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A systematic literature review on the integration of scientific reasoning skills into science education

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ABSTRACT
Scientific reasoning skills (SRS) have become essential abilities for the 21st century. Scientific reasoning skills constitute a set of interrelated cognitive processes that underpin effective science learning. This study aims to analyse SRS through a systematic literature review from the years 2014 to 2023. This study conducted a systematic literature review using the PRISMA approach. Document searches were conducted using the keywords "Scientific Reasoning Skill" "Scientific Reasoning Competence" "Scientific Reasoning" or "Scientific thinking" "science education" "science learning" "social science" or "science" or "education" through the Scopus database. A total of 43 documents were analysed as the final data in this study. The results of the study indicate that SRS research in science education became the most published research category in 2021. The use of Lawson's Classroom Test of Scientific Reasoning (LCTSR) is the most dominant instrument used by researchers in measuring SRS. In terms of strategies that can be used to facilitate the SRS, it is through inquiry-based learning that students are encouraged to actively explore, question, and construct their own understanding through investigation and critical thinking rather than relying solely on direct instruction. Given the importance of scientific reasoning skills in science learning, an emphasis on these skills within the science education curriculum is essential.

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Introduction

Science learning is closely related to the process of inquiry (Ekici & Erdem, 2020). Experimental activities in the inquiry approach begin with the observation of a phenomenon, then move onto identification of possible underlying variables, stating hypotheses, setting up experiments using control variables, analysing results, formulating conclusions, and writing reports. Each of these processes involves SRS-related thinking skills (Bhaw et al., 2023). This is in line with the essence of science, which recognises itself as a product, a process, and an attitude (Chiappetta & Koballa, 2010; Lederman et al., 2013; Irzik & Nola, 2014). Science as a product refers to a discipline that discusses the facts, concepts and theoretical principles that can explain and understand nature and the phenomena occurring within it. Science is necessary for acquiring knowledge and numerous skills to detect, apply and investigate natural phenomena at various stages. Science learning also requires the development of scientific attitudes (Kurniawan et al., 2019; Oh, 2017; Saputri et al., 2019; Suryandari et al., 2022).

Lehrer & Schauble suggest that science is theory, science is logic, and science is practice. Science, as a body of theory, regards experiments as theoretical tests that may lead to conceptual change. In this context, the term "theory" refers to a conceptual framework such as the Atomic Theory that guides the interpretation of experimental evidence and supports the evolution of scientific understanding (Driver et al., 1996; Posner et al., 1982; Lederman & Lederman, 2023) Science as logic focuses on the use of control variables during experiments. Lastly, Science as practice views science not merely as a body of knowledge, but as a dynamic process of constructing, testing, and refining ideas through reasoning, modelling, and representation. Within this perspective, theory and reasoning function as essential tools that guide the development of models and representations to make abstract or unobservable phenomena accessible and understandable. Through modelling, learners engage in authentic scientific practices such as explaining, predicting, and revising their understanding reflecting how scientists interpret and communicate complex natural processes. This approach emphasizes that knowledge in science is not transmitted passively but actively constructed through inquiry, argumentation, and collaboration. Consequently, *science as practice* bridges theoretical understanding with hands-on investigation, enabling students to think and act like scientists. Such an orientation aligns with contemporary science education goals that promote inquiry, modelling, and reasoning as central components of scientific literacy. (Lehrer & Schauble, 2007). These characteristics of science allow students to observe a phenomenon using scientific reasoning. The application of scientific reasoning is identified in pedagogical environments that require students to learn scientific methods during experimental activities (Bhaw et al., 2023). Science as practice views science not merely as a body of knowledge, but as a dynamic process of constructing, testing, and refining ideas through reasoning, modelling, and representation. Within this perspective, theory and reasoning function as essential tools that guide the development of models and representations to make abstract or unobservable phenomena accessible and understandable. For pupils at the primary and secondary levels, engaging in such practices enables them to experience science as a way of thinking and doing rather than as facts to be memorised. Through modelling and inquiry, they learn to explain, predict, and revise their understanding, reflecting authentic scientific activity. This approach emphasises that scientific knowledge is actively constructed through exploration, argumentation, and collaboration. Consequently, *science as practice* bridges theoretical understanding with hands-on investigation, fostering scientific literacy from an early age.

Scientific Reasoning Skill are prerequisite skills that must be possessed by learners to master scientific activities (Edward et al., 2017; Stylinski et al., 2020). (Hasruddin & Aulia, 2023; Kambeyo & Scapo, 2018). Student learning outcomes improve when they can engage more deeply in scientific activities (Burgess et al., 2017; Edward et al., 2017; Gray et al., 2017; Phillips et al., 2018; Stylinski et al., 2020). Science as practice views science not merely as a collection of facts, but as an active process of constructing, testing, and refining ideas through reasoning, modelling, and representation (Ülger, 2021). Within this framework, theory and reasoning guide the development of models that help pupils make sense of abstract or unobservable phenomena. By engaging in authentic scientific practices—

such as designing investigations, interpreting data, and revising explanations—pupils experience science as both a way of knowing and a way of doing. This experiential approach nurtures their ability to think critically and reason scientifically.

This is also supported by the findings of Bruckermann et al. (2020), which show that scientific reasoning skills foster pupils' conceptual understanding of scientific phenomena and their capacity to apply knowledge in new contexts. Consequently, developing scientific reasoning is not only essential for learning scientific content but also for deepening understanding of how scientific knowledge is generated and validated through practice. It is further explained that science learning, especially in inquiry activities, depends on certain prerequisites, namely students' proficiency in scientific reasoning (Bruckermann et al., 2023). Low scientific reasoning skills will have an impact on the decline in the process of inquiry received by students, it can also hinder the achievement of learning outcomes (Burgess et al., 2017; Edward et al., 2017; Gray et al., 2017; Phillips et al., 2018; Stylinski et al., 2020).

Previous research has consistently highlighted the importance of scientific reasoning skills (SRS) in enhancing pupils' understanding of scientific concepts and practices. These skills enable learners to formulate hypotheses, interpret evidence, and construct explanations that reflect authentic scientific inquiry. Bruckermann et al. (2020) demonstrated that the development of SRS contributes to pupils' conceptual understanding and their ability to apply knowledge across different contexts. Similarly, Zimmerman (2007) emphasised that reasoning processes such as control of variables, evidence evaluation, and causal inference are central to meaningful science learning. Building on this body of research, the present study seeks to explore how SRS can be effectively facilitated through inquiry-based learning approaches that encourage pupils to engage in modelling, reasoning, and reflection. This focus aims to deepen understanding of how learners develop and use scientific reasoning as part of their overall scientific literacy. The higher the scientific skill of students, the more likely they are to understand a broader range of knowledge (Ding et al., 2023; Moore & Rubbo, 2012). As per the study conducted by Bao et al., scientific reasoning is strongly correlated with cognitive abilities (Bao et al., 2009). Scientific reasoning skills will improve at all levels if taught with a focus on critical thinking skills (Blumer & Beck, 2019; Hester et al., 2018; Yanto et al., 2019). Other studies suggest that scientific reasoning can be developed at an early age (Zimmerman, 2007). There is increasing evidence that primary school pupils possess various scientific reasoning skills. Early development of scientific reasoning provides learners with greater opportunities to acquire higher-level reasoning skills (Nagy & Korom, 2023). Higher-level reasoning is necessary for problem-solving and decision-making, including understanding complex concepts (Lawson, 2004).

Many studies have examined the importance of scientific reasoning skills in science learning, but there has been relatively little in-depth investigation into scientific reasoning skills in science education (Rampean & Rohaeti, 2025). Analysing credible research on scientific reasoning skills provides a profound overview of the paradigm shift in education, moving from a focus on content memorisation towards the development of scientific thinking processes that prepare learners to solve real-world problems (Miftakhul Falah et al., 2024). While numerous studies examine scientific reasoning, the literature remains scattered across various subjects, educational levels, and methodological approaches, as well as the evaluations used, making it difficult for educators to implement evidence-based practices. Previous studies have underscored the significance of scientific reasoning skills (SRS) in promoting meaningful science learning (Bruckermann et al., 2020; Zimmerman, 2007). SRS enable pupils to interpret evidence, formulate hypotheses, and justify conclusions—core components of scientific literacy. However, research also indicates that these skills are often insufficiently developed in school contexts, where science instruction tends to emphasise factual recall rather than reasoning and inquiry (Istyadji & Sauqina, 2023). Moreover, the integration of inquiry-based learning (IBL) as a pedagogical approach to enhance SRS remains underexplored in certain educational settings. Addressing these issues is essential for cultivating learners who can think critically, reason scientifically, and engage in authentic scientific practices.

Considering the importance of this skill as a fundamental skill that students must possess in experimental and inquiry activities, conducting a systematic literature review can explore the efforts of researchers and educators in developing scientific reasoning skills (Illescas-Navarro et al., 2025). This systematic literature review aims to analyse learning models that facilitate scientific reasoning skills, the aspects and indicators of scientific reasoning skills, and the correlation between scientific reasoning skills and other variables. In addition, it will also explore the research trends on the topic in terms of countries, institutions, and most productive authors, as well as the differences in the types of research conducted by researchers. Accordingly, the present study aims to address this gap by exploring the role of inquiry-based learning in developing scientific reasoning skills among pupils in science classrooms. A literature review is used as an effective method for creating a strong foundation for facilitating knowledge and facilitating theory development (Webster & Watson, 2002). By integrating the results and perspectives of many empirical studies, The literature review informs the direction of this study by mapping existing knowledge, evaluating its limitations, and articulating the research questions that have not yet been empirically addressed (Snyder, 2019). While meta-analysis statistically aggregates results across studies, a literature review synthesises theoretical and empirical insights to construct a conceptual framework that guides further research (Snyder, 2019). This systematic literature review is important to provide information to researchers, teachers, and education practitioners (Ubaidillah et al., 2023), especially regarding the development of leaners' scientific reasoning skills. The results of this study can be used as a strong basis for planning and developing a science education curriculum that is more effective in encouraging and strengthening scientific reasoning skills as a very important skill in science learning.

The objective of this research is to analyse articles sourced from the Scopus database from 2014 to 2023, focusing on scientific reasoning skills in science learning. This study has the following problem statement:

1. What are the dominant trends and developments in research on scientific reasoning skills (SRS) in science education between 2014 and 2023?
2. Which science learning strategies have been reported to facilitate SRS development?
3. What aspects and instruments have been used to measure SRS across studies?
4. How does research on SRS vary according to educational level (e.g., primary, secondary, tertiary)?
5. What relationships between SRS and other variables have been explored in existing literature?

Methods

Research Type

This study is a systematic literature review research. The use of a literature review is an effective method for establishing a strong foundation for facilitating knowledge and facilitating theory development (Webster & Watson, 2002). This method is used to identify and critically assess relevant studies, as well as to collect and analyse data from these studies (Liberati, 2009). The purpose of this systematic review is to identify all empirical evidence that meets the predefined inclusive criteria to answer the research questions. By using a systematic method to review articles and all available empirical evidence, bias can be minimised, making the findings reliable for drawing conclusions and making decisions (Moher, 2009; Snyder, 2019).

Data Collection

Literature data collection was conducted using the Scopus database, spanning the last 10 years from 2014 to 2023. Scopus is one of the high-quality data sources, making it a consideration in document selection (Wei et al., 2023). Data selection was conducted using the PRISMA method developed by Moher, Liberti, Tetzlaff, & Altman (Moher, 2009). The PRISMA method is the most widely used method for systematic literature reviews (Page et al., 2021). The PRISMA method provides a roadmap for reporting systematic reviews in a transparent, objective, and explicit manner (Rehman et al., 2020). This systematic review (Fig. 1) adapted from Kulakli & Osmanaj; Yang, et al; Bonilla-Chaves & Palos-Sánchez; Wei, et al (Bonilla-Chaves & Palos-Sánchez, 2023; Kulakli & Osmanaj, 2020; Wei et al., 2023; Yang et al., 2017).

Data Analysis

The literature search was conducted in March-April 2024 through the Scopus database. This study was conducted using keywords with Boolean operators AND and OR resulting in the following search terms "Scientific Reasoning Skill" OR "Scientific Reasoning Competence" "Scientific Reasoning" OR "Scientific thinking" AND "science education" OR "science learning" OR "social science" OR "science" OR "education".

Table 1

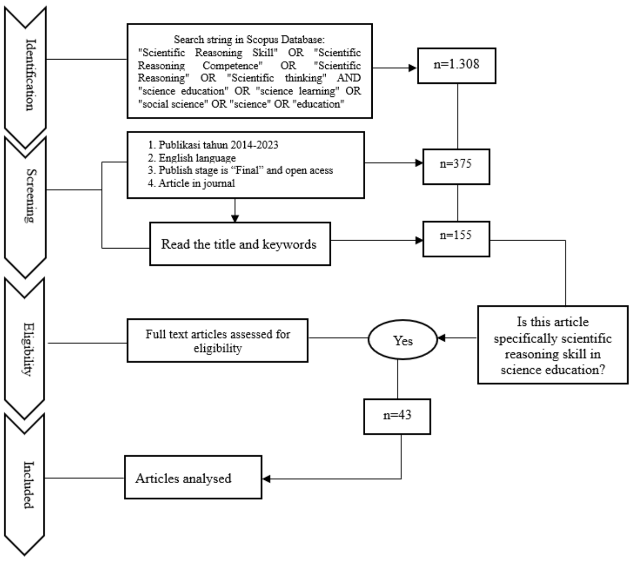
Presents a summary of these criteria

Criteria	Decision
When the predefined keywords exist as a whole or at least in the title, keywords, or abstract section of the paper.	Inclusion
The paper was published in a scientific journal.	Inclusion
The paper should be written in the English language.	Inclusion
Papers that were published before 2014.	Exclusion
Papers that are not accessible, review papers, and meta-data.	Exclusion

A total of 1,308 documents were obtained for the years 2014-2023. The obtained documents were then filtered to include only those in English, document types such as journal articles, final stage documents, and open access, resulting in 375 documents. Next, their relevance to the research topic was analysed through titles, abstracts, and keywords, resulting in 155 documents. After conducting an in-depth analysis through a full-text examination, a total of 43 final documents were obtained. The data were analysed using the PRISMA stages, which consist of four stages: identification, screening, eligibility, and inclusion.

Figure 1

Presents the flow of the research procedure applied in this review



The identification stage is the first stage in the PRISMA method. This stage involves identifying what, how, and where to find the relevant data. Once all the data is obtained, the data is then identified and filtered. This identification process is conducted as thoroughly as possible to avoid missing any important data. This process is referred to as sensitivity in the initial screening stage (Siddaway et al., 2019).

The next stage is screening, where articles are assessed to determine if they meet the criteria for inclusion in the qualitative synthesis. Assessment is based on inclusive assessment (Busalim & Hussin, 2016), meaning that document assessment is based on reputable journals or journals indexed in Scopus. In selecting data sources, Scopus was prioritised due to its extensive repository of peer-reviewed research and established reputation for quality indexing (Wei et al., 2023). Document screening is also conducted on documents that are only in the form of journal articles because they are considered the most recent records or the latest scientific studies of knowledge in any field, and journals are deemed more up-to-date than other sources (Cronin et al., 2008; Rehman et al., 2020) Therefore, documents other than journals, such as books and conference are ignored. Relevant studies were identified through searches of Scopus, Web of Science, and ERIC. To ensure comparability and methodological rigour, only peer-reviewed journal articles published in English were considered. English is an internationally recognised language so it is a recommended language in writing journal articles, especially in reputable journals. The period of 2014–2023 was chosen to provide a balanced representation of recent research trends in scientific reasoning skills. While extending the timeframe could yield a larger sample, Cronin et al. (2008) emphasise that an overly broad range may dilute focus and include conceptually obsolete studies. Thus, a ten-year span is adequate to ensure both scope and relevance (Cronin et al., 2008). Cronin et al. suggest that ideally, the document timeframe for a systematic literature review is 5-10 years, while Nundy et al. corroborated that systematic literature reviews have been conducted over the last 10 years (Nundy et al., 2022).

The next stage is eligibility, during this stage, the screened documents are read thoroughly, including their full papers. If it is in line with the research objectives, the next step is data extraction and qualitative analysis. This research uses Microsoft Excel for data extraction. This form is used to organise qualitative synthetic information (Rehman et al., 2020). Several columns containing notes of important information include the author's name, year, title, institution, research design, types of learning models supporting SR, research subjects, and the correlation between SR and other variables.
Based on the analysis of the systematic literature review procedure steps, Figure 2 is a conceptual mapping obtained from the keyword search results.

Figure 2

Conceptual mapping

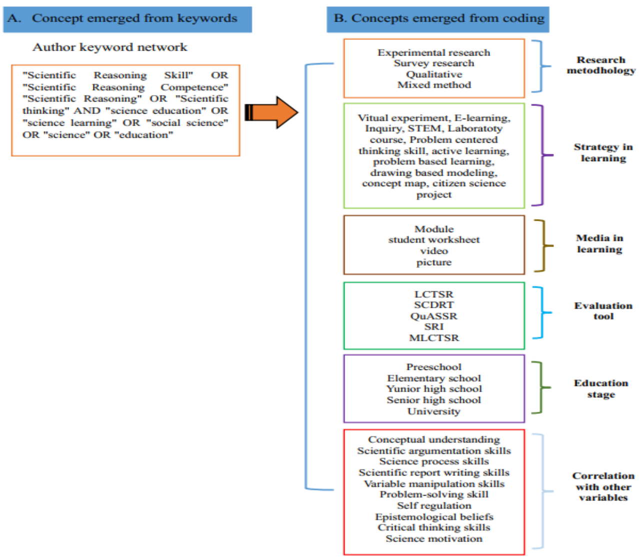


Figure 2 presents the conceptual mapping generated from the keyword analysis. This mapping served as the basis for developing the coding framework applied to the selected articles in the systematic review.

Findings

The study analyses the profile of studies on scientific reasoning skills, how to facilitate scientific reasoning skills, aspect and measurement instruments of scientific reasoning skills, differences in types of institutions, and the correlation between scientific reasoning skills and other variables.

The Profile of Research on Scientific Reasoning Skills in Science Education Based on the Number of Publications from 2014 to 2023

Research on scientific reasoning skills in science education over the past 10 years, from 2014 to 2023, sourced from the Scopus database, reveals that studies on this theme consistently contribute each year (Fig. 3).

Figure 3

Comparison of research on SRS from 2014 to 2023

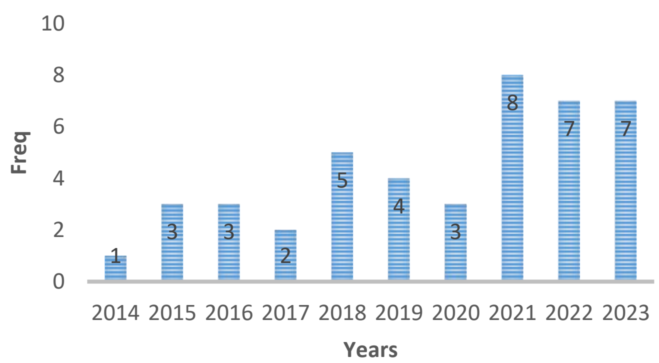


Figure 3 shows a modest increase in publications around 2021, when eight studies on scientific reasoning skills were published. Nonetheless, with fewer than fifty studies overall, this variation reflects a descriptive pattern rather than a statistically meaningful change in research productivity. However, a slight decline was observed in 2022. Over the ten-year period, nearly all studies were written collaboratively, with only a single publication authored individually. This indicates that research on scientific reasoning skills is typically conducted through collaborative efforts. These results indicate that researchers worldwide have extensively engaged in collaboration when researching scientific reasoning skills.

The apparent decline in the integration of scientific reasoning skills within science education research should be viewed as tentative. It may reflect contextual factors such as evolving research priorities, publication delays, or the emergence of alternative conceptual frameworks rather than a true reduction in scholarly attention. One of them is the limitations of a curriculum that focuses more on mastering material than developing scientific thinking skills (C. A. Dewi & Rahayu, 2024). This is exacerbated by a standardised test-based evaluation system that emphasises memorisation over analysis and synthesis of information. In addition, the readiness of educators is also an important factor, where many teachers have not received adequate training in teaching scientific reasoning explicitly. The continued dominance of lecture-based and memorisation-oriented teaching methods in tertiary science education may limit students' opportunities to develop higher-order cognitive and scientific reasoning skills, also do not provide enough space to develop learners' critical thinking skills. Another contributing factor is limited resources, including a lack of access to teaching aids, laboratories, and institutional support in the form of training and professional development. Low pupil motivation and limited engagement in science lessons can hinder the development of scientific reasoning skills, particularly when instructional materials are perceived as difficult or disconnected from students’ everyday experiences. Furthermore, rapid changes in educational policy—such as the increasing emphasis on digitalisation and STEM literacy—may unintentionally divert attention away from cultivating scientific thinking skills in science education (Kaçar, 2023). These factors suggest that both pedagogical and systemic influences play important roles in shaping the extent to which scientific reasoning is integrated into classroom practice.

Although the data do not conclusively demonstrate a decline in the integration of scientific reasoning skills, there remains significant potential to strengthen their presence in science education. One promising direction is the adoption of inquiry-based and problem-based learning approaches, which provide pupils with authentic opportunities to investigate phenomena, conduct experiments, and engage in real-world problem-solving. These pedagogical strategies can help bridge the gap between theoretical knowledge and practical scientific reasoning. In addition, improving the quality of training for educators is also of key importance in ensuring that teachers have sufficient skills to teach scientific reasoning effectively (Kirya et al., 2024). The use of digital technologies and tools, such as simulations, virtual laboratories, and artificial intelligence-based learning platforms, can also help them analyse data, formulate hypotheses, and test their conclusions in greater depth. The integration of cross-disciplinary approaches, such as linking science with mathematics, engineering and social sciences, can also strengthen students' understanding of the importance of scientific reasoning in various contexts. In addition, reforms in the evaluation system, by replacing rote-based assessment methods with performance-based assessments such as open-ended investigations and concept mapping, can encourage students to further develop their critical thinking skills. Governments and educational institutions can also play a role in designing policies and curricula that explicitly accommodate the development of scientific reasoning skills as part of the main learning objectives. With these concerted efforts, scientific reasoning skills can once again become a central component of science education, equipping pupils with the critical thinking and problem-solving abilities necessary to navigate the challenges of the future.

Different Types of Research on the Theme of Scientific Reasoning Skill

Various types of research are conducted to study scientific reasoning skills. The reviewed studies were categorised into five types: empirical research articles, position papers, theoretical papers, review articles, and others. However, only papers presenting new empirical data were included in the final analysis. The differences in these types of research are adopted from Lin et al., 2014 and Tsai & Lydia Wen, 2005 Based on the analysis results, research on scientific reasoning skills is predominantly conducted empirically (41 documents). The remainder consists of review studies (1 document) and theoretical papers (1 document). The empirical research conducted by researchers consists of four classifications: qualitative research, quantitative research, and mixed methods.

Table 2

Differences in empirical research in scientific reasoning skills

Empirical Research Type	Freq
Experimental quantitative	25
Survey quantitative	6
Qualitative	8
Mixed method	3

Table 2 shows that experimental research is the most frequently conducted type of research by researchers in facilitating scientific reasoning skills, with a total of 25 documents. Experimental research is conducted by researchers to compare learning outcomes between experimental and control groups. Survey research is the second most dominant type of research after experimental research. Researchers extensively investigate the relationship between scientific reasoning skills and other skills or abilities through surveys. Additionally, researchers have extensively investigated the level of scientific reasoning skills using various standardized test instruments.

Strategies for Facilitating Scientific Reasoning Skills

Scientific reasoning skills can be facilitated through hands-on activity-based science learning. Hands-on activities are conducted through practicum activities, either performed in person or online. Table 3 explains the strategies used to facilitate scientific reasoning skills.

Table 3

Strategies for facilitating scientific reasoning skills

Authors	Strategy	Freq.
(Omarchevska et al., 2022; Parmin et al., 2022)	Virtual experiment	2
(Acar & Patton, 2016; Blumer & Beck, 2019; Kaiser & Mayer, 2019; Malone & Schuchardt, 2023; Novia & Riandi, 2017; Olschewski et al., 2023; Omarchevska et al., 2022; Orosz et al., 2022; Schlatter et al., 2020; Willemsen et al., 2023)	Inquiry	10
(Owens et al., 2020; Özkul & Özden, 2020; Van Vo & Csapó, 2023)	STEM	3
(Coleman et al., 2023; Russ & Odden, 2017; van der Graaf et al., 2018)	Laboratory course	3
(L. Dewi et al., 2023)	Problem Centred Thinking Skills (PCTS)	1
(Acar & Patton, 2016; Iwuanyanwu, 2023)	Scientific Argumentation	2
(Marušić & Dragojević, 2020)	Active Learning	1
(Mendoza et al., 2018)	Problem Based Learning	1
(Heijnes et al., 2018)	Drawing based modelling	1
(Dowd et al., 2019)	Concept map	1
(Bruckermann et al., 2023)	Citizen science project	1
(Rost & Knuuttila, 2022)	Epistemic artifact	1
(Cheng et al., 2018)	Problem-Solving Instruction	1
(Hardy et al., 2021)	Scaffolding	1
(Mendoza et al., 2018)	Collaborative learning	1
(Owens et al., 2020)	SSI	1
(Cabello et al., 2021)	Image Representation	1
(Upmeier Zu Belzen et al., 2021)	Abductive Learning Model	1
(Vaesen & Houkes, 2021)	Gieres' Framework Model	1
(Alabdulaziz et al., 2022)	E-learning	1

Table 3 shows that inquiry-based learning has been identified in several empirical studies as the most effective strategy for facilitating scientific reasoning skills. Science learning through inquiry focuses on experimental activities, whether conducted in-person or online. Some types of inquiry-based learning used are inquiry learning through virtual laboratories (J. Chen et al., 2018; Omarchevska et al., 2022), *guided inquiry* (Acar & Patton, 2016; Blumer & Beck, 2019; Kaiser & Mayer, 2019; Orosz et al., 2022), and *argumentation based inquiry course* (Acar & Patton, 2016). These results show that the majority of researchers are using guided inquiry in conducting investigations as a model to facilitate SRS.

Strategies for integrating scientific reasoning skills in science education can be more effective if they are tailored to the educational level and cultural context. Each level of education has different cognitive characteristics and learning needs, while cultural backgrounds also influence how students understand and apply scientific concepts. Therefore, a flexible approach is required for these strategies to be optimally implemented.

At the primary level, learning strategies should emphasize inquiry-based and exploratory approaches that engage pupils through enjoyable, hands-on experiences. Pupils can be introduced to scientific concepts through simple experiments, storytelling, and guided questions that encourage curiosity. As noted in previous studies, inquiry-based and exploratory approaches enable pupils to observe, predict, and reason about phenomena logically, while avoiding the difficulties associated with abstract conceptual understanding at early developmental stages (Harlen, 2021). Meanwhile, at the intermediate and senior levels, strategies can be more oriented towards problem-based learning (PBL) and STEM (Kurniahtunnisa et al., 2024). Learners can be involved in case studies, data analysis, and evidence-based discussions that demand critical thinking skills. The use of virtual laboratories and digital tools can also help them understand the scientific process more interactively. At the higher education level, inquiry-based approaches, STEM, PBL, and Problem solving become more effective. Students can be encouraged to critique scientific literature, design experiments, and engage in academic discussions to strengthen analytical and problem-solving skills in various disciplines.

In addition to adapting strategies to the level of education, adaptations also need to be made to the cultural context. In Western education systems that tend to emphasise inquiry-based learning and student autonomy, more open strategies such as independent projects, democratic discussions, and evidence-based investigations can be applied to improve scientific reasoning. In contrast, in collectivist cultures such as in many Asian, African and Latin American countries, cooperation-based approaches are more effective. Strategies involving group projects, collaboration-based learning, and peer teaching can help students develop scientific thinking skills in an environment that fits their social norms. Meanwhile, in resource-constrained areas, strategies need to be adapted to the availability of facilities. The use of local materials for experiments, and community-based projects, as well as the utilisation of open digital resources and mobile learning, can be solutions to ensure that scientific reasoning skills can still be taught effectively despite limited infrastructure.

By customising strategies based on educational level and cultural context, the integration of scientific reasoning skills in science education can be done more effectively. This approach not only assists students in better understanding and applying scientific concepts but also ensures that they have critical thinking and problem-solving skills relevant to their learning environment.

Besides the learning models, various media can be used to facilitate scientific reasoning skills. The media used include modules, student worksheets, pictures, and videos. For more details, refer to Table 4.

Table 4

Media for facilitating scientific reasoning skills

Authors	Media	Freq.
(Blumer & Beck, 2019; Coleman et al., 2023)	Modules	2
(Orosz et al., 2022; Russ & Odden, 2017; Schlatter et al., 2020, 2021, 2022)	Student worksheets	5

Authors	Media	Freq.
(Bicak et al., 2021; Kaiser & Mayer, 2019; Russ & Odden, 2017)	Videos	3
(Cabello et al., 2021)	Pictures	1

Table 4 shows that the media used in science learning is student worksheets, with 5 researchers utilising this media to facilitate SRS. Based on the data analysis results, 80% of video media is used in inquiry-based learning.

Aspects and Instruments for Measuring Scientific Reasoning Skills

Scientific reasoning skills have dimensions related to the inquiry process. Starting from analysing problems to concluding. This becomes an aspect measured by researchers in analysing scientific reasoning skills. Based on the results of the meta-analysis, it was found that all researchers measured scientific reasoning skills used test-based instruments. A total of 27% of studies used the Lawson Classroom Test Scientific Reasoning (LCTSR) instrument developed by Lawson (Lawson, 2004). Table 5 illustrates the complete types of instruments for measuring scientific reasoning skills.

Table 5

Aspects and instruments for measuring scientific reasoning skills

Aspect	Instrument	Freq.
Conservation of matter and volume, proportional reasoning, control of variables, probability reasoning, correlation reasoning, and hypothetical-deductive reasoning	Lawson Classroom Test Scientific Reasoning (LCTSR)	14
Understanding scientific concepts and problem-solving	Scientific Concept Dependent Reasoning Test (SCDRT)	1
Complexity, perspective taking, inquiry, scepticism, fracking, Branville	The Quantitative Assessment of SSR (QuASSR)	1
Generating investigable questions, evaluating evidence, designing experiments, drawing conclusions	Scientific Reasoning InventoryThinking (SRI)	2
Conservative reasoning, proportional reasoning, controlling variables, combinatorial reasoning, probabilistic reasoning, correlational reasoning	Modified *Lawson* Classroom *Test* of Scientific Reasoning (MLCTSR)	1

Table 5 shows that research on scientific reasoning skills is frequently measured using the Lawson Classroom Test of Scientific Reasoning (LCTSR) instrument. The dimensions of scientific reasoning skills according to LCTSR include Conservation of matter and volume, proportional reasoning, control of variables, probability reasoning, correlation reasoning, and hypothetical-deductive reasoning.

Different Types of Institutions in Scientific Reasoning Skills Research

Research on scientific reasoning skills in science education has been conducted extensively in various institutions from preschool to university level.

Figure 4

Different types of institutions in scientific reasoning skills research

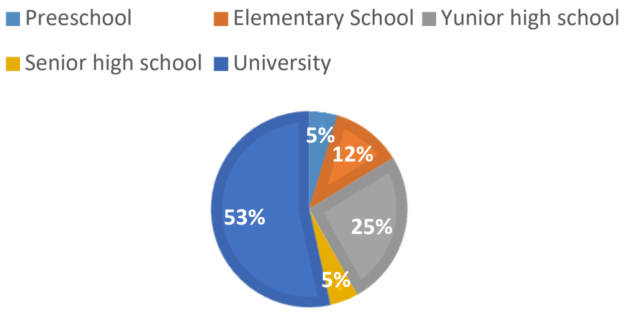


Figure 4 illustrates that the university level is the most frequently studied institution, accounting for 53%. This indicates that the measurement of scientific reasoning skills has been extensively conducted at the university level, particularly targeting prospective science teachers.

The Correlation of Scientific Reasoning Skills with Other Variables

Scientific reasoning skills are correlated with other variables. Some researchers associate scientific reasoning skills with other skills. Table 6 represents the correlation of scientific reasoning skills with other variables.

Table 6

The correlation of scientific reasoning skills with other variables

Authors	Correlation between variables	Freq.
(Acar & Patton, 2016; Cheng et al., 2018; Ding et al., 2016; Malone & Schuchardt, 2023)	Conceptual understanding	4
(Fischer et al., 2022; Iwuanyanwu, 2023)	Scientific argumentation skills	2
(Coleman et al., 2023)	Science process skills	1
(Dowd et al., 2019)	Scientific report writing skills	1
(van der Graaf et al., 2015; Van Vo & Csapó, 2023)	Variable manipulation skills	2
(Cheng et al., 2018; Hejnová et al., 2018; Iwuanyanwu, 2023; Olschewski et al., 2023)	Problem-solving skill	4
(Blumer & Beck, 2019)	Experiment design skills	1
(Omarchevska et al., 2022)	Self regulation	1
(Bruckermann et al., 2023)	Epistemological beliefs	1
(L. Dewi et al., 2023)	Critical thinking skills	1
(Van Vo & Csapó, 2023)	Science motivation	1

Table 6 shows that conceptual understanding and problem-solving skills are the variables most frequently researched by researchers about SRS.

Understanding the correlation between scientific reasoning skills and the effectiveness of science education can be the basis for designing a more integrative and effective curriculum. The integration of these skills into the curriculum should be done systematically by ensuring that each stage of learning supports the development of students' critical and analytical thinking. One way of utilising this correlation is by adopting an inquiry-based approach that emphasises not only concept mastery but also scientific thinking processes. An effective curriculum can incorporate methods such as problem-based learning (PBL), and STEM, as well as inquiry-based approaches that require students to analyse data, design experiments, and draw evidence-based conclusions. In addition, the curriculum needs to adapt learning strategies to the cognitive development level of learners.

At the primary level, exploratory approaches with simple experiments and guided discussions can be used to build the foundation of scientific thinking, while at the middle and upper levels, pupils can be given more complex challenges through case studies, data analysis, and independent hypothesis testing. To ensure its effectiveness, the curriculum also needs to adapt to the cultural context and available resources. In environments with limited laboratory facilities, simulation-based technologies or community-based projects can be an alternative to still practicing scientific reasoning skills. By designing a curriculum that links conceptual understanding with scientific thinking skills, science education not only improves students' science literacy but also equips them with critical thinking abilities that can be applied in various aspects of life and future careers.

Discussion

Based on content analysis results, inquiry-based learning is predominantly used by researchers worldwide to facilitate SRS. These analysis results are relevant to the explanation that Scientific Reasoning Skill (SRS) is a prerequisite skill that learners must possess to master scientific activities, particularly in inquiry-based learning (Edward et al., 2017; Stylinski et al., 2020). Low scientific reasoning skills will have an impact on the decline in the inquiry process received by students (Burgess et al., 2017; Edward et al., 2017; Gray et al., 2017; Phillips et al., 2018; Stylinski et al., 2020). This explanation corroborates the research findings that the majority of researchers utilise the inquiry model to facilitate SRS (Acar & Patton, 2016; Blumer & Beck, 2019; Kaiser & Mayer, 2019; Malone & Schuchardt, 2023; Novia & Riandi, 2017; Olschewski et al., 2023; Omarchevska et al., 2022; Orosz et al., 2022; Schlatter et al., 2020; Willemsen et al., 2023).

Guided inquiry-based science learning is the majority choice used by several researchers in facilitating SRS (Acar & Patton, 2016; Blumer & Beck, 2019; Kaiser & Mayer, 2019; Orosz et al., 2022). Guided inquiry makes it easy for learners to conduct investigations, allowing the inquiry process to be carried out systematically. Sahin & Oren found that the guided inquiry model proved to be able to influence the SRS (Sahin & Sasmaz Oren, 2022). In guided inquiry, the teacher plays a crucial role in directing pupils to understand the questions, conducting investigations, reaching accurate conclusions, and reflecting on the results (Orosz et al., 2022). Without appropriate guidance from the teacher, pupils are unlikely to grasp the purpose or process of scientific investigations, as they often lack the procedural knowledge and experience needed to conduct such inquiries independently (Hmelo-Silver et al., 2007). Blumer et al. corroborate that learning through guided inquiry can effectively facilitate SRS (Blumer & Beck, 2019).

Media-based inquiry models provide educators with ease in facilitating SRS. The use of worksheets is the media used by the majority of researchers worldwide. The use of inquiry-based worksheets makes it easier for students to conduct investigations. In inquiry-based learning, the worksheets used by researchers are the steps learners must take to test a hypothesis. Schlatter et al. found that inquiry-based learning facilitated by tiered worksheets is capable of enhancing scientific reasoning skills (Schlatter et al., 2022).

Science learning in facilitating SRS is often conducted using experimental research, which compares the experimental group with the control group. This type of research is chosen by researchers worldwide because, through experiments, treatments can be applied to determine whether they affect the dependent variables (Creswell, 2012). The existence of these treatments provides empirical evidence of the effects of the treatments. Thus, it can be clearly and accurately observed how SRS is developed in science learning.

The measurement of Scientific Reasoning Skills in science education is often conducted using the Lawson Classroom Test Scientific Reasoning (LCTSR). The LCTSR measures SRS across five dimensions: Conservation of matter and volume, proportional reasoning, control of variables, probability reasoning, correlation reasoning, and hypothetical-deductive reasoning. The Lawson Classroom Test Scientific Reasoning (LCTSR) is a popular instrument that measures the development of students' scientific reasoning skills (Cahyaningrum, 2019; Zhou et al., 2021). It is known that the

LCTSR instrument has good overall reliability. This test has been given to several thousand students and the results have been published where the test referred to using the LCTSR (Hrouzková & Richterek, 2021). Many researchers use this test because it is suitable for broader contexts, such as in universities, high schools, and middle schools (Hrouzková & Richterek, 2021). The results also have relevance to research subjects involving students, as conducted by researchers worldwide. The analysis results indicate that the majority of research on SRS is conducted in higher education institutions, as evidenced by studies (Alabdulaziz et al., 2022; Bruckermann et al., 2023; Coleman et al., 2023; Iwuanyanwu, 2023; Karakoyun & Asiltürk, 2021; Olschewski et al., 2023; Omarchevska et al., 2022; Parmin et al., 2022; Upmeier Zu Belzen et al., 2021; Vaesen & Houkes, 2021; Yoon et al., 2020).

In terms of the correlation between SRS and other variables, Problem-solving skills and conceptual understanding are the variables that have the most correlation with SRS. SRS is a skill that can encourage students to understand science concepts in depth. The search for these concepts requires good problem-solving skills. These skills will be needed later to find a solution. These results are relevant to the research conducted by Acar & Patton which demonstrates that SRS is closely related to students' conceptual understanding or misconceptions. (Acar & Patton, 2016). Other research has shown that students with low SRS also have high misconceptions (Acar, 2014). SRS plays an important role in developing problem-solving skills. The activities of observing phenomena, seeking literature to test hypotheses, conducting investigations, and drawing conclusions are activities that can improve problem-solving skills (Charysma et al., 2018; Iwuanyanwu, 2023).

Conclusion and Implications

The study showed that in 2021, SRS research in science education emerged as the most extensively studied area. In studies on scientific reasoning skills, empirical research predominates, as researchers seek measurable evidence of learners' reasoning processes and the effectiveness of instructional strategies through experimental or quasi-experimental designs. *Lawson's Classroom Test of Scientific Reasoning (LCTSR) became the most used instrument in research to measure SRS.* In terms of strategies that can be used to facilitate the SRS, it is through inquiry-based learning. The university level is the most studied institution to be the subject of research. Conceptual understanding and problem-solving skills are the skills that are most relevant to SRS research. Inquiry-based learning has been proven to be a learning model used by researchers worldwide to facilitate scientific reasoning skills. Modified inquiry learning can maximise scientific reasoning skills, such as using STEM-based inquiry learning.

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References

Acar, Ö. (2014). Scientific reasoning, conceptual knowledge, & achievement differences between prospective science teachers having a consistent misconception and those having a scientific conception in an argumentation-based guided inquiry course. *Learning and Individual Differences*, *30*, 148–154. https://doi.org/10.1016/j.lindif.2013.12.002

Acar, Ö., & Patton, B. R. (2016). Examination of learning equity among prospective science teachers who are concrete, formal and postformal reasoners after an argumentation-based inquiry course. *Australian Journal of Teacher Education*, *41*(2), 69–90. Scopus. https://doi.org/10.14221/ajte.2016v41n2.5

Acar, Ö., Türkmen, L., & Bilgin, A. (2015). Examination of gender differences on cognitive and motivational factors that influence 8th ömer acar graders' science achievement in turkey. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(5), 1027–1040. Scopus. https://doi.org/10.12973/eurasia.2015.1372a

Alabdulaziz, M. S., Hassan, H. F., & Soliman, M. W. (2022). The effect of the interaction between crowdsourced style and cognitive style on developing research and scientific thinking skills. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(10). Scopus. https://doi.org/10.29333/ejmste/12428

Bao, L., Cai, T., Koenig, K., Fang, K., Han, J., Wang, J., Liu, Q., Ding, L., Cui, L., Luo, Y., Wang, Y., Li, L., & Wu, N. (2009). Learning and Scientific Reasoning. *Science*, *323*(5914), 586–587. https://doi.org/10.1126/science.1167740

Bhaw, N., Kriek, J., & Lemmer, M. (2023). Insights from coherence in students' scientific reasoning skills. *Heliyon*, *9*(7), e17349. https://doi.org/10.1016/j.heliyon.2023.e17349

Bicak, B. E., Borchert, C. E., & Höner, K. (2021). Measuring and fostering preservice chemistry teachers' scientific reasoning competency. *Education Sciences*, *11*(9). Scopus. https://doi.org/10.3390/educsci11090496

Blumer, L. S., & Beck, C. W. (2019). Laboratory Courses with Guided-Inquiry Modules Improve Scientific Reasoning and Experimental Design Skills for the Least-Prepared Undergraduate Students. *CBE—Life Sciences Education*, *18*(1), ar2. https://doi.org/10.1187/cbe.18-08-0152

Bonilla-Chaves, E. F., & Palos-Sánchez, P. R. (2023). Exploring the Evolution of Human Resource Analytics: A Bibliometric Study. *Behavioral Sciences*, *13*(3), 244. https://doi.org/10.3390/bs13030244

Bruckermann, T., Greving, H., Schumann, A., Stillfried, M., Börner, K., Kimmig, S. E., Hagen, R., Brandt, M., & Harms, U. (2023). Scientific reasoning skills predict topic-specific knowledge after participation in a citizen science project on urban wildlife ecology. *Journal of Research in Science Teaching*, *60*(9), 1915–1941. https://doi.org/10.1002/tea.21835

Burgess, H. K., DeBey, L. B., Froehlich, H. E., Schmidt, N., Theobald, E. J., Ettinger, A. K., HilleRisLambers, J., Tewksbury, J., & Parrish, J. K. (2017). The science of citizen science: Exploring barriers to use as a primary research tool. *Biological Conservation*, *208*, 113–120. https://doi.org/10.1016/j.biocon.2016.05.014

Busalim, A. H., & Hussin, A. R. C. (2016). Understanding social commerce: A systematic literature review and directions for further research. *International Journal of Information Management*, *36*(6), 1075–1088. https://doi.org/10.1016/j.ijinfomgt.2016.06.005

Cabello, V. M., Moreira, P. M., & Morales, P. G. (2021). Elementary students' reasoning in drawn explanations based on a scientific theory. *Education Sciences*, *11*(10). Scopus. https://doi.org/10.3390/educsci11100581

Cahyaningrum, R. (2019). Lawson Instrument: Analyzing Student's Scientific Reasoning Skill in Junior High School. *Proceedings of the 6th International Conference on Community Development (ICCD 2019)*. Proceedings of the 6th International Conference on Community Development (ICCD 2019), Bandar Seri Begawan, Indonesia. https://doi.org/10.2991/iccd-19.2019.116

Charysma, D. V. R., Widoretno, S., & Dwiastuti, S. (2018). The Proportion of Problem Solving and Scientific Reasoning Skills in Biology References. *Journal of Education and Learning (EduLearn)*, *12*(4), 717–724. https://doi.org/10.11591/edulearn.v12i4.10224

Chen, H.-J. (2015). Effects of empowerment programs in remote junior high schools on scientific epistemological beliefs, self-regulation strategies, and academic achievement in science. *Journal of Research in Education Sciences*, *60*(4), 21–54. Scopus. https://doi.org/10.6209/JORIES.2015.60(4).02

Chen, J., Wang, M., Grotzer, T. A., & Dede, C. (2018). Using a three-dimensional thinking graph to support inquiry learning. *Journal of Research in Science Teaching*, *55*(9), 1239–1263. Scopus. https://doi.org/10.1002/tea.21450

Cheng, S.-C., She, H.-C., & Huang, L.-Y. (2018). The impact of problem-solving instruction on middle school students' physical science learning: Interplays of knowledge, reasoning, and problem solving. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(3), 731–743. Scopus. https://doi.org/10.12973/ejmste/80902

Coleman, A. B., Lorenzo, K., McLamb, F., Sanku, A., Khan, S., & Bozinovic, G. (2023). Imagining, designing, and interpreting experiments: Using quantitative assessment to improve instruction in scientific reasoning. *Biochemistry and Molecular Biology Education*, *51*(3), 286–301. Scopus. https://doi.org/10.1002/bmb.21727

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Pearson Education.

Cronin, P., Ryan, F., & Coughlan, M. (2008). Undertaking a literature review: A step-by-step approach. *British Journal of Nursing*, *17*(1), 38–43. https://doi.org/10.12968/bjon.2008.17.1.28059

Dewi, C. A., & Rahayu, S. (2024). Implementation of case-based learning in science education: A systematic review. *Journal of Turkish Science Education*, *20*(4), 729–749. https://doi.org/10.36681/tused.2023.041

Dewi, L., Susilana, R., Setiawan, B., Alias, N., & Zulnaidi, H. (2023). A Proposed Problem-Centered Thinking Skill (PCTS) Model at Secondary Schools in Indonesia and Malaysia. *International Journal of Instruction*, *16*(3), 615–638. Scopus. https://doi.org/10.29333/iji.2023.16333a

Ding, L. (2014). Verification of causal influences of reasoning skills and epistemology on physics conceptual learning. *Physical Review Special Topics - Physics Education Research*, *10*(2). Scopus. https://doi.org/10.1103/PhysRevSTPER.10.023101

Ding, L., Li, T., Jiang, S., & Gapud, A. (2023). Students' perceptions of using ChatGPT in a physics class as a virtual tutor. *International Journal of Educational Technology in Higher Education*, *20*(1), 63. https://doi.org/10.1186/s41239-023-00434-1

Ding, L., Wei, X., & Liu, X. (2016). Variations in University Students' Scientific Reasoning Skills Across Majors, Years, and Types of Institutions. *Research in Science Education*, *46*(5), 613–632. https://doi.org/10.1007/s11165-015-9473-y

Dowd, J. E., Thompson, R. J., Schiff, L., Haas, K., Hohmann, C., Roy, C., Meck, W., Bruno, J., & Reynolds, J. A. (2019). Student learning dispositions: Multidimensional profiles highlight important differences among undergraduate stem honors thesis writers. *CBE Life Sciences Education*, *18*(2). Scopus. https://doi.org/10.1187/cbe.18-07-0141

Edward, R., McDonnell, D., Simpson, I., & Wilson, A. (2017). *Educational backgrounds, project design, andinquiry learning in citizen science. In C. Herodotou, M. Sharples, & E. Scanlon (Eds.)* (Citizen inquiry: Syn-thesising science and inquiry learning). Routledge.

Ekici, M., & Erdem, M. (2020). Developing Science Process Skills through Mobile Scientific Inquiry. *Thinking Skills and Creativity*, *36*, 100658. https://doi.org/10.1016/j.tsc.2020.100658

Fischer, F., Bauer, E., Seidel, T., Schmidmaier, R., Radkowitsch, A., Neuhaus, B. J., Hofer, S. I., Sommerhoff, D., Ufer, S., Kuhn, J., Küchemann, S., Sailer, M., Koenen, J., Gartmeier, M., Berberat, P., Frenzel, A., Heitzmann, N., Holzberger, D., Pfeffer, J., … Fischer, M. R. (2022). Representational scaffolding in digital simulations – learning professional practices in higher education. *Information and Learning Science*, *123*(11–12), 645–665. Scopus. https://doi.org/10.1108/ILS-06-2022-0076

Gray, S., Jordan, R., Crall, A., Newman, G., Hmelo-Silver, C., Huang, J., Novak, W., Mellor, D., Frensley, T., Prysby, M., & Singer, A. (2017). Combining participatory modelling and citizen science to support volunteer conservation action. *Biological Conservation*, *208*, 76–86. https://doi.org/10.1016/j.biocon.2016.07.037

Hardy, I., Stephan-Gramberg, S., & Jurecka, A. (2021). The use of scaffolding to promote preschool children's competencies of evidence-based reasoning. *Unterrichtswissenschaft*, *49*(1), 91–115. Scopus. https://doi.org/10.1007/s42010-020-00094-4

Hasruddin, H., & Aulia, R. N. (2023). Students' scientific reasoning skills through RICOSRE model in environmental changes topic. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *9*(3), 445–451. https://doi.org/10.22219/jpbi.v9i3.29308

Heijnes, D., van Joolingen, W., & Leenaars, F. (2018). Stimulating Scientific Reasoning with Drawing-Based Modeling. *Journal of Science Education and Technology*, *27*(1), 45–56. Scopus. https://doi.org/10.1007/s10956-017-9707-z

Hejnová, E., Eisenmann, P., Cihlář, J., & Přibyl, J. (2018). Relations between scientific reasoning, culture of problem solving and pupil´s school performance. *Journal on Efficiency and Responsibility in Education and Science*, *11*(2), 38–44. Scopus. https://doi.org/10.7160/eriesj.2018.110203

Hester, S. D., Nadler, M., Katcher, J., Elfring, L. K., Dykstra, E., Rezende, L. F., & Bolger, M. S. (2018). Authentic Inquiry through Modeling in Biology (AIM-Bio): An Introductory Laboratory Curriculum That Increases Undergraduates' Scientific Agency and Skills. *CBE—Life Sciences Education*, *17*(4), ar63. https://doi.org/10.1187/cbe.18-06-0090

Hrouzková, T., & Richterek, L. (2021). Lawson Classroom Test of Scientific Reasoning at Entrance University Level. *Proceedings of the 4th International Baltic Symposium on Science and Technology Education (BalticSTE2021), Šiauliai, 21–22 June, 2021*, 74–85. https://doi.org/10.33225/BalticSTE/2021.74

Illescas-Navarro, M., Cruz-Guzmán Alcalá, M., Criado García-Legaz, A. M., & García-Carmona, A. (2025). Prospective primary teachers′ knowledge about breastfeeding as part of scientific literacy. *Journal of Turkish Science Education*, *22*(1), 87–105. https://doi.org/10.36681/tused.2025.006

Istyadji, M. & Sauqina. (2023). Conception of scientific literacy in the development of scientific literacy assessment tools: A systematic theoretical review. *Journal of Turkish Science Education*, *20*(2), 281–308. https://doi.org/10.36681/tused.2023.016

Iwuanyanwu, P. N. (2023). When Science Is Taught This Way, Students Become Critical Friends: Setting the Stage for Student Teachers. *Research in Science Education*, *53*(6), 1063–1079. Scopus. https://doi.org/10.1007/s11165-023-10122-9

Kaçar, S. (2023). Thematic content analysis of postgraduate theses on epistemological beliefs in science education: The Türkiye context: Research Article. *Journal of Turkish Science Education*, *20*(3), 504–533. https://doi.org/10.36681/tused.2023.029

Kaiser, I., & Mayer, J. (2019). The Long-Term Benefit of Video Modeling Examples for Guided Inquiry. *Frontiers in Education*, *4*. Scopus. https://doi.org/10.3389/feduc.2019.00104

Kambeyo, L., & Scapo, B. (2018). Scientific reasoning skills: A theoretical background on science education. *Reform Forum*, *1*, 27–36.

Karakoyun, G. Ö., & Asiltürk, E. (2021). The role of heuristics in the reasoning process of pre-service science teachers on the "chemical structure – acidity/basicity relationship" topic. *Acta Chimica Slovenica*, *63*(3), 645–657. Scopus. https://doi.org/10.17344/ACSI.2021.6666

Kirya, K. R., Mashood, K. K., & Yadav, L. L. (2024). Development of a Circular Motion Concept Inventory for Use in Ugandan Science Education. *Journal of Turkish Science Education*, *20*(1). https://doi.org/10.36681/tused.2022.176

Kulakli, A., & Osmanaj, V. (2020). Global Research on Big Data in Relation with Artificial Intelligence (A Bibliometric Study: 2008-2019). *International Journal of Online and Biomedical Engineering (iJOE)*, *16*(02), 31. https://doi.org/10.3991/ijoe.v16i02.12617

Kurniahtunnisa, Wola, B. R., Harahap, F., Tumewu, W. A., & Warouw, Z. W. M. (2024). Research trends of science process skills in Indonesian science education journals. *Journal of Turkish Science Education*, *21*(4), 668–687. https://doi.org/10.36681/tused.2024.036

Kurniawan, D. A., Astalini, A., Darmaji, D., & Melsayanti, R. (2019). Students' attitude towards natural sciences. *International Journal of Evaluation and Research in Education (IJERE)*, *8*(3), 455. https://doi.org/10.11591/ijere.v8i3.16395

Lawson, A. E. (2004). The Nature and Development of Scientific Reasoning: A Synthetic View. *International Journal of Science and Mathematics Education*, *2*(3), 307–338. https://doi.org/10.1007/s10763-004-3224-2

Lehrer, R., & Schauble, L. (2007). Scientific Thinking and Science Literacy. In W. Damon & R. M. Lerner (Eds.), *Handbook of Child Psychology* (1st ed.). Wiley. https://doi.org/10.1002/9780470147658.chpsy0405

Liberati, A. (2009). The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. *Annals of Internal Medicine*, *151*(4), W. https://doi.org/10.7326/0003-4819-151-4-200908180-00136

Lin, T.-C., Lin, T.-J., & Tsai, C.-C. (2014). Research Trends in Science Education from 2008 to 2012: A systematic content analysis of publications in selected journals. *International Journal of Science Education*, *36*(8), 1346–1372. https://doi.org/10.1080/09500693.2013.864428

Malone, K. L., & Schuchardt, A. (2023). Modelling-based pedagogy as a theme across science disciplines–Effects on scientific reasoning and content understanding. *European Journal of Science and Mathematics Education*, *11*(4), 717–737. Scopus. https://doi.org/10.30935/scimath/13516

Marušić, M., & Dragojević, A. (2020). Assessing pharmacy students' scientific reasoning after completing a physics course taught using active-learning methods. *American Journal of Pharmaceutical Education*, *84*(8), 1112–1122. Scopus. https://doi.org/10.5688/ajpe7610

Mendoza, B. J. R., Diaz, M. M. O.-D., & Silva, L. C. M. (2018). Strengthening of reasoning levels in higher education students through the use of learning strategies (problem-based learning and collaborative learning) using ICT's. *Electronic Journal of Research in Educational Psychology*, *16*(45), 477–502. Scopus. https://doi.org/10.25115/ejrep.v16i45.2102

Miftakhul Falah, M., Hartono, H., Eko Nugroho, S., & Ridlo, S. (2024). Socio-scientific Issues (SSI) research trends: A systematic literature review of publications 2011 – 2022. *Journal of Turkish Science Education*, *21*(1), 61–81. https://doi.org/10.36681/tused.2024.004

Moher, D. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The Prisma Statement. *Annals of Internal Medicine*, *151*(4), 264. https://doi.org/10.7326/0003-4819-151-4-200908180-00135

Moore, J. C., & Rubbo, L. J. (2012). Scientific reasoning abilities of nonscience majors in physics-based courses. *Physical Review Special Topics - Physics Education Research*, *8*(1), 010106. https://doi.org/10.1103/PhysRevSTPER.8.010106

Nagy, M. T., & Korom, E. (2023). Measuring Scientific Reasoning of Fourth Graders: Validation of the Science-K Inventory in Paper-Based and Computer-Based Testing Environments. *Journal of Baltic Science Education*, *22*(6), 1050–1062. https://doi.org/10.33225/jbse/23.22.1050

Novia, N., & Riandi, R. (2017). The analysis of students scientific reasoning ability in solving the modified lawson classroom test of scientific reasoning (MLCTSR) problems by applying the levels of inquiry. *Jurnal Pendidikan IPA Indonesia*, *6*(1), 116–122. Scopus. https://doi.org/10.15294/jpii.v6i1.9600

Nundy, S., Kakar, A., & Bhutta, Z. A. (2022). How to Do a Review of the Literature? In S. Nundy, A. Kakar, & Z. A. Bhutta, *How to Practice Academic Medicine and Publish from Developing Countries?* (pp. 201–212). Springer Nature Singapore. https://doi.org/10.1007/978-981-16-5248-6_18

Nyberg, K., Koerber, S., & Osterhaus, C. (2020). How to measure scientific reasoning in primary school: A comparison of different test modalities. *European Journal of Science and Mathematics Education*, *8*(3), 136–144. Scopus. https://doi.org/10.30935/scimath/9552

Oh, J.-Y. (2017). Suggesting a NOS Map for Nature of Science for Science Education Instruction. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(5). https://doi.org/10.12973/eurasia.2017.00680a

Olschewski, P., Herzmann, P., & Schlüter, K. (2023). Group Work during Inquiry-Based Learning in Biology Teacher Education: A Praxeological Perspective on the Task of (Collaborative) Protocol Generation. *Education Sciences*, *13*(4). Scopus. https://doi.org/10.3390/educsci13040401

Omarchevska, Y., Lachner, A., Richter, J., & Scheiter, K. (2022). It takes two to tango: How scientific reasoning and self-regulation processes impact argumentation quality. *Journal of the Learning Sciences*, *31*(2), 237–277. Scopus. https://doi.org/10.1080/10508406.2021.1966633

Orosz, G., Németh, V., Kovács, L., Somogyi, Z., & Korom, E. (2022). Guided inquiry-based learning in secondary-school chemistry classes: A case study. *Chemistry Education Research and Practice*, *24*(1), 50–70. Scopus. https://doi.org/10.1039/d2rp00110a

Owens, D. C., Petitt, D. N., Lally, D., & Forbes, C. T. (2020). Cultivating water literacy in stem education: Undergraduates' socio-scientific reasoning about socio-hydrologic issues. *Water (Switzerland)*, *12*(10). Scopus. https://doi.org/10.3390/w12102857

Özkul, H., & Özden, M. (2020). Investigation of the Effects of Engineering-Oriented STEM Integration Activities on Scientific Process Skills and STEM Career Interests: A Mixed Methods Study. *Egitim ve Bilim*, *45*(204), 41–63. Scopus. https://doi.org/10.15390/EB.2020.8870

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Journal of Clinical Epidemiology*, *134*, 178–189. https://doi.org/10.1016/j.jclinepi.2021.03.001

Parmin, P., Khusniati, M., El Islami, R. A. Z., Deta, U. A., & Saregar, A. (2022). Online Scientific Argumentation Strategy on Improving Pre-Service Science Teachers' Scientific Reasoning through Experiment Activity: A Case Study in Indonesia. *Perspektivy Nauki i Obrazovania*, *55*(1), 607–619. Scopus. https://doi.org/10.32744/pse.2022.1.39

Phillips, T., Porticella, N., Constas, M., & Bonney, R. (2018). A Framework for Articulating and Measuring Individual Learning Outcomes from Participation in Citizen Science. *Citizen Science: Theory and Practice*, *3*(2), 3. https://doi.org/10.5334/cstp.126

Rampean, B. A. O., & Rohaeti, E. (2025). The development of an integrated instrument to measure higher order thinking skills and scientific attitudes. *Journal of Turkish Science Education*, *22*(1), 48–62. https://doi.org/10.36681/tused.2025.004

Rehman, Z. U., Baharun, R., & Salleh, N. Z. M. (2020). Antecedents, consequences, and reducers of perceived risk in social media: A systematic literature review and directions for further research. *Psychology & Marketing*, *37*(1), 74–86. https://doi.org/10.1002/mar.21281

Rost, M., & Knuuttila, T. (2022). Models as Epistemic Artifacts for Scientific Reasoning in Science Education Research. *Education Sciences*, *12*(4). Scopus. https://doi.org/10.3390/educsci12040276

Russ, R. S., & Odden, T. O. B. (2017). Intertwining evidence- and model-based reasoning in physics sensemaking: An example from electrostatics. *Physical Review Physics Education Research*, *13*(2). Scopus. https://doi.org/10.1103/PhysRevPhysEducRes.13.020105

Sahin, F., & Sasmaz Oren, F. (2022). Laboratory as an Instrument in Improving the Scientific Reasoning Skills of Pre-Service Science Teachers with Different Cognitive Styles. *Science Insights Education Frontiers*, *13*(2), 1875–1897. https://doi.org/10.15354/sief.22.or072

Saputri, A. C., Sajidan, S., Rinanto, Y., Afandi, A., & Prasetyanti, N. M. (2019). Improving Students' Critical Thinking Skills in Cell-Metabolism Learning Using Stimulating Higher Order Thinking Skills Model. *International Journal of Instruction*, *12*(1), 327–342. https://doi.org/10.29333/iji.2019.12122a

Schlatter, E., Molenaar, I., & Lazonder, A. W. (2020). Individual Differences in Children's Development of Scientific Reasoning Through Inquiry-Based Instruction: Who Needs Additional Guidance? *Frontiers in Psychology*, *11*. Scopus. https://doi.org/10.3389/fpsyg.2020.00904

Schlatter, E., Molenaar, I., & Lazonder, A. W. (2021). Learning scientific reasoning: A latent transition analysis. *Learning and Individual Differences*, *92*. Scopus. https://doi.org/10.1016/j.lindif.2021.102043

Schlatter, E., Molenaar, I., & Lazonder, A. W. (2022). Adapting scientific reasoning instruction to children's needs: Effects on learning processes and learning outcomes. *International Journal of Science Education*, *44*(17), 2589–2612. Scopus. https://doi.org/10.1080/09500693.2022.2140019

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses. *Annual Review of Psychology*, *70*(1), 747–770. https://doi.org/10.1146/annurev-psych-010418-102803

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Stylinski, C. D., Peterman, K., Phillips, T., Linhart, J., & Becker-Klein, R. (2020). Assessing science inquiry skills of citizen science volunteers: A snapshot of the field. *International Journal of Science Education, Part B*, *10*(1), 77–92. https://doi.org/10.1080/21548455.2020.1719288

Suryandari, K. C., Rokhmaniyah, R., Salimi, M., & Fatimah, S. (2022). Involvement of Teachers, Parents, and School Committees in Improving Scientific Attitudes of Elementary School Students: Application of Rasch Model Analysis. *International Journal of Educational Methodology*, *8*(4), 783–794. https://doi.org/10.12973/ijem.8.4.783

Tsai, C., & Lydia Wen, M. (2005). Research and trends in science education from 1998 to 2002: A content analysis of publication in selected journals. *International Journal of Science Education*, *27*(1), 3–14. https://doi.org/10.1080/0950069042000243727

Ubaidillah, M., Hartono, H., Marwoto, P., Wiyanto, W., & Subali, B. (2023). How to Improve Critical Thinking in Physics Learning? A Systematic Literature Review. *Journal of Educational, Cultural and Psychological Studies (ECPS Journal)*, *28*, 8. https://doi.org/10.7358/ecps-2023-028-ubai

Upmeier Zu Belzen, A., Engelschalt, P., & Krüger, D. (2021). Modeling as scientific reasoning—The role of abductive reasoning for modeling competence. *Education Sciences*, *11*(9). Scopus. https://doi.org/10.3390/educsci11090495

Ülger, B. B. (2021). An Adaptation Study for the Measurement of Scientific Process Skills for Gifted Students in Science: The Diet Cola Test. *Journal of Turkish Science Education,* 18(3), 542-554.

Vaesen, K., & Houkes, W. (2021). A new framework for teaching scientific reasoning to students from application-oriented sciences. *European Journal for Philosophy of Science*, *11*(2). Scopus. https://doi.org/10.1007/s13194-021-00379-0

van der Graaf, J., Segers, E., & Verhoeven, L. (2015). Scientific reasoning abilities in kindergarten: Dynamic assessment of the control of variables strategy. *Instructional Science*, *43*(3), 381–400. Scopus. https://doi.org/10.1007/s11251-015-9344-y

van der Graaf, J., Segers, E., & Verhoeven, L. (2018). Individual differences in the development of scientific thinking in kindergarten. *Learning and Instruction*, *56*, 1–9. Scopus. https://doi.org/10.1016/j.learninstruc.2018.03.005

Van Vo, D., & Csapó, B. (2023). Exploring Inductive Reasoning, Scientific Reasoning and Science Motivation, and Their Role in Predicting STEM Achievement Across Grade Levels. *International Journal of Science and Mathematics Education*, *21*(8), 2375–2398. Scopus. https://doi.org/10.1007/s10763-022-10349-4

Webster, J., & Watson, R. T. (2002). Analyzing the Past to Prepare for the Future: Writing a Literature Review. *Management Information Systems Quarterly*, *26*.

Wei, Y., Zhang, Q., Guo, J., & Chen, M. (2023). Learning to teach through noticing: A bibliometric review of teacher noticing research in mathematics education during 2006–2021. *Humanities and Social Sciences Communications*, *10*(1), 218. https://doi.org/10.1057/s41599-023-01718-7

Willemsen, R. H., de Vink, I. C., Kroesbergen, E. H., & Lazonder, A. W. (2023). The role of creative thinking in children's scientific reasoning. *Thinking Skills and Creativity*, *49*. Scopus. https://doi.org/10.1016/j.tsc.2023.101375

Woolley, J. S., Deal, A. M., Green, J., Hathenbruck, F., Kurtz, S. A., Park, T. K. H., Pollock, S. V., Transtrum, M. B., & Jensen, J. L. (2018). Undergraduate students demonstrate common false scientific reasoning strategies. *Thinking Skills and Creativity*, *27*, 101–113. Scopus. https://doi.org/10.1016/j.tsc.2017.12.004

Yang, L., Sun, T., & Liu, Y. (2017). A Bibliometric Investigation of Flipped Classroom Research during 2000-2015. *International Journal of Emerging Technologies in Learning (iJET)*, *12*(06), 178. https://doi.org/10.3991/ijet.v12i06.7095

Yanto, B. E., Subali, B., & Suyanto, S. (2019). Improving Students' Scientific Reasoning Skills through the Three Levels of Inquiry. *International Journal of Instruction*, *12*(4), 689–704. https://doi.org/10.29333/iji.2019.12444a

Yoon, J., Jo, T.-J., & Kang, S.-J. (2020). A study on the possibility of the relationship among group creativity, empathy, and scientific inquiry ability of elementary school students. *International Journal of Science Education*, *42*(13), 2113–2125. https://doi.org/10.1080/09500693.2020.1813347

Zhou, S.-N., Liu, Q.-Y., Koenig, K., Li, Q., Xiao, Y., & Bao, L. (2021). Analysis of Two-Tier Question Scoring Methods: A Case Study on The Lawson's Classroom Test Of Scientific Reasoning. *Journal of Baltic Science Education*, *20*(1), 146–159. https://doi.org/10.33225/jbse/21.20.146

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review*, *27*(2), 172–223. https://doi.org/10.1016/j.dr.2006.12.001