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The Impact of Refutation Texts in Scientific Conception: A Meta-Analysis Study

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Abstract: This research aimed to analyze the role and impact of refutational text on student conceptions and learning outcomes. Utilizing meta-analysis methods, this study sourced articles from the Scopus and Web of Science databases, covering publications from 2001 to 2023. The article selection process adhered to the PRISMA technique, implemented systematically in several stages to ensure rigor and transparency. The meta-analysis used the random-effects model to account for variability among studies, offering a more generalized understanding of the effects of refutational text across different contexts and populations. The results were synthesized through a Forest plot, revealing a standard mean difference with a P value of <0.01, indicating a statistically significant effect of refutational text on students' conceptions. This suggests that the use of refutational text substantially influences learning, particularly in addressing misconceptions. Additionally, the study highlighted that while the potential for applying refutational texts in Indonesia is promising, the number of global and internationally indexed publications on this topic remains limited. This lack of extensive research limits the broader application of refutational text in educational contexts. However, the findings suggest that refutational text holds significant promise for science education, especially for topics where students commonly hold misconceptions about difficult concepts. Further research is recommended to explore its full potential and to encourage the publication and wider application of refutation texts in science education.

Keywords: refutation text, meta-analysis, conception, conceptual change.

▪ INTRODUCTION

Research on refutation text and conceptual change text reflects a global interest in utilizing text to support conceptual change. Refutation text is a type of text that aims to refute or contradict a previously held belief or argument (Broughton et al., 2010; Jacobson et al., 2021). Refutation text is effective in promoting knowledge updating and conceptual change in learners. However, there are also concerns that Refutation text may not promote deep engagement and critical thinking in learners. Refutation's text structure is written directly and explicitly to tell readers what they should be aware of, which might hinder sustained thinking about issues and arguments (Tippett, 2010). The hope is that Refutation Text can be used best in various educational contexts and how Refutation text can improve scientific conception and critical thinking in students.

Refutation text is a type of text used to identify and refute false or ineffective arguments. Refutational text is usually also known as conceptual change text, but the difference lies in the explicit presentation of information in the two texts. These two types of text are more widely used in learning that contains concepts that are difficult to understand. This text consists of three main components, statements, namely misconceptions, refutation sentences, and scientific explanations (Kendeou et al., 2014;

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Prinz et al., 2019, 2022). They are frequently used in various disciplines, especially in educational contexts to reduce misconceptions and encourage conceptual change. In writing, refutation text is placed by stating opposing arguments, admitting parts of valid arguments, and destroying false or ineffective arguments. Writing refutation texts requires the right skills and techniques to balance and respect opposing arguments. Based on the Scopus database literature search with the keywords "Refutation AND Text", the visualization is presented in Figure 1.

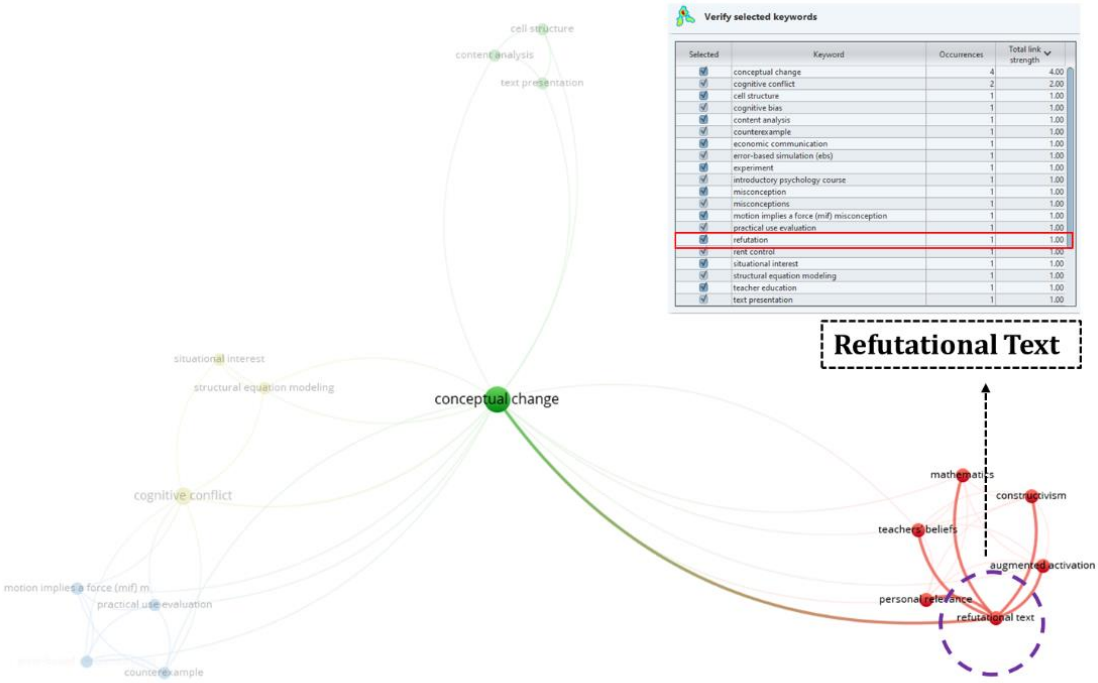

Figure 1. Visualization of a network of refutational text

Based on Figure 1, the co-occurrence keywords network from the Scopus database results with the “Refutation Text” keyword are presented. The link strength for the word refutation is 1.00 which has a direct relationship to conceptual change, in other words, refutation text is another alternative for changing conceptions. According to Dole (2000); Mason et al. (2017); Sinatra and Broughton (2011), refutation text is an alternative used to change students' conceptions. Based on the results of the help of connected papers (see. https://www.connectedpapers.com) can help in seeing the development trend of a research topic. In this context, by searching for 'Refutation Text' for the last ten years, a visualization is obtained as shown in Figure 2.

Figure 2 presents the relationship between papers and the keyword refutation text during 2010-2023. The size of the circle in Figure 2 provides information that the article with that author has the most citations. With the help of web-connected papers, we can explore further the studies that are most relevant to the research topic being studied. Refutation texts identify common misconceptions, state that those assumptions are wrong, and then introduce scientific explanations as alternatives to the correct concept (Braasch et al., 2013; Prinz et al., 2021). Therefore, refutation texts stimulate the

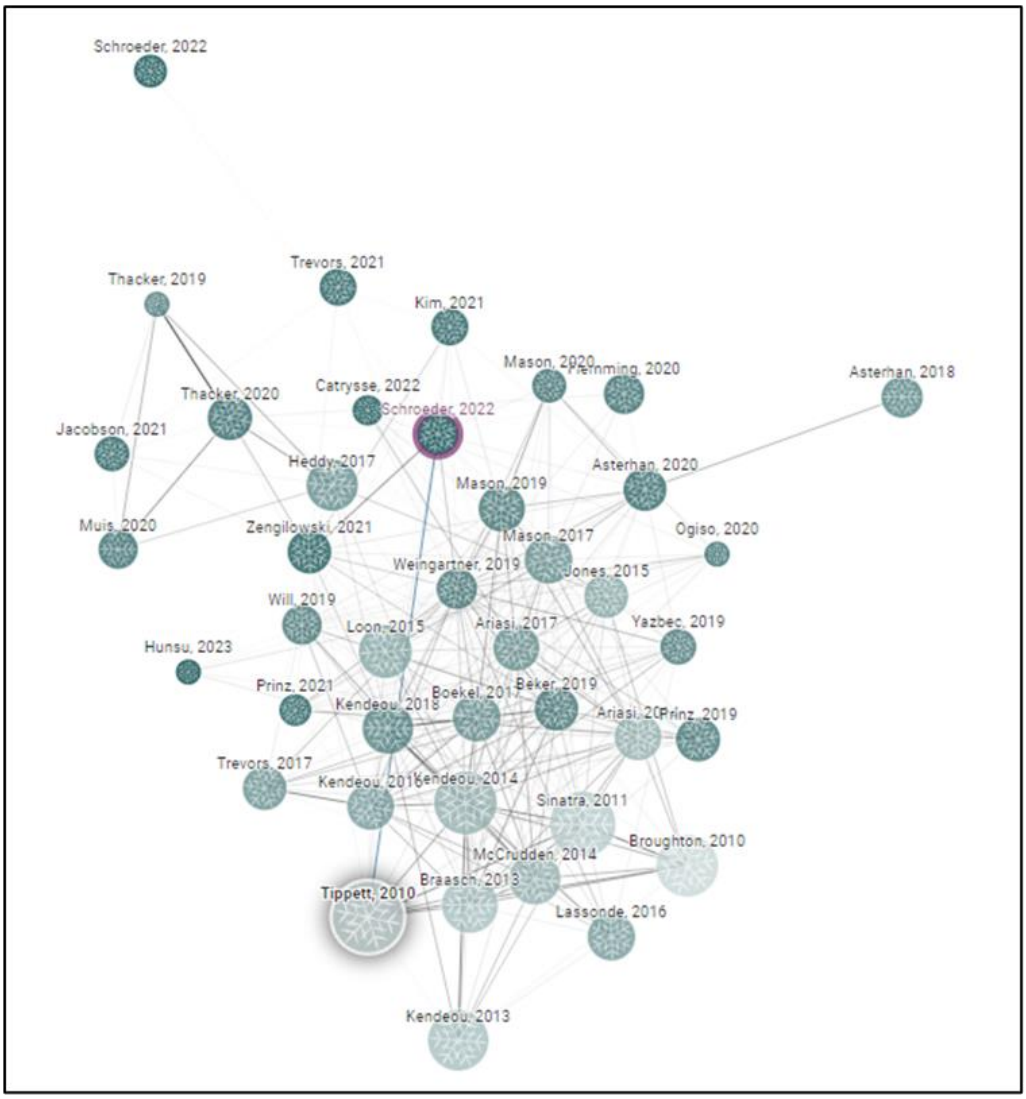

Figure 2. Visualization of connected papers

reactivation of the learner's previous beliefs (i.e. false beliefs) and relevant correct information in the learner's associative memory. This direct comparison can encourage conceptual change (Diakidoy et al., 2011; Harsch & Kendeou, 2023; Scott et al., 2013). This process involves experiencing cognitive conflict, evaluating (prior) knowledge, dissatisfaction with (prior) knowledge, and establishing consistency in (prior) knowledge . Other than that, refutation texts are designed to revise reasonable beliefs through direct contradiction of false beliefs, and demonstration of scientifically correct beliefs (Taylor & Kowalski, 2023; Vaughn, 2018; Zengilowski et al., 2021).

Refutation texts, compared to expository texts, also show effectiveness in revising knowledge (Beker et al., 2019; Poehnl, S., & Bogner, 2013). Knowledge revision can be expressed as information integration, as information interacts with prior knowledge and adapts to the updated viewpoint. Concerning conceptual change, knowledge revision is a slow and gradual process. Reading refutation texts has shown positive effects on the retention of scientific information on various scientific topics (Braasch et al., 2013; Schroeder & Kucera, 2022). Moreover, knowledge retention can last more than a month.

Refutation texts are also more effective than expository texts in producing valid conclusions (Mason et al., 2019; Will et al., 2019; Zengilowski et al.,2021). An example and the main components of a refutation text (Devianty & Syuhendri, 2023; Tippett, 2010) are presented in Figure 3.

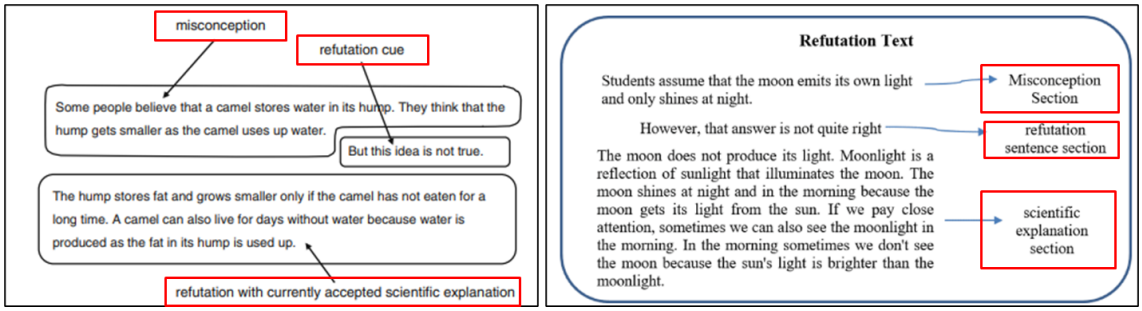

Figure 3. An example of refutation text with component

Studies on the topic of refutational text are growing rapidly and have the potential to be used in learning conceptual change. Several previous studies have used refutational text for conceptual change (Dersch et al., 2022; Djudin, 2021; Mason et al., 2017; Sinatra & Broughton, 2011; Thacker et al., 2020). The use of refutation text in educational fields also continues to grow, such as physics (Caleon & Subramaniam, 2013; Fratiwi et al., 2020; Guzzetti et al., 1997; Samsudin et al., 2021), Biology (Adesope et al., 2017; Heddy & Sinatra, 2013; Prinz et al., 2019), and Chemistry (Calik et al., 2010; PinarbaŞi et al., 2006). Furthermore, meta-analysis and review studies have also been conducted by Schroeder and Kucera (2022) and Tippett (2010), who stated that refutational texts are effective but depend on the context and audience. However, previous studies have not specifically discussed the potential for using refutational texts within a single country. This study will examine research on refutational texts in Indonesia based on the Scopus database, which is globally accessible.

This research will conduct a meta-analysis of article sources searched based on the Scopus and Web of Science databases with the keywords "Refutation AND Text". This work will analyze the effectiveness of refutation text in learning and oppoturnities in Indonesia, especially in reducing misconceptions and changing students' conceptions. The detailed questions that will be answered are presented at sub definition of scope and research.

▪ METHOD

This research employed meta-analysis methods to analyze articles that were relevant and met the requirements for conducting meta-analysis. The research steps used in this study are presented in Figure 4.

Definition of Scope and Research

Two questions will be discussed in this research. Answer questions will be obtained through reading results and analysis results of selected articles by criteria that are already determined. The following presents the research question (RQ).

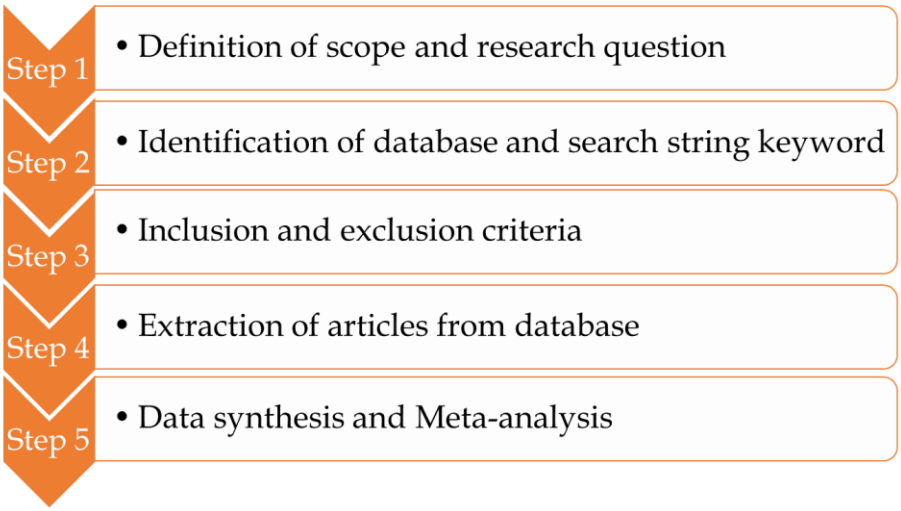

Figure 4. The process review for meta-analysis

RQ1. What is the effect size of the refutation text implementation?
RQ2. What are the opportunities for Refutation text in education in Indonesia?

Identification of Database

The primary criterion in this research was that the database used must be sourced from Scopus and Web of Science (WoS) to ensure the inclusion of high-quality, peer-reviewed studies. The Scopus and WoS databases were chosen because they provide access to high-quality, peer-reviewed, and internationally indexed publications. These databases are widely recognized for their comprehensive coverage of scientific literature, ensuring that the selected studies meet rigorous academic standards.To identify relevant studies, a systematic search strategy was implemented using the keywords "Refutation AND Text." The search was conducted on December 19, 2023, covering publications from 2021 to 2023. This timeframe was selected to focus on the most recent and relevant research on refutational texts in education. The article selection process followed a structured approach to minimize bias and ensure the inclusion of studies that met the research objectives. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) technique was used to filter and refine the search results systematically. The search yielded a collection of studies, which were then evaluated based on predefined inclusion and exclusion criteria. Articles that did not meet the eligibility requirements, such as those not related to education or lacking empirical data, were excluded.

The meta-analysis in this study utilized both Scopus and WoS databases as primary research sources. These databases were chosen because they provide access to internationally indexed publications, ensuring that the selected studies meet rigorous academic standards. By employing a structured and systematic approach to article selection, this research aims to provide a comprehensive and reliable analysis of the impact of refutational texts on student conceptions and learning outcomes. This study also highlights the limited number of globally indexed publications on refutational texts, particularly in Indonesia, emphasizing the need for further research and international dissemination in this area.

Extraction of Article

Total articles from Scopus (n=63 docs) and WoS (n=53 docs) databases. Then, the article is limited to 2001-2023, so it becomes (Scopus = 56; WoS = 50). Next, exclude by the reason with article type and final publish (Scopus = 41; WoS = 38). In addition, duplicate (n = 4), Inaccessible (n = 14), Review (n = 5), Not related to the topic of study (n = 48), and did not answer the research questions (n = 2). So (n=6) articles included in the meta-analysis criteria were excluded. The criteria intended to continue the meta-analysis are i) there are experimental and control groups in the article, ii) there is statistical data N= sample, X = means, and SD=standard deviation, iii) Experimental, truly experimental, or quasi-experimental research design. The previously mentioned process is presented in Figure 5.

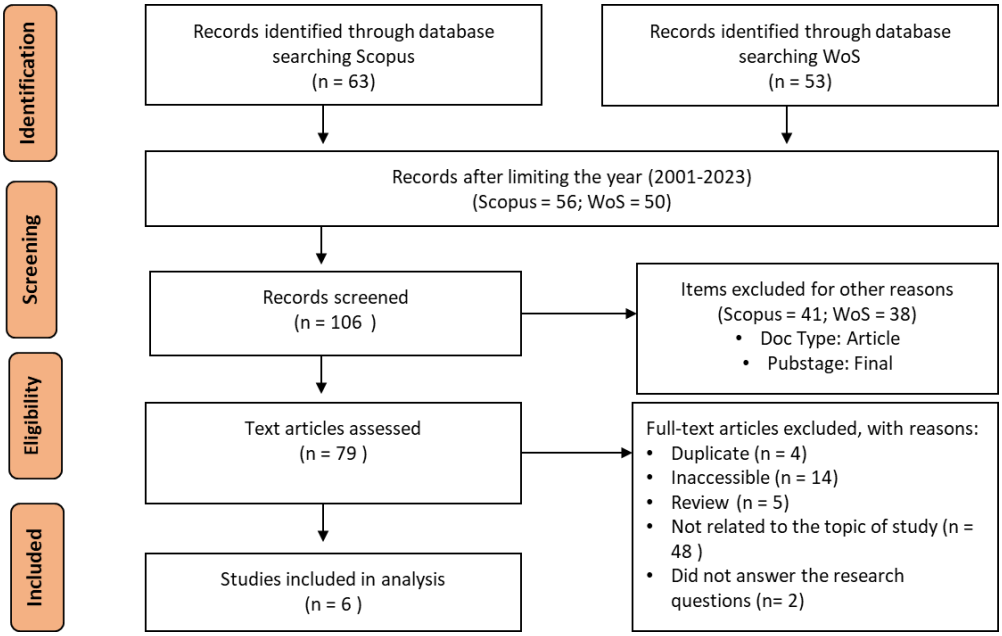

Figure 5. The procedure of selection article

Data Synthesis and Meta-analysis

The process of synthesizing selected articles was conducted in accordance with the criteria determined by the researcher and the criteria for conducting meta-analysis (see https://doi.org/10.6084/m9.figshare.28356086.v1). In this meta-analysis, the collected data were analyzed using statistical methods to determine the overall effect of refutational texts on student conceptions. The study employed the random-effects model, which accounts for variability between studies and provides a more generalized understanding of the effect sizes across different contexts. The effect size was calculated using the standardized mean difference (SMD), and the results were synthesized through a Forest plot, which visually represents the impact of refutational texts. Additionally, statistical measures such as Cochran's Q test and I^2 statistic were used to assess heterogeneity among studies, determining whether variations in results were due to chance or actual differences in study conditions.

Furthermore, a publication bias analysis was conducted using Egger's test and a funnel plot to evaluate the presence of bias in the selected studies. By applying these rigorous statistical techniques, this study ensures a comprehensive and reliable analysis of how refutational texts influence students' conceptions and misconceptions. The meta-analysis process was first carried out by fulfilling the predetermined criteria, then assisted by the ***LounchOpenMEE*** application, which was accessible for free, open-access, and provides the necessary data presentation features required for this meta-analysis. Meanwhile, the literature review process was conducted manually to ensure that the selected articles aligned with the objectives of this study.

▪ RESULT AND DISSCUSSION

This article will answer and discuss research questions as outlined in the introduction. The explanation given will be a little deeper and broader in each sub-chapter of the answer given to provide more insight to the reader about refutation text.

RQ1: The effect size of the refutation text implementation

The meta-analysis study carried out six articles that met the requirements for further analysis. One thing to pay attention to when conducting a meta-analysis is looking at the impact of a study through its influence on the control group and experimental group. One statistical test that can be used to find out this is to look at the effect size. According to Fritz et al. (2012), effect size is an analysis that can be used to see the magnitude of the effect after treatment is given. In this case, the effect in question is using refutation text in learning. The effect size results for each article that has been analyzed are presented in Figure 6.

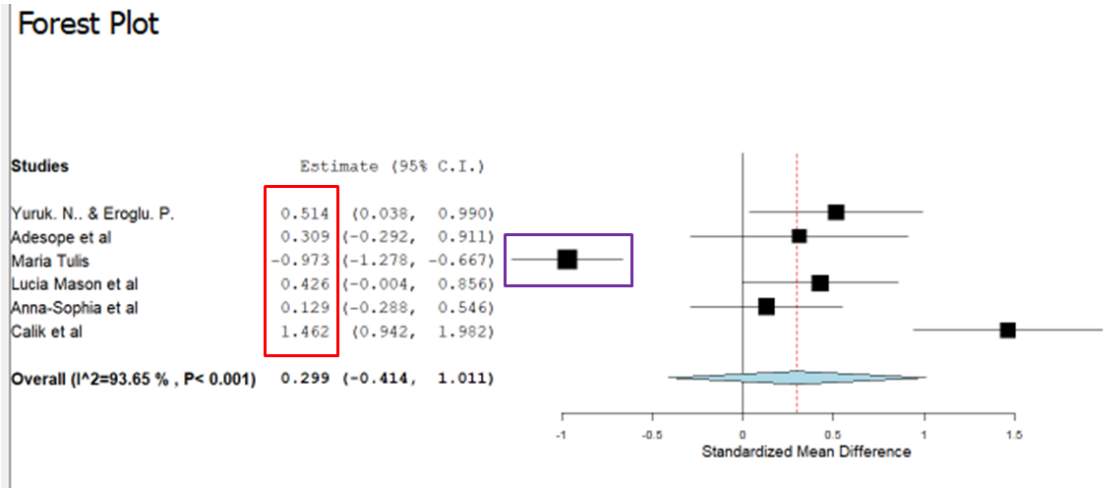

Figure 6. Forest plot

Figure 6 presents information from the effect size test that was carried out on the six articles studied. The results given in the red box are the results of the effect size that has been calculated. Based on these results, we can see that there is a minus number (-0.973) which means that the control group's mean is better than the experimental group that used refutation text. To see more detail, you can observe the forest plot with small

black boxes for each study. The zero-line reference point indicates that the refutation text cumulatively has a positive impact or influence on the learning carried out. According to the categories and classifications of Cohen et al. (2018), if the effect size falls between 0.00 to 0.19, it is considered negligible and can be ignored. A small effect size, ranging from 0.19 to 0.49, indicates a minor but noticeable impact. A medium effect size, between 0.49 and 0.79, suggests a moderate and meaningful influence. A large effect size, from 0.79 to 1.29, signifies a strong impact. Lastly, an effect size greater than 1.29 is classified as very large, indicating a highly significant and substantial effect in the analysis.

Based on Cohen's effect size classification, the forest plot presents various effect sizes ranging from negligible to very large. Yuruk, N. & Eroglu, P. reported a medium effect size (0.514), indicating a moderate and meaningful impact. Adesope et al and Lucia Mason et al showed small effect sizes (0.309 and 0.426, respectively), suggesting minor but noticeable influences. Anna-Sophia et al had a negligible effect size (0.129), meaning its impact is very small and can be disregarded. In contrast, Maria Tulis reported a negative large effect size (-0.973), suggesting a strong negative influence, potentially implying that the intervention or variable studied had an adverse effect. This can occur because the number of samples in the experimental class is less than in the control class so that it is one of the factors why the results show a minus. Meanwhile, Calik et al demonstrated a very large effect size (1.462), highlighting a highly significant and substantial impact. The overall effect size (0.299, CI: -0.414 to 1.011) falls within the small effect category, indicating that, on average, the intervention or factor under investigation has a minor influence. However, the confidence interval includes negative values, implying variability and uncertainty in the overall effectiveness. This high heterogeneity ($I^2 = 93.65\%$) suggests that the included studies differ considerably in their findings, potentially due to variations in study design, sample characteristics, or intervention types. While some individual studies show promising results, the overall small effect size implies that the intervention or factor may not have a substantial impact in general.

This can be confirmed through the forest plot for each box on the right side, which means that the application of refutation text in the experimental class has a better value than the control class. Overall, the results of the standard mean difference via Forest plot with a P value <0.01 means that there is a significant influence from the application of refutation text in learning. This is supported by research results from Sinatra and Broughton (2011), that refutation text helps change students' conceptions. Refutation text is one of the most effective text-based learning tools for changing readers' misconceptions (Aguilar et al., 2019). Based on the effect size study, the research results state that refutation text influences students' conceptual change and misconceptions. After that, to see whether there is bias from the six studies that carried out the meta-analysis, you can refer to the Funnel plot presented in Figure 7.

Figure 7 presents funnel plot information that can identify bias in the research being analyzed. The funnel plot supports the statement regarding the impact of refutation text on learning, especially on students' conceptions. When in the funnel plot there are white dots but not black, then this indicates that there is bias in the refutation text research being analyzed. However, Figure 7 states that all the dots are black, which means there is no bias in the research being conducted (Zwetsloot et al., 2017). Thus, this can be a supporting argument to say that refutation text has a big influence on changes in students'

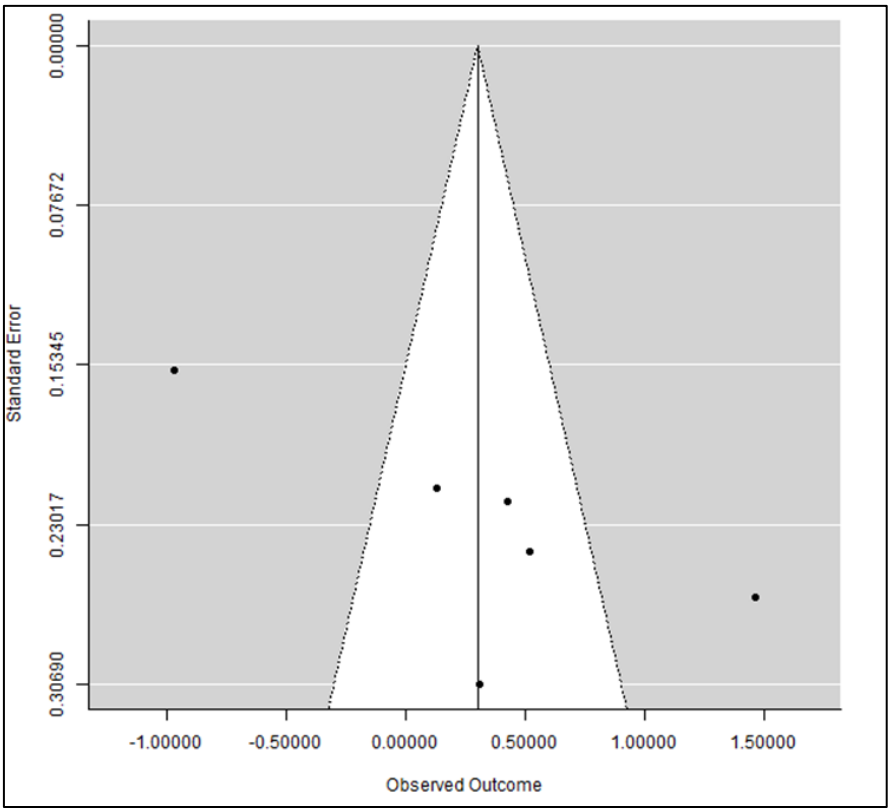

Figure 7. Funnel plot

conceptions. These findings can be a further basis for applying concepts that often experience misconceptions. Bias in research can lead to incorrect conclusions, influence policies, and hinder scientific progress (Cochrane et al., 2024; Cheema et al., 2022). Therefore, it is crucial to detect and address bias using techniques such as funnel plot analysis, Egger's test, and the trim-and-fill method to adjust effect size estimates in meta-analysis (Afonso et al., 2024; Rodgers & Pustejovsky, 2021).

Refutational texts are more suitable for use at the junior high school level and above as they require a more detailed understanding of concepts (Diakidoy et al., 2011; Mason et al., 2019; Sinatra & Broughton, 2011). These texts present misconceptions or opposing viewpoints first, and then provide corrections or counter-arguments based on evidence. At the junior high school level, students begin to develop critical thinking skills, which allow them to compare different perspectives and assess the validity of information (Lai, 2011). Unlike younger children, who tend to take information for granted, older students can analyze and evaluate arguments, making rebuttal texts an effective tool for deeper learning. Moreover, refutation texts help students identify and correct common misconceptions, improving their conceptual understanding in subjects like science (Danielson, 2025; Jin et al., 2024). Research shows that confronting misconceptions head-on can improve retention and application of knowledge compared to simply presenting factual information. By engaging with conflicting ideas, students strengthen their cognitive abilities and become more adept at reasoning and argumentation (Hendratmoko et al., 2024; Suriano et al., 2025).

RQ2: The opportunities for refutation text in education in Indonesia

Research on refutational texts in Indonesia is still in the development stage, as evidenced by the low number of publications indexed in major international databases such as Scopus and Web of Science (WoS). The data presented in Figure 8 shows that there are only four studies indexed in Scopus (n=4), while none are found in WoS (n=0). This indicates that Indonesian researchers have yet to gain significant international recognition for their contributions in this field. One possible reason for this is the lack of collaboration with international researchers, which can increase the visibility and impact of research. In addition, much Indonesian research on refutational texts is published in local journals indexed by Sinta, the main academic database in Indonesia (e.g., Basyit et al., 2024; Mariati et al., 2023; Wahyuningsih et al., 2019). While Sinta plays an important role in promoting domestic research, its limited global reach limits the accessibility of Indonesian research to the wider academic community.

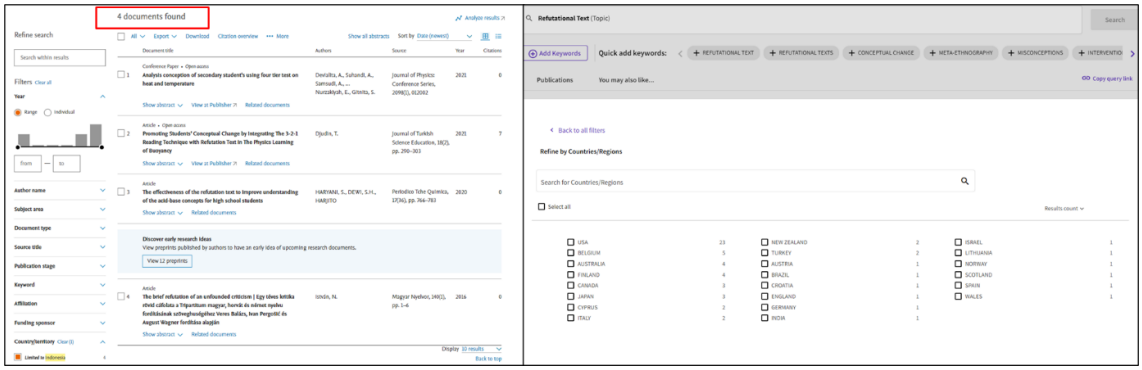

Figure 8. Cumulative publication refutation text

Research in Indonesia still publishes little in journals indexed by Scopus and Wos, but in Indonesia itself, many publish articles with the keyword refutation text with the Sinta indexer which is the main indexer in Indonesia (Mufida et al., 2023; Muliyani, 2018; Samsudin et al., 2023) provides new insight for Indonesian researchers to continue developing refutation text so that it can be published on international indexers such as the most familiar Scopus and Wos. Several challenges hinder the international publication of Indonesian research on refutational texts. One major issue is language barriers, as many Indonesian researchers write in Bahasa Indonesia, making it difficult to reach an international audience (e.g., Adnan, 2009; Azizah & Budiman, 2017). Writing in English and improving academic writing skills through training and workshops can help overcome this challenge. Additionally, methodological rigor and research design are crucial in meeting the standards of high-impact international journals. By adopting robust research methodologies, including experimental designs and statistical analyses, Indonesian researchers can enhance the credibility of their work (e.g., Manik et al., 2022; Nadiyah et al., 2023). Another challenge is the perception of local research as being region-specific rather than universally applicable. Researchers must ensure their findings contribute to the broader discourse on refutational texts by linking their work to global trends in education and cognitive science. Despite these challenges, opportunities exist for Indonesian scholars to increase their research impact. Government initiatives and funding programs for international publications can support researchers in achieving

higher publication standards (e.g, Dwivedi et al., 2024 Khan et al., 2025; Salager-Meyer, 2008).

To advance research on refutational texts in Indonesia and increase its global recognition, several strategic steps must be taken. First, fostering international collaboration can significantly enhance the quality and reach of research (see. Fernandes et al., 2022; Jacob & Meek, 2013). Indonesian researchers should seek partnerships with scholars from countries with strong academic traditions in educational psychology and literacy studies. Joint research projects, exchange programs, and co-authored publications can help bridge the gap between local and international research communities (Kwiek, 2018). Second, improving access to high-quality research resources, such as international journals and databases (see. Baas et al., 2020; Rafi et al., 2019), will enable Indonesian scholars to stay updated with global advancements in the field. Universities and research institutions should provide training programs on publishing in high-impact journals, including manuscript preparation, peer review processes, and ethical publishing practices (see. Azer et al., 2024; Halverson et al., 2012). Finally, integrating digital tools and advanced research methodologies be able enhance the credibility of Indonesian research on refutational texts. By addressing these key areas, Indonesian researchers can contribute more significantly to the global academic discourse and position Indonesia as a leading contributor in the study of refutational texts.

▪ CONCLUSION

From the results of the meta-analysis that have been carried out, several conclusions can be drawn as follows: (i) Overall, refutational text has a large influence on changes in students' conceptions as evidenced by the effect size value, which is only found overall and has a value of $P < 0.01$; (ii) Meta-analysis measurements can only be carried out in research that uses experiments that contain a control class and an experimental class; (iii) The potential for research in Indonesia on the topic of refutation text has very potential prospects, but there are still very few internationally recognized publications. In this way, research on the topic of refutational text has an urgency to be developed because it can help students understand certain concepts. Apart from that, it is important to consider research results that can be accepted globally through international standard indexers and collaborations.

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