative ideas, which train the ability to formulate arguments and alternative solutions. 3) Prototyping and testing, where students must test hypotheses and support arguments with empirical evidence. 4) Evaluation and reflection, which encourages revision of arguments based on test results and feedback, so that scientific argumentation skills are honed critically and systematically. 5) This process builds critical thinking skills, scientific communication, and collaboration, all important elements in scientific argumentation. In other words, design thinking not only hones creativity, but also supports students to develop strong scientific arguments based on data and reflection (Rumahlatu et al., 2021).

Based on the graphical analysis in Figure 3, the trend of design thinking usage from 2020-2025 shows the dominance of quantitative research methods. In addition, R&D research methods show a significant increase in 2024, indicating a shift in the focus of design thinking towards innovation and development. On the other hand, articles using qualitative research methods show stable fluctuations with a peak in 2023, although the number of articles is lower than quantitative and R&D research methods. Overall, this trend reflects a shift towards a more practical, data-driven, and research- and development-focused application of design thinking in recent years.

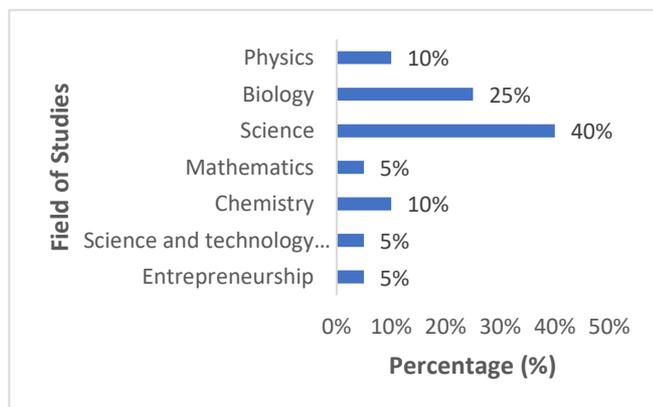


Figure 3. Trends used of the design thinking for 2020-2025

Based on the graphical analysis in Figure 4, Learning outcomes include the development of creativity, critical thinking skills, learning outcomes, numeracy, learning interests, motivation, scientific attitudes and critical thinking in a more meaningful learning process.

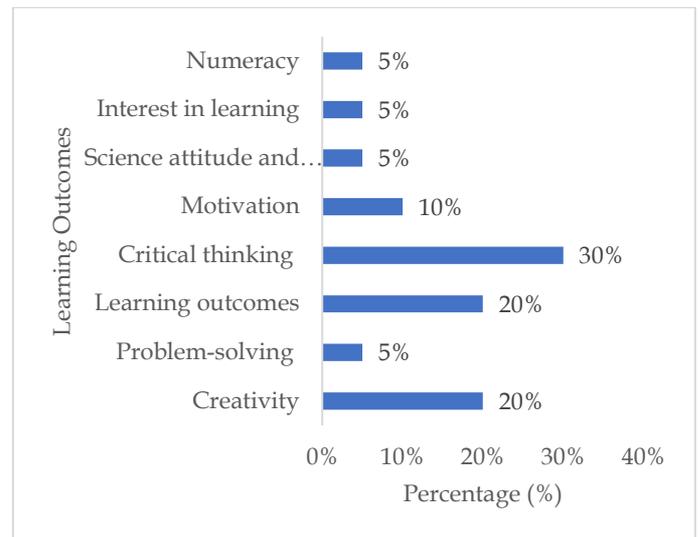


Figure 4. Learning outcomes achieved by used design thinking for 2020-2025

Overall, the application of Design Thinking supports the learning process to improve learning outcomes (Fitriyyah et al., 2024; Honra & Monterola, 2024; Ladachart et al., 2022; Simeon et al., 2022) and develop creativity (Atmojo et al., 2023; Siew & Arifin, 2025; Roth et al., 2020). In addition, Design thinking encourages critical thinking skills through in-depth analysis of problems from various perspectives, systematic evaluation of information and logical formulation of solutions (Ananda et al., 2023; McCurdy et al., 2020; Riti et al., 2021; Rumahlatu et al., 2021; Kurniawan & Winarsih, 2022; Wulandari et al., 2023). The application of design thinking can also develop numeracy, learning interest, scientific attitudes, problem solving and motivation (Riyadi et al., 2024; Jannah et al., 2024; Galoyan et al., 2022; S.Pou et al., 2024; (Rahmawati et al., 2024).

Based on the graphical analysis in Figure 5, In terms of subjects, the application of design thinking in various fields of study in 2020 - 2025 shows that science subjects are often used in the application of design thinking by 40%. Biology subjects by 30%, and physics by 10%. Meanwhile, chemistry, mathematics, science and technology subjects through sports and entrepreneurship by 5%. This finding shows that design thinking tends to be applied more in the context of science learning, especially in science and biology subjects.

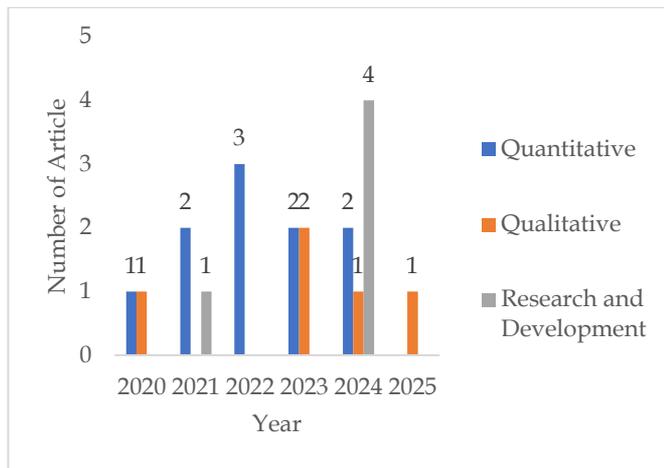


Figure 5. field of studies frequently used in design thinking for 2020-2025

The application of design thinking in learning can support the development of scientific argumentation skills by shifting the learning approach from merely solving problems to a deeper understanding of students' needs and perspectives. This approach trains students to think holistically and argumentatively in a scientific context, and to develop reasoning through collaborative projects based on real experiences. Specifically, design thinking contributes to the formation of scientific argumentation skills through several core stages. In the empathy and definition phase, students are trained to observe and analyze authentic problems. Students identify learning needs, express opinions based on observations, and analyze the obstacles faced. This activity is an initial form of claim formulation and evidence collection as the foundation of scientific argumentation. Furthermore, in the ideation and prototype phases, students develop solutions based on data and previous learning experiences. This process encourages them to formulate justifications for the choice of solutions that are considered the most effective. Discussion and collaborative work in the preparation of learning media, such as posters or other products, encourage explicit argumentation practices through activities of expressing opinions, giving reasons, and defending ideas rationally. In the final phase, namely the test, students receive and provide feedback on their friends' work. This process involves the skills of putting forward reasons, refuting, or accepting arguments based on visual clarity, strength of content, and relevance to conceptual understanding. This stage reflects the practice of scientific argumentation as a whole, where students build, evaluate, and revise claims based on evidence and logical reasoning (Jannah et al., 2024). Thus, the implementation of design thinking not only increases student engagement and creativity but also significantly trains and strengthens scientific

argumentation skills that are essential in science learning.

Conclusion

The results of this study indicate that the application of design thinking in learning follows systematic stages that not only enhance creativity but also strengthen students' scientific argumentation skills through data-based reasoning and reflective practice. The trend analysis shows that quantitative research methods have been most widely used, followed by a growing number of research and development (R&D) studies in 2024 and a smaller proportion of qualitative studies in 2025. The implementation of design thinking has been found to improve various learning outcomes, including creativity, critical thinking, academic achievement, numeracy, learning interest, motivation, and scientific attitudes. Most applications of design thinking occur in science and biology subjects, emphasizing its relevance to science education. Overall, design thinking effectively fosters student engagement, promotes innovative problem-solving, and significantly contributes to developing and reinforcing scientific argumentation skills that are essential for 21st-century scientific literacy.

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Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest

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