Journal of Turkish Science Education, 2026, *23*(2), 226-251.
DOI no: 10.36681/tused.2026.011

The Refutation Text (RT) as a bridge for scientific conceptual change in science education: A systematic literature review

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ABSTRACT
This research aimed to explore the role of refutation texts within the domain of science education. A systematic literature review (SLR) was conducted following the PRISMA guidelines to analyse 41 selected articles indexed in Scopus (Q1–Q3). The inclusion criteria require that all articles be published in English and focus specifically on refutation texts in the field of science education. The findings reveal that refutation texts define this term in the science domain have been published in six countries, the United Kingdom (n = 16), the United States (n = 11), the Netherlands (n = 9), Turkey (n = 3), Switzerland (n = 1), and Lithuania (n = 1). Methodologically, the reviewed studies employed quantitative (n = 36), qualitative (n = 3), and mixed methods (n = 2) approaches. Refutation texts were found to be implemented across various educational levels, ranging from primary school to university undergraduates. Furthermore, the use of refutation texts was shown to contribute to three core educational components: cognitive processes, pedagogical insights, and conceptual change. This study highlights current trends and the pedagogical significance of refutation texts in science learning, particularly in enhancing conceptual understanding and promoting deeper learning.

RESEARCH ARTICLE

ARTICLE INFORMATION
Received: 27.01.2025
Accepted: 09.07.2025
Available Online: 12.05.2026

KEYWORDS:
Conceptual change, refutation texts, science education, conceptual understanding, cognitive process.

To cite this article: Amiruddin, M. Z. B., Winarno, N., Samsudin, A., Suhandi, A., Costu, B., & Kapıcı, H. Ö. (2026). The Refutation Text (RT) as a bridge for scientific conceptual change in science education: A systematic literature review. *Journal of Turkish Science Education, 23*(2), 226-251. http://doi.org/10.36681/tused.2026.011

Introduction

Scientific concepts are an essential component of science education. The terms ‘alternative conceptions’, ‘preconceptions’, or ‘misconceptions’ are often used interchangeably to describe learners understandings that are inconsistent with established scientific theories and knowledge (Assem et al., 2023; Gilbert & Watts, 1983; Larkin, 2012). Several examples of misconceptions in physics topics

include work and energy (Samsudin et al., 2025a), momentum and impulse (Samsudin et al., 2025b). According to Fries et al. (2021), Önder (2006), Schwarz et al. (2009), and Vosniadou and Brewer (1994), scientific knowledge is not acquired suddenly but requires a long and gradual process to be accurately assimilated. The process of forming scientific conceptions occurs when learners connect their understanding of something with a scientific explanation (De Andrade et al., 2019; Schwarz et al., 2009; Wu & Puntambekar, 2012). However, it is important to note that when the understanding expressed is inconsistent, it has the potential to become a misconception. Therefore, it is crucial to handle such situations with care and attention in science learning.

In order to master and apply scientific explanations effectively, learners must develop a strong conceptual understanding of the subject matter. Such understanding enables them to comprehend scientific explanations, recognise errors in their intuitive thinking, and learn more effectively from experts (Chi et al., 1989; Glaser, 1991; Smith III et al., 1994). In response to this need, recent research has focused on learning approaches that promote conceptual change, particularly through the use of targeted strategies (Pettersson, 2021), instructional materials (Al Mamun et al., 2020), and text-based interventions (e.g., Arya & Maul, 2016; McNamara et al., 1996; Tobler et al., 2024). However, many of the texts currently employed, especially those found in educational repositories, are not optimally designed to support conceptual change. As a result, there is a growing need for innovative text designs that more effectively challenge misconceptions and support the construction of accurate scientific understanding. One such innovation involves the development of conceptual change texts and refutation texts, which have been introduced with the aim of bridging the gap between prior conceptions and scientifically accepted ideas. Refutation texts, in particular, are designed to explicitly confront learners' misconceptions by first stating the incorrect idea, then refuting it, and finally presenting the correct scientific concept. This structure has been shown to be effective in promoting deeper conceptual understanding and long-term learning.

This research presents a systematic literature review of refutation texts to analyse and synthesize how these texts contribute to conceptual change in science education. Refutation texts were selected as the central focus of the review due to their unique potential in addressing persistent misconceptions—an issue widely recognised in the teaching and learning of science. Misconceptions are not merely random or unintentional errors in understanding; rather, they often represent learners' active attempts to make sense of new scientific information based on their prior experiences and everyday reasoning. By highlighting the role of refutation texts, the study underscores the importance of confronting learners' pre-existizng conceptions directly and constructively, thereby facilitating meaningful conceptual change and improving science learning outcomes.

Refutation Texts as Agents of Conceptual Change

One strategy to encourage learners to consider the conflict between their ideas and those presented in the text is to use refutation statements (Broughton et al., 2010; Tippett, 2010). Refutation texts are designed to promote conceptual change learning by explicitly acknowledging commonly held alternative conceptions about a topic, directly rejecting them, and providing more comprehensive explanations (Dole, 2000; Hynd, 2003; Hynd et al., 1994; Mason et al., 2017; Sinatra & Broughton, 2011). Refutational texts are frequently employed to address scientifically incompatible conceptions and have been shown to be effective (Dersch et al., 2022; Sinatra & Broughton, 2011; Tippett, 2010). In a refutation text, non-scientific assumptions (or their misunderstandings) are introduced and promptly refuted. According to Kendeou and Van Den Broek (2007); Van Den Broek and Kendeou (2008), research suggests that this approach allows learners to activate both naïve and scientific ideas in memory simultaneously, facilitating comparison and identification of contradictions. Learners are more likely to adjust their thinking when they encounter contradictory information.

Most of the learning materials used in schools are in written form, and learning is very dependent on pupils' ability to read the contents of the text (Brigham et al., 2011), build mental representations of the information contained in the text, and integrate these mental representations

with previous knowledge (Derman et al., 2019). This process is very complex and requires the reader to establish consistency between prior knowledge and mental representations of new information. Therefore, in the context of scientific texts, consistency often requires the readjustment of prejudices or perceptions when previous knowledge does not align with the new information being processed. The refutation texts were developed to address this potential consistency imbalance by directly highlighting the misunderstanding. Refutation texts consist of several elements, (i) identify common misunderstandings that students have about a topic, (ii) firmly refute those misunderstandings, (iii) and present scientific explanations as attractive alternatives (Ariasi et al., 2017; Asterhan & Resnick, 2020; Mason et al., 2008; Weingartner & Masnick, 2019). The refutation texts that correspond to the example given are presented as follows:

> "Many people believe that the only greenhouse gas emitted by human activity is carbon dioxide (CO2). **However, this is not quite true**. Greenhouse gasses also consist of varying amounts of water vapour and such gasses as methane, nitrous oxide, ozone, and fluorinated gasses"
> "Some believe recent changes in global average temperature are caused by natural factors alone. **However, scientific research suggests that this is not quite true**. Existing evidence suggests that current climate change is largely caused by human activities, such as increased greenhouse gas emissions from burning fossil fuels and deforestation."

Research on the use of refutation texts to stimulate conceptual change is theoretically rooted in Piaget's concept of accommodation (Posner et al., 1982). Accommodation occurs when existing schemas or knowledge are changed or completely replaced with new schemas or knowledge in response to new information. The use of refutation texts has been widely researched (Hynd et al., 1994; Mason et al., 2019; Zengilowski et al., 2022) and has proven to be effective in science learning contexts. In contrast to traditional expository texts, refutation texts highlight differences between learners' previous knowledge or beliefs and scientific explanations, thereby increasing the possibility of consistency (Vosniadou, 2020). Researchers have claimed that new approaches with refutation texts can also increase students' engagement with the material (Sinatra & Broughton, 2011). Deeper engagement can occur when learners find the refutation text relevant, especially when the misconceptions identified in the text coherently align with their misconceptions. This can encourage them to evaluate scientific explanations in refutation texts more critically than if they were only given expository texts. In addition, evidence shows that refutation texts are most effective when readers' attention is directed to the conflict between their conception and the scientific conception, both are activated, integrated, and compared, while at the same time, there is evidence that supports the highly interconnected scientific conception. More intensive engagement with refutational texts can increase the likelihood of conceptual change and promote progress in science learning (Dole, 2000).

Scientific Conceptual Change in Science Education

Prior knowledge, especially in terms of its quality, has a significant impact on the learning of a particular topic (Ausubel, 2012; Cook, 2006). Prior knowledge can support the learning process when combined with new information, but can also hinder learning if there is a discrepancy between existing and new information (Hafizhah Putri et al., 2022). Although misconceptions are present in almost every field of study, they appear to be more common in the context of science due to the large number of people who experience them (Tippett, 2010). Some strong misconceptions about basic phenomena in science develop from an early age and continue to be reinforced by everyday experiences in mainstream culture (Sinatra et al., 2008; Vosniadou, 2020). The conceptual change approach refers to the process of correcting or replacing inaccurate understanding with scientific knowledge (Mason & Zaccoletti, 2021; Vosniadou & Brewer, 1994).

This is a process in which inappropriate ideas that learners have developed change into ideas that are more in line with science (Posner et al., 1982) .Conceptual change involves several

contributing components that must be considered in efforts to construct knowledge (Nadelson et al., 2018). Conceptual change learning occurs when learners change or replace their initial conceptions with new conceptions (Amin et al., 2014). This is not just replacing old, wrong conceptions with new concepts, but opening up new conceptual space (Amin et al., 2014). Thus, conceptual change includes abandoning and revising certain previously existing conceptions and realizing interconnections and relationships between concepts that may have never been thought of before. Conceptual change is usually very difficult to achieve because everyday conceptions are often so strong that abandoning them and gaining a new perspective is not easy. Achieving conceptual change usually requires a person to be aware of the gap between his or her conceptions and scientific ideas and to be willing to change his or her conceptions to be more aligned with science (Posner et al., 1982; Treagust & Duit, 2008; Vosniadou, 2007). That is why systematic learning and teaching is often a prerequisite for conceptual change (Duit, 1999; Sinatra et al., 2014).

In the domain of conceptual change, researchers have conducted extensive studies regarding key ideas such as characteristics and types of conceptual change (Murphy & Alexander, 2009; Nadelson et al., 2018; Sinatra & Mason, 2013; Vosniadou et al., 2008). One of the early models that considers conceptual change is the Conceptual Change Model (CCM), which identifies four general conditions under which change occurs (Posner et al., 1982). Firstly, students must feel dissatisfied with the existing concept because it is considered inadequate in solving the problems they face. Secondly, the new conception must be understandable by the learner. Thirdly, new information must make sense to learners based on their understanding of the world. Finally, the new information must be useful in explaining other phenomena or solving other problems.

The Present Study

Some previous research only focuses on the impact of refutation texts on conceptual change (Tippett, 2010); reading refutation texts is better than traditional expository texts for producing conceptual change (Schroeder et al., 2022a; Schroeder & Kucera, 2022b); and criticising methodological and theoretical limitations (Zengilowski et al., 2021). Previous research has more directly used refutation texts for conceptual change (e.g., Sinatra & Broughton, 2011; Weingartner & Masnick, 2019; Asterhan & Resnick, 2020). However, previous studies have not presented information related to the distribution of refutation texts in science education (e.g., publication trends, top countries publication, methods used, content areas). In addition, this research has also not presented benefits such as cognitive process and pedagogical impact.

Therefore, the aim of the research will be to complement and add to this gap by exploring the impact of text refutation on scientific conceptions in science learning, through a comprehensive review of the literature. More specifically, this study aims to investigate how text refutation can help to identify and correct misconceptions, while also facilitating the transfer of scientific concepts by building connections between prior knowledge and new information. Following a comprehensive review of the literature and understanding of refutation texts, we have drawn up the following research question (RQ):

RQ1: What is the distribution of refutational texts research trends?
RQ2: What are the benefits of refutation texts in science learning?

Methods

Systematic literature review (SLR) research is carried out using the PRISMA model which is able to explore and provide in-depth studies on a topic. According to Moher et al. (2015); Page et al. (2021), applying the PRISMA model in analysis helps improve the quality and openness of reports by providing an in-depth theoretical understanding and a structured approach to researching a topic thoroughly. Apart from that, it is able to provide appropriate direction to display the current state of

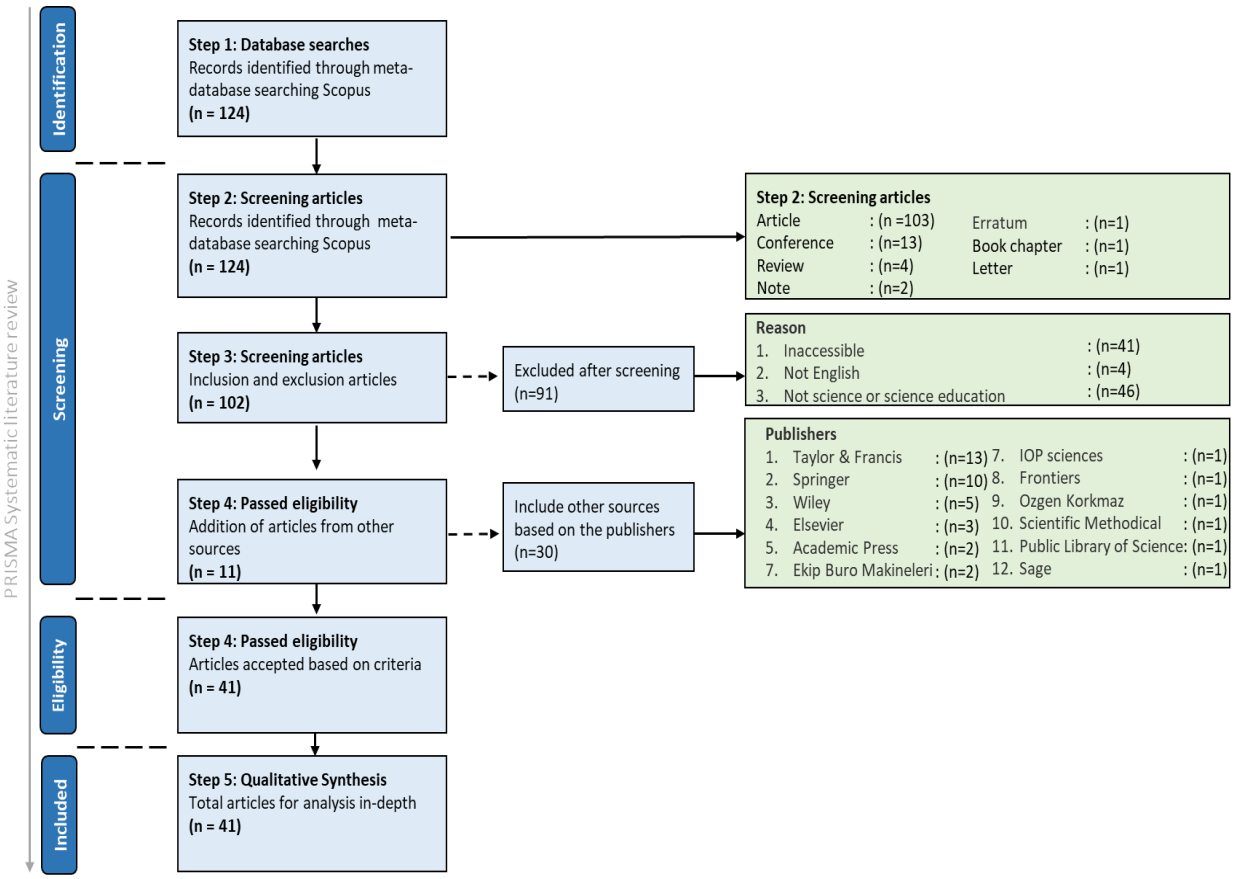
knowledge in a research area. The PRISMA model is implemented by utilising four stages to conduct a systematic literature review, being identification, screening, eligibility and inclusion, and determining which articles will be included or not included. Through the PRISMA model, standards for reporting evidence-based results can be met, thereby increasing the reproducibility of findings through robust, accurate, and comprehensive reporting of research questions. That way, it allows researchers to take advantage and reach significant conclusions from the data.

Search Criteria, Database, and Keywords

Initially, searches were carried out only using the Scopus meta-database with keywords or the search string "TITLE-ABS-KEY ("Refutation Text" OR "Refutation Text"), then limiting the year of publication by adding criteria "TITLE-ABS-KEY ("Refutation Text" OR " Refutational Text") AND PUB YEAR > 2012 AND PUB YEAR < 2024)". After that, this study delimited once more to ensure greater precsion with the string "TITLE-ABS-KEY ("Refutation Text" OR "Refutation Text") ANDPUB YEAR > 2012 AND PUB YEAR < 2024 AND (LIMIT-TO (DOCTYPE, "ar")). Then, the keywords "TITLE-ABS-KEY (Refutation Text" OR "Refutation Text") AND PUB YEAR > 2012 AND PUB YEAR < 2024 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")). This range of years was chosen to ensure the relevance of the findings to recent developments in science education, particularly with regard to the use of refutation texts. However, the database found is still not specific to science learning so it needs to be explored more deeply. In this way, the search keywords "Refutation Text" OR "Refutation Text" AND "Conceptual Change Text" are used in various databases (Taylor & Francis, ScienceDirect, Springer, ERIC, Sage Journal, MDPI, Wiley, Proquest, Google Scholar, and Semantic Scholar) and publisher credible (see Figure 1).

Figure 1

The screening procedure



Article Inclusion and Exclusion

To be included in this study, the topic of each article had to be relevant to conceptual change texts, particularly those employing refutation texts. All of articles used in this study were indexed in Scopus, an internationally recognized and credible database. Step 3 is done from the source database Scopus which is taken and then in screening where the results are visible at step 4. Thus, an alternative approach was employed by manually searching top and reputable publishers using additional keywords, with the requirement that the articles had a close connection to refutation text research. Furthermore, the selected articles had to be written in English and be open access to enable an in-depth analysis of the topic. Besides that, inclusion and exclusion were also based on our research objectives. Although the initial search was restricted to publications between 2012 and 2024, several seminal studies published before 2012 were identified during the screening and eligibility stages and were retained in the final review because of their significant theoretical and empirical contributions to the development of refutation text and conceptual change research.

Findings

RQ1: What is the distribution of refutational texts research trends?

The Yearly Publication Number

The distribution of annual publications presented is an illustration or mapping related to the trend of refutation of text over time. The search covered the years 1989 to 2023 and was examined in greater depth to include only articles related to science education. In this way, cumulative publications related to refutation texts in science learning are presented in Figure 2.

Figure 2

The annual publication

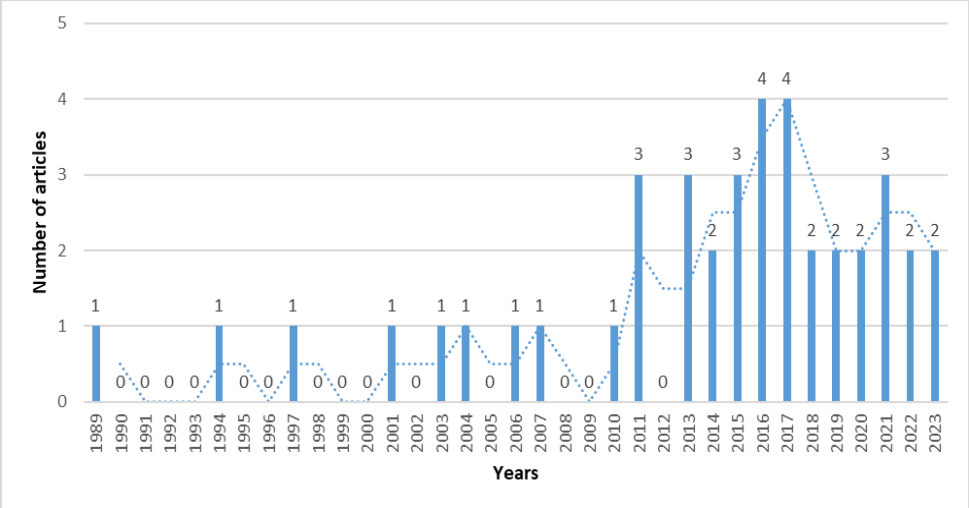


Figure 2 presents the distribution of refutation text articles in science learning. Based on the data presented in Figure 2, it can be seen that the highest number of articles is 4 documents and the least is 1 document. On the other hand, there are years without any publications related to refutation text. Research related to refutation in 2023 contained only 2 article documents.

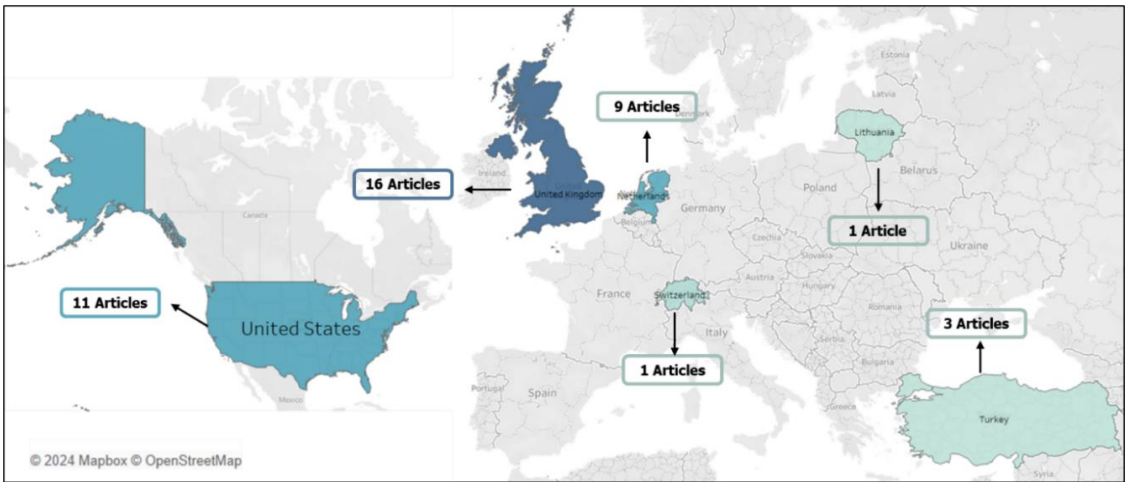
The Country of This Study

The country can be a publication reference for expertise in the field of text refutation in science learning. We need to know the distribution of countries to provide information related to research

development topics in a country. The following shows the countries with the number of publications in the field of refutation text in Figure 3.

Figure 3

The map of countries' publications of refutation texts



Based on Figure 3, we can see that of the 41 articles that have been published regarding refutational texts in science education, they are only distributed in six countries. The countries that dominate are the United Kingdom with 16 articles (40%), the United States with 11 articles (28%), and the Netherlands with 9 articles (21%). Meanwhile, Turkey with 3 articles (7%), Switzerland with 1 article (2%), and Lithuania with 1 article (2%) have very few publications in the field of refutation texts. This shows that the topic of refutation texts is still not widely spread because it is only in 6 countries. Thus, the opportunity to apply refutation texts to countries not listed above is huge and could even be new to the country.

The Journal Source Spread

Sources that publish publications related to refutation texts are very diverse, both from journals and publishers. This diversity can be a future goal for publishing articles related to refutation texts. The details are presented in Table 1.

Table 1

The Journal and publisher spread

Name of Journal	f	Publisher	Index By	SJR (2023)	H-Index	Country
PloS ONE	1	Public Library of Science	Scopus (Q1)	0.84	435	United States
Computer & Education	1	Elsevier Ltd	Scopus (Q1)	3.65	232	United Kingdom
Journal of Research in Science Teaching	2	John Wiley & Sons Inc.	Scopus (Q1)	1.91	157	United States
Learning and Instruction	2	Elsevier B.V.	Scopus (Q1)	2.36	144	United Kingdom
Science Education	1	Wiley-Liss Inc.	Scopus (Q1)	1.54	135	United States

Name of Journal	f	Publisher	Index By	SJR (2023)	H-Index	Country
Contemporary Educational Psychology	2	Academic Press Inc.	Scopus (Q1)	3.86	130	United States
International Journal of Science Education	3	Taylor and Francis Ltd	Scopus (Q1)	0.97	126	United Kingdom
Journal of Educational Research	2	Routledge	Scopus (Q2)	0.65	90	United States
Journal of Science Education and Technology	3	Springer	Scopus (Q1)	1.6	80	Netherlands
Journal of Educational Computing Research	1	Sage Publication Inc.	Scopus (Q1)	1.79	76	United States
Discourse Processes	1	Taylor and Francis Ltd	Scopus (Q1)	0.9	68	United Kingdom
Journal of Cognition and Development	1	Psychology Press Ltd	Scopus (Q2)	1	68	United States
Research in Science Education	2	Springer	Scopus (Q1)	1.05	67	Netherlands
Journal of Research in Reading	2	Wiley-Blackwell Publishing Ltd	Scopus (Q1)	1.13	61	United Kingdom
Science and Education	1	Springer	Scopus (Q1)	1.12	58	Netherlands
Journal of Science Teacher Education	1	Taylor and Francis Ltd.	Scopus (Q1)	0.95	57	United Kingdom
International Journal of Science and Mathematics Education	3	Springer	Scopus (Q1)	1.04	56	Netherlands
Scandinavian Journal of Educational Research	1	Routledge	Scopus (Q1)	1.04	56	United Kingdom
Journal of Geoscience Education	3	Taylor and Francis Ltd	Scopus (Q2)	0.44	43	United Kingdom
Frontiers in Education	1	Frontiers Media SA	Scopus (Q2)	0.63	40	Switzerland
Technology, Knowledge, and Learning	1	Springer Science + Business Media	Scopus (Q1)	1.15	39	United States
Physics Education	1	IOP Publish Ltd.	Scopus (Q2)	0.39	36	United Kingdom
Journal of Baltic Science Education	1	Scientific Methodical Centre	Scopus (Q2)	0.39	26	Lithuania
Journal of Turkish Science Education	2	Ekip Buro Makineleri A.S.	Scopus (Q2)	0.5	25	Turkey
Educational and Developmental Psychologist	1	Routledge	Scopus (Q2)	0.44	21	United Kingdom
Participatory Educational Research (PER)	1	Ozgen Korkmaz	Scopus (Q3)	0.25	11	Turkey

Name of Journal	f	Publisher	Index By	SJR (2023)	H-Index	Country

f (Frequency); Index by; SJR; and H-index based on the Scopus database as of 12 Mei 2024.

As presented in Table 1, 41 articles analysed were published in various journals with the Scopus index starting from Q3-Q1. Based on Table 1, 17 journals were indexed in Q1, 8 in Q2, and 1 in Q3. This states that publications related to the topic of refutational texts in science learning are of very good quality, as most are top-indexed by international indexers and dominating publishers were Taylor and Francis and Springer.

The Educational Level and Content Area

One of the moderator variables in this research is educational level. However, this of course also adjusts to the content area and concept that will be studied because it must have a strong basis for why the research was carried out at that level and concept. A summary of the results is presented in Table 2.

Table 2

Distribution of educational level and content area

No	Code	Authors	Educational Level	Content Area	Concept
1	SLR1	(Hunsu et al., 2023)	Undergraduates	Biology	Genetics
2	SLR2	(McCrudden & Kendeou, 2014)	Upper Secondary School	Science	Newton's law
3	SLR3	(Sevim, 2013)	Graduated High School	Chemistry	Chemical bonds and intermolecular forces
4	SLR4	(Weingartner & Masnick, 2019)	Undergraduates	Physics	Motion
5	SLR5	(Djudin, 2021)	Upper Secondary School	Physics	Buoyancy
6	SLR6	(Stuhlsatz et al., 2020)	Upper Secondary School	Biology	Genetics
7	SLR7	(Broughton et al., 2013)	Primary School	Science	Planet
8	SLR8	(Södervik et al., 2015)	Undergraduates	Bioscience	Photosynthesis
9	SLR9	(Kim & Kendeou, 2021)	Undergraduates	Biology	Vaccination
10	SLR10	(Trevors & Muis, 2015)	Undergraduates	Biology	Biological evolution
11	SLR11	(Asterhan & Resnick, 2020)	Undergraduates	Biology	Biological evolution
12	SLR12	(Adesope et al., 2017)	Undergraduates	Biology	Climate change and global warming
13	SLR13	(Vosniadou & Skopeliti, 2017)	Primary School	Science	Day/night cycle
14	SLR14	(Safadi et al.,	Lower Secondary School	Physics	Simple electric

No	Code	Authors	Educational Level	Content Area	Concept
		2017)			circuits
15	SLR15	(Heddy et al., 2022)	Undergraduates	Biology	Climate change
16	SLR16	(Chang et al., 2018)	Upper Secondary School	Science	Climate change
17	SLR17	(Özmen, 2011)	Primary School	Science	Nature of matter
18	SLR18	(Korur et al., 2016)	Lower Secondary School	Physics	Planet
19	SLR19	(Çalik et al., 2010)	Upper Secondary School	Chemistry	Rate of reaction.
20	SLR20	(Mason et al., 2019)	Primary School	Science	Energy
21	SLR21	(Nussbaum et al., 2017)	Undergraduates	Science	Global warming
22	SLR22	(Schroeder, 2016)	Pre-Service Teacher	Science	Genetically modified crops
23	SLR23	(Danielson et al., 2016)	Undergraduates	Science	Greenhouse
24	SLR24	(PinarbaŞi et al., 2006)	Undergraduates	Chemistry	Solution chemistry
25	SLR25	Södervik et al. (2014)	Pre-Service Teacher	Biology	Photosynthesis
26	SLR26	(Alvermann & Hague, 1989)	Undergraduates	Physics	Newton
27	SLR27	(Hynd et al., 1994)	Upper Secondary School	Physics	Newton's laws of motion
28	SLR28	(Mikkilä-Erdmann, 2001)	Primary School	Science	Photosynthesis
29	SLR29	(Vilppu et al., 2013)	Pre-Service Teacher	Science	Photosynthesis
30	SLR30	(Taşlıdere, 2021)	Pre-Service Teacher	Science	Waves
31	SLR31	(Saitta et al., 2011)	Upper Secondary School	Chemistry	Chemical reactions and thermodynamics.
32	SLR32	(Chambers & Andre, 1997)	Undergraduates	Physics	Electricity
33	SLR33	(da Rosa, 2022)	Undergraduates	Science	Climate change
34	SLR34	(Yürük & Eroğlu, 2016)	Pre-Service Teacher	Science	Heat and temperature
35	SLR35	(Yürük, 2007)	Upper Secondary School	Chemistry	Electrochemical cells
36	SLR36	(Yilmaz et al., 2011)	Lower Secondary School	Science	Genetics
37	SLR37	(Ozkan & Selcuk, 2016)	Lower Secondary School	Science	Pressure

No	Code	Authors	Educational Level	Content Area	Concept
38	SLR38	(Yazbec et al., 2019)	Undergraduate	Integrated Science	Newton's Laws, Astrophysics, Genetics, Economic geography
39	SLR39	(Taşlıdere & Yıldırım, 2023)	Pre-Service Teacher	Science	Simple electricity
40	SLR40	(Palmer, 2003)	Lower Secondary School	Science	Ecological
41	SLR41	(Venkadasalam & Ganea, 2018)	Primary School	Science	Free falling object

Table 2 presents information related to the author and focus of the research studies conducted both at the educational level and the concepts discussed. Apart from that, the author created a code for each author to make it easier to present further information. The content area studied is in the realm of science and there is even integrated science at primary, lower secondary, upper secondary, undergraduate, and even pre-service teacher levels. The concepts discussed are indeed related to science, so they are specifically related to the topic of conceptual change which leads to understanding concepts in science learning. The distribution by educational level is undergraduate (37%), upper secondary school (19%), pre-service teacher (15%), primary school (15%), lower secondary school (12%), and graduate high school (2%).

The Research Approach Used

The research approach in the article is determined by the method chosen to conduct the research. This is crucial for ensuring the effective implementation and success of the research. Figure 4 presents the three main approaches used, namely, quantitative, qualitative, and mixed methods.

Figure 4

The type of research approach

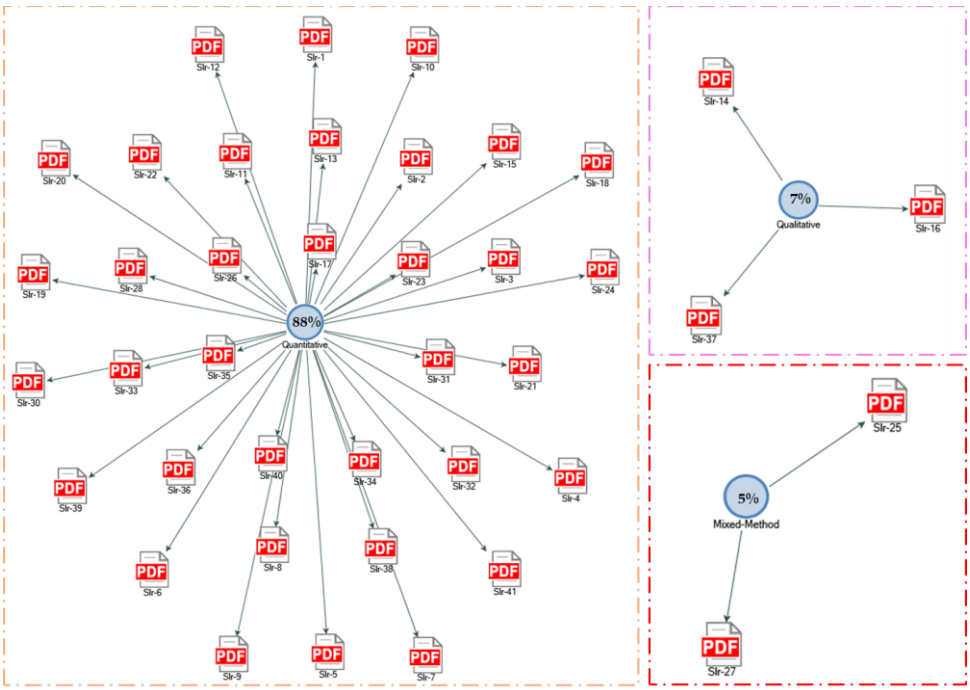


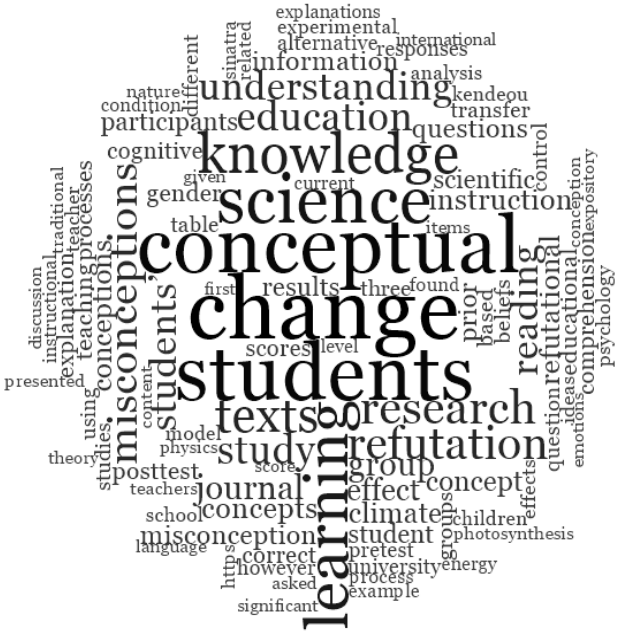
Figure 4 presents three research approaches in the 41 research articles analysed. The most widely used research approachs are quantitative (88%), qualitative (7%), and mixed-method (5%). Quantitative approach dominates because it offers the ability to measure and analyse data numerically, allowing researchers to obtain more measurable and objective results. Data resulting from a quantitative approach can be analysed statistically to identify patterns and relationships between variables, providing a strong basis for making generalisations. However, it is important to remember that each research method has its advantages and disadvantages, and the choice between quantitative, qualitative, or mixed methods should be based on the research question being asked, the research objectives, and the context.

The keyword Distribution

Keywords help readers to quickly identify the main topics or issues discussed in an article. Keywords briefly reflect the essence of the research or writing, allowing readers to know what they can expect from reading the article. In the 41 articles reviewed, keywords are displayed in Figure 5.

Figure 5

The Keyword distribution



Based on Figure 5, we can see that keywords often cover specific concepts or areas that are important in research or writing. Thus, keywords help in marking and distinguishing aspects of the topic being discussed. In this study, the keywords that appear most frequently are conceptual change, students, understanding, education, refutation, and misconception. The keywords that appear represent an in-depth study on the topic of refutation texts in science learning.

RQ2: What are the benefits of text refutation in science learning?

This study also presents the benefits of refutation text which are grouped into three main parts, namely cognitive process, conceptual change, and pedagogical insight. This grouping was carried out based on an in-depth analysis of 41 articles, which were classified into three categories. However, not all articles discussed are in each category (for instance, SLR11 is not in cognitive

processes but is in conceptual change). In addition, this certainly has a close relationship with science education.

Cognitive processes and conceptual change are closely intertwined in the formation of human understanding. Cognitive processes, such as information processing, reasoning, and mental representation, play an important role in conceptual change (Chi, 2009; Nersessian, 2010; Vosniadou, 1994). When individuals receive new information, their cognitive processes are responsible for integrating it into existing cognitive frameworks, as well as evaluating its consistency with existing concepts. In addition, cognitive processes also allow individuals to identify inconsistencies or contradictions between new and existing knowledge, which can trigger the process of conceptual change (Carey & Spelke, 1994; Limón, 2001; Vosniadou & Brewer, 1992). Thus, the relationship between cognitive processes and conceptual change reflects how individuals use their cognitive capacity to change and update their understanding of the world (concept).

The Cognitive Process

Refutational texts can encourage scientific conceptual change, which involves specific cognitive processes. Statements that specifically address misconceptions can raise awareness and accommodate new information. A summary of the benefits of cognitive processes is presented in Table 3.

Table 3

The benefits of research related to cognitive process

No	Benefits	Code	frequency
1	Encourage the use of cognitive processes that support prior knowledge	SLR1, SLR2, SLR8, SLR10, SLR13, SLR19, SLR20, SLR23, SLR25, SLR26, SL32	10
2	Activating initial knowledge and leading to a better understanding	SLR5, SLR21, SLR37, SLR38	4
3	Enhancing retention and transfer of science information	SL12	1
4	Problem-solving activities on promoting argumentation	SLR14	1
5	Provided insights into the process of knowledge restructuring	SLR16, SLR17, SLR28	3
6	Enhance understanding and knowledge retention	SLR18	1
7	Long-term impact on conceptual understanding	SLR34, SLR36, SLR41	3
Total			23

Table 3 presents information related to the benefits of refutational texts in cognitive processes. These adjustments were made based on an in-depth study regarding how the article responded to participants' cognition in research that used refutational texts. The benefits presented in the cognitive process are arranged simultaneously without distinguishing between educational levels so that it focuses on the impact of using refutation texts in the research carried out. In this context, everyone focuses on the impact of text refutation on their knowledge management. Out of the 41 articles analysed, 23 articles imparted benefits in cognitive processes as shown in Table 3.

The Conceptual Change

Refutation texts not only present information but are also an effective tool in facilitating conceptual change learning. Through challenging existing understandings, encouraging deep processing of information, and introducing variations in perspective. This text helps readers build a more solid, in-depth, and accurate understanding of scientific concepts. The benefits of conceptual change are presented in Table 4.

Table 4

The benefits of research related to conceptual change

No	Benefits	Code	frequency
1	Understanding and resolving misconceptions	SLR1, SLR2, SLR3, SLR4, SLR8, SLR14, SLR21, SLR32, SLR33	9
2	Improve conceptual understanding	SLR5, SLR11, SLR15, SLR16, SLR18, SLR19, SLR20, SLR22, SLR23, SLR24, SLR25, SLR28, SLR30, SLR32, SLR34	15
3	Deeper Understand and articulate concepts	SLR6, SLR7, SLR9, SLR10, SLR12, SLR27, SLR29, SLR35, SLR40	9
4	Identifying and understanding misconceptions	SL313, SLR17, SLR31, SLR36, SLR38, SLR39, SLR41	7
Total			41

Table 4 shows the benefits of 41 articles that discuss refutation texts toward conceptual change. Through the description of Table 4, we can see that all of articles refer to understanding. This is because, in the process of interpreting concepts, a deep understanding of the concept being studied is required (see. Cooper, 2023; Hırça et al., 2011; Wang et al., 2023). The results presented provide holistic benefits, namely facilitating learning of conceptual change, especially in the context of science knowledge.

The Pedagogical Insight

Educators indeed, cannot be separated from the world of education, both at the primary and higher education levels. Mapping related to the benefits of research conducted using refutational texts on pedagogy aspect. A summary of pedagogical benefits are presented in Table 5.

Table 5

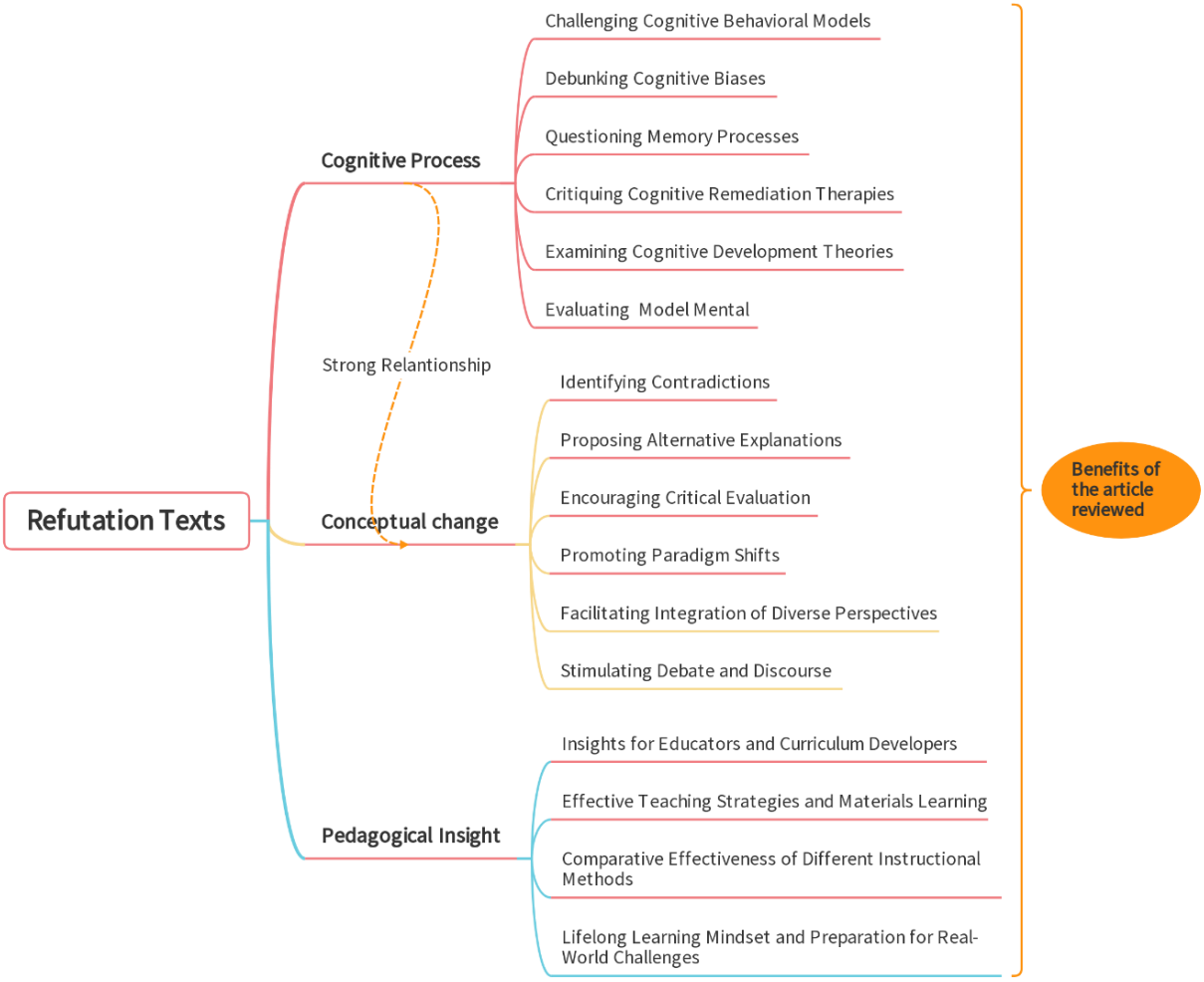
The benefits of research related pedagogical aspects

No	Benefits	Code	frequency
1	Provide valuable insights for educators and curriculum developers to improve learning outcomes	SLR1, SLR7, SLR15, SLR18, SLR22, SLR25, SLR30, SLR33, SLR35, SLR37	10
2	Effective teaching strategies and materials learning	SLR2, SLR5, SLR13, SLR14, SLR21, SLR24, SLR27, SLR29, SLR32, SLR40, SLR41	11
3	Shedding light on the comparative effectiveness of different instructional methods	SLR3, SLR8, SLR16, SLR20, SLR34, SLR36, SLR38, SLR39	8
Total			29

Table 5 shows the benefits of refutational text research on pedagogical insight. The benefits provided are not only for participants but also for teachers and policymakers. Educators are often closely related to educational psychology, which studies the mental processes involved in learning and teaching. These include motivation, perception, memory, problem-solving, and other psychological aspects that influence learning in detail (see Table 5), insights from 29 articles from research results on pedagogy. Figure 6 summarises the benefits of the 41 articles reviewed in this literature review.

Figure 6

Thee benefits of refutation texts analysed



Discussion

This research reviewed 41 articles published in a journal that is indexed by Scopus (Q3-Q1) with a search focus on the keywords 'refutation text' or 'conceptual change text'. The trend distribution of refutation text over time and the benefits gained after using refutation text in learning science. The published articles indexed by Scopus is still relatively low considering that the highest number of publications obtained through literature review was only 4 articles in a particular year. Additionally, in the last year 2023, there were only 2 articles. Browsing quantities of publications per year on literature reviews are very important because they can identify a booming research trend. This matter is in line with Booth et al. (2021); Lacey et al. (2011); Siddaway et al. (2019), who stated that a search distribution study with criteria certain and content becomes one of the things important in the

process of writing a literature review. Considering the number and year of publications in a literature review, researchers scan ensure that they obtain the most relevant, up-to-date, and reliable information to support their arguments or findings (Lacey et al., 2011; Pickering & Byrne, 2014; Ridley, 2012)

The role of the state in suporting institution publications is very significant in facilitating research, cultural development, and the dissemination of knowledge in society. In this context, there are only 6 countries that publish on the topic of refutation text in science learning. The highest number of publications was obtained by the United Kongdom (16 articles). This is due to the large scientific research and development centre the United Kingdom has many universities, research institutions, and scientific publishers that produce many refutation texts. In addition, broad academic freedom and the diversity of research approaches in the country encourage the production of quality work (Chankseliani et al., 2021; Vähäsantanen et al., 2020). According to Abouzeid et al. (2022), factors such as intellectual traditions, research infrastructure, access to resources, and financial support influence the dominance of research production in a country. However, it is important to remember that refutation texts can be found all over the world, depending on the topic and context of the research in question. In this study, only 6 countries published articles with the categories determined by the researchers. In this way, it also opens up opportunities for institutions of the other countries to apply and adapt refutation texts to conceptual change in a better direction.

Then, scientific journal plays a crucial role in publishing research finding. According to Lang et al. (2012); Park et al. (2023), journals enable researchers to share their results of their research widely, allowing new knowledge to become accessible to the broader scientific community. This contributes to a broader and deeper understanding of different areas of science. The journals that commonly publish studies on refutational texts in science learning are mainly education journals, although some psychology journals also appear, since refutation involves cognitive processes central to learning. Scientific journals play an important role in supporting the overall scientific process, especially journals that are indexed internationally with a high h-index (Alonso et al., 2009; Roldan-Valadez et al., 2019). In addition, some publishers help validate and disseminate scientific findings, as well as facilitate dialogue and collaboration between researchers in the scientific community.

The research approaches that are most widely used on the topic of text refutation in science learning are quantitative (36 articles), qualitative (3 articles), and mixed-method (2 articles). The quantitative approach is the most widely used, as it allows researchers to compare the use of refutational texts with other instructional media, such as explanatory texts, by analyzing differences in achievement, control classes, and experimental classes. According to Goe et al. (2008); Guetterman et al. (2015); Mohajan (2020), a quantitative approach allows researchers to measure the impact and effectiveness more measurably and objectively In addition, refutation texts are often studied in the context of education and cognitive psychology, where quantitative approaches are often used to evaluate their impact on conceptual understanding and cognitive processes. Additionally, quantitative research is often considered more objective and accountable, because it produces data that can be measured and analysed directly (Black, 1999). This can provide a stronger basis for making empirical conclusions about the effectiveness of refutation texts in supporting conceptual change learning.

In constrast, the qualitative approach focuses on understanding how refutational texts contribute to science learning, particularly in facilitating conceptual change. According to Ormston et al. (2014); Tracy (2019), qualitative research approach to this phenomenon often involves understanding context, interpretation, and nuances in individual responses to texts that challenge previous beliefs or knowledge. This is typically done through in-depth data analysis, such as interview transcripts or textual content analysis, allowing researchers to identify themes, patterns, and constructions of meaning in participants' responses to refutational texts. Furthermore, some studies employ a mixed-method approach, combining both quantitative and qualitative techniques to obtain more comprehensive insights. Ultimately, the choice of research method should be aligned with the specific objectives and needs of the study being conducted.

Furthermore, refutation texts in science education were implemented at several educational levels as follows: pre-service teacher, undergraduate, enrolled sophomores, graduated high school, upper secondary school, lower secondary school, and primary school. In addition, the studies also varied in content area (physics, chemistry, biology, science, and integrated science) (see Table 2). Refutation texts can strengthen and help students identify errors or deficiencies in their understanding of a particular concept or topic (Beker et al., 2019; McCrudden & Kendeou, 2014; Tippett, 2010). From the point of view Baron and Kenny (1986); Bauman et al. (2002), concept studies can potentially be a moderator variable, especially if this variable influences the strength or direction of the relationship between the independent variable and the dependent variable in the research context. That way, it can also be a potential update in research. Previous studies also investigated content based on educational level (Deveci & Çepni, 2017; Winarno et al., 2020).

This study also analyses keywords from the 41 articles through mapping used Nvivo and obtains keywords with visualisation (see Figure 5). The top ten most frequent keywords identified through the word frequency query are presented in Table 6.

Table 6

Top 10-word frequency

Word	Length	Count
Change	6	2743
Conceptual	10	2485
Students	8	2466
Science	7	2038
Learning	8	1807
Knowledge	9	1600
Texts	5	1385
Research	8	1308
Refutation	10	1261
Misconceptions	14	1149

The keywords presented in Table 6 are part of Figure 5. This shows that in the refutation text study, the top 10 words that appear most frequently are as presented above. According to Behzadi & Gajdács (2021); Fortunati & Vincent (2014), using the right keywords in scientific articles has many benefits, both for writers and readers. Keywords help in topic identification, searching, structure markers, indexation, scientific communication, and explanation of important concepts. Apart from that, keywords can also be used to highlight important concepts or relevant terms in articles. keywords help readers to understand and explore topics in more depth (Bloor & Wood, 2006; Wang, 2018). The appearance of keywords such as "misconception," "conceptual change," and "text" supports the core focus of the refutation text literature. This finding strengthens the argument that keyword analysis can reflect the thematic orientation and depth of a scientific domain.

Further studies present the benefits of using refutation text in learning science. The first benefit is related to cognitive processes when using refutation texts. According to Hynd (2003); Trevors and Muis (2015), the awareness gained from refutational texts is awareness caused by cognitive dissonance or cognitive conflict. By reading refutational texts, readers are encouraged to reflect on their prior conceptions and recognize when these differ from scientifically accepted concepts. This can be identified because of the explicit refutation text specified misconceptions followed by refutation as well as scientific concepts. That way the reader will admit the misconception they experience. Results analysis in-depth on 23 articles (see Table 3) highlights the importance of refutation text structure in promoting the use of cognitive processes that support text comprehension. Specifically, these findings suggest that the structure of refutation texts encourages deliberate efforts

on the part of readers to resolve discrepancies between the information presented in the text and the reader's prior knowledge. Readers tend to actively engage in cognitive problem-solving processes as they try to reconcile conflicting information in the text with their prior knowledge (Hayes, 2013; Limón, 2001; Stadtler et al., 2013).

Through cognitive processes, it will certainly impact or result in conceptual changes in students related to the concept being studied. The benefits of refutation texts presented in Table 4 can be understood in more detail as follows (i) Understanding and resolving misconceptions; This process includes understanding and resolving discrepancies between students' incorrect understanding or misconceptions and actual concepts. Students need to understand that they have misconceptions and then try to overcome these misconceptions by improving their understanding (ii) Improve students' conceptual understanding; The main aim of this process is to increase students' conceptual understanding by helping them overcome misconceptions and deepen their understanding of the concepts being taught, (iii) Deeper understand and articulate concepts; This process leads to a deeper understanding of the concepts being studied, where students not only understand the concepts, but are also able to explain and articulate the meaning clearly, (iv) Identifying and understanding the misconceptions; The initial step in the process is identifying the misconceptions that students have, which is then followed by efforts to understand the origins of these misconceptions and overcome them through appropriate learning. The previous presentation is in line with research conducted by (Asterhan & Resnick, 2020; Broughton et al., 2010; Palmer, 2003), stating that refutation texts do play a particular role in conceptual changes in science learning. According to Münchow et al. (2023); Vosniadou (1994), changes in conceptual understanding are more likely to occur when conflicting information is presented in a believable or reasoned manner.

In the process of developing, creating, and presenting refutation text, what we can be certain of is not apart from the strategy that is used by studies for teachers to maximise the results that will be obtained. In matter, this aspect is pedagogically very important. Based on the analysis presented in Table 5, it can be concluded that refutation texts can give new colour in pedagogical aspects. Other research Basso & Cottini (2023); Cuevas et al. (2023), states that refutation texts can give insight into pedagogy for practitioners and researchers in the fields of science education and cognitive psychology. Educators can use the insights provided to develop and implement teaching strategies that are more effective in teaching scientific concepts to students. By understanding how text structure and the organization of information influence students' cognitive processes during learning (Albus et al., 2021; Kendeou & Van Den Broek, 2007), educators enable to design more effective instructional environments that support deeper comprehension and knowledge integration (Kasneci et al., 2023; Monte-Sano et al., 2014). Well-structured texts that explicitly address misconceptions such as refutation texts can reduce cognitive load, guide attention to key concepts, and facilitate conceptual change. Research has shown that such environments not only improve immediate understanding but also lead to better long-term retention, critical thinking development, and transfer of knowledge to new contexts (Kasneci et al., 2023).

sResearchers in the field of cognitive psychology can also use these findings as a basis for further research, which could provide deeper insight into the cognitive mechanisms involved in text learning. Thus, these findings not only support the development of more effective pedagogy but also facilitate the creation of better learning environments, which in turn can improve student learning outcomes in science education.

Conclusion and Implications

In conclusion, the analysis of 41 selected articles reveals both similarities and differences in terms of methods, educational levels, and reported benefits regarding the use of refutation texts in science learning. Despite these variations, a consistent finding across the studies is that refutation texts effectively facilitate conceptual change within the scientific domains addressed. Moreover, refutation texts have demonstrated a positive influence on students' cognitive processes, conceptual change, and offer valuable pedagogical insights for science educators. These findings underscore the potential of

refutation texts as a powerful instructional tool in addressing misconceptions and deepening scientific understanding. Given their importance in shaping students' conceptual frameworks and supporting future-oriented science education, further research is strongly recommended. Future investigations should explore innovative applications, long-term impacts, and integration with diverse teaching strategies to maximize their effectiveness.

This research only analyzed articles that were published and did not analyze the results of conferences, book reviews, book chapters, notes, and inaccessible articles. Apart from that, the study is in the area of science education. This article is limited to a systematic literature review by searching for the keywords "Refutation Texts" OR "Refutation Texts" OR "Conceptual Change Texts". Additionally, articles other than language English were also not included in further analyses. The selected articles are only articles indexed by Scopus Q3-Q1 so that the quality of the article can be guaranteed.

Future research on refutation texts holds significant potential for further development in science education. Based on the reviewed literature, several research directions are recommended. These include: (i) exploring the use of illustrative examples in refutation texts, and (ii) investigating how text structure affects offline learning processes. Additionally, (iii) studies are needed to examine the long-term impact of refutation texts on conceptual understanding, and (iv) comparative research should assess the effectiveness of conceptual change texts versus analogies. Research with larger and more diverse samples is also encouraged. Other directions include: (v) evaluating pedagogical strategies that integrate conceptual change texts, (vi) comparing implicit and explicit refutation formats, and (vii) developing innovative teaching methodologies to address misconceptions. Further studies may (viii) define gender as a social construct in science education, (ix) assess revision of mental models and individual belief differences, and (x) use delayed post-tests to explore the role of epistemic beliefs. Moreover, (xi) cross-cultural research on controversial topics is needed, considering motivational and value-based influences. Lastly, researchers are encouraged to (xii) examine text structures on counterintuitive learning, (xiii) integrate AR/VR in refutation texts, (xiv) enhance generalizability through broad sampling, and (xv) investigate the role of formative assessment in promoting conceptual change.

Declaration of Interest

We have no conflicts of interest to disclose. All authors declare that they have no conflicts of interest**.**

Funding Statement

The authors would like to thank the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia with DRTPM and "Program Pendidikan Magister Menuju Doktor untuk Sarjana Unggul (PMDSU) Batch VII" which has provided funding support and opportunities [Contract Number: 101/C3/DT.05.00/PL/2025]

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