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Mapping Two Decades of Research on Faded Examples and Science Reasoning: Bibliometric Analysis Using VOSviewer

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Abstract. Scientific reasoning skills are key competencies in 21st-century science education. One learning strategy believed to promote the development of these skills is the faded example, which involves presenting examples whose solutions are gradually reduced to support students' independent thinking processes. This study aims to map trends and relationships between the faded example strategy and scientific reasoning through bibliometric analysis using VOSviewer. A total of 87 articles meeting the inclusion criteria were analyzed thematically. The visualization results show that the topic of faded examples is frequently associated with problem-solving, while scientific reasoning appears more often in the broader context of science education. Although no explicit relationship has been found in the existing literature, there are indications of a conceptual connection between the two. Furthermore, further research is needed that explicitly and systematically integrates the faded example strategy into the development of scientific reasoning in inquiry-based science learning.

Keywords: faded example, science reasoning, bibliometric

1. Introduction

Problem-solving skills are essential in 21st-century learning[1], especially in science subjects such as physics. However, in reality, many students have difficulty understanding energy concepts and applying them in real-life situations [2]. Various studies show that many students have difficulty solving concept-based problems, especially in abstract energy topics that require in-depth understanding[3,4]. The Merdeka Curriculum emphasizes the importance of developing higher-order thinking skills, including problem solving and scientific reasoning.

In the context of physics learning, particularly on the topic of energy, many students still experience difficulties in integrating conceptual knowledge with problem-solving procedures [5]. These difficulties arise due to the dominance of traditional learning approaches that tend to focus on memorizing formulas and mechanical problem-solving, rather than on understanding concepts and scientific thinking processes [6]. Scaffolding-based learning strategies are a potential alternative. Scaffolding is temporary support provided to students to help them achieve certain understandings or skills [7]. Recent research shows that systematically designed scaffolding can increase student active participation, encourage idea exploration, and guide students to achieve more complex problem solving.

One promising approach to bridging this gap in understanding is the use of faded examples. With this approach, students are given the opportunity to understand the thought process involved in solving a problem before being given full responsibility for solving it themselves[8]. The faded example model is also in line with the principle of reducing cognitive load in learning, because students are not immediately faced with complex problems without support [9,10]. Faded examples are a technique for presenting examples of problems in which the assistance provided in solving them is gradually reduced. In the initial stage, students are given complete examples (worked examples) that show the steps for solving the problem in detail. Subsequently, parts of the solution are gradually removed until students are able to solve the problem independently [11]. When combined with scaffolding, this approach can provide a structured yet flexible learning experience, allowing students to build conceptual and procedural understanding gradually.

Faded examples can improve problem-solving skills [12–14]. In addition, faded examples also trigger the process of self-explanation, which is the ability of students to explain and reflect on the steps of problem-solving independently ("fading [...] triggers self-explanation activities"). This approach has been proven to improve learning transfer and strengthen problem-solving skills by encouraging students to actively engage in the thinking process [15].

Based on current research, a review explaining the concept of the faded example strategy to improve scientific reasoning is still needed. There have been no bibliometric studies on the terms "faded example" and "science reasoning" to date. Given the above reasons, the purpose of this study is to fill the research gap by conducting a comprehensive bibliometric analysis of the literature on scientific reasoning. We analyzed and classified the distribution of authors and affiliations of publications published and indexed by Scopus.

This study was conducted using bibliometric analysis techniques, utilizing VOS viewer, presenting findings, followed by a discussion session, and conclusions drawn from a literature review based on the completed bibliometric analysis.

2. Methode

This study uses a thematic literature review approach to analyze empirical studies that evaluate the effectiveness of the faded example strategy in improving science reasoning skills. This strategy was chosen because it provides gradual scaffolding to students in solving problems or understanding complex concepts, especially in the context of science learning and critical thinking.

2.1 *Data Sources and Research Procedures*

This study took data from the Scopus database using the keywords TITLE-ABS-KEY ("faded example" OR "science reasoning") AND PUBYEAR > 2015 AND PUBYEAR < 2026. The source of the articles was Scopus from 2015 to 2025. These keywords were chosen to limit the articles in the Scopus database to those focusing on the faded example strategy. In addition, the researchers also searched for articles in the database related to science reasoning research. The articles sought were those that examined faded examples or science reasoning. Therefore, the conjunction "or" was chosen over "and." The conjunction "and" was also used in the search but did not yield any results. In other words, articles that examine both in one paper have not been found in the Scopus database. This reinforces the novelty of this article. The following are the inclusion criteria for the articles searched:

- An empirical article that examines faded example strategies or science reasoning abilities
- Written in English
- Published between 2016 and 2024
- Clear abstract and methodological information available

2.2 *Analysis Procedure*

The analysis was conducted using a thematic approach, whereby articles were grouped into themes:

- Studies focusing on faded example strategies
- Studies measuring science reasoning abilities
- Studies indicating a potential relationship between the two.

3. Results and Discussion

A total of 87 articles were included in the study. The majority of authors were from the United States (66% of 87).

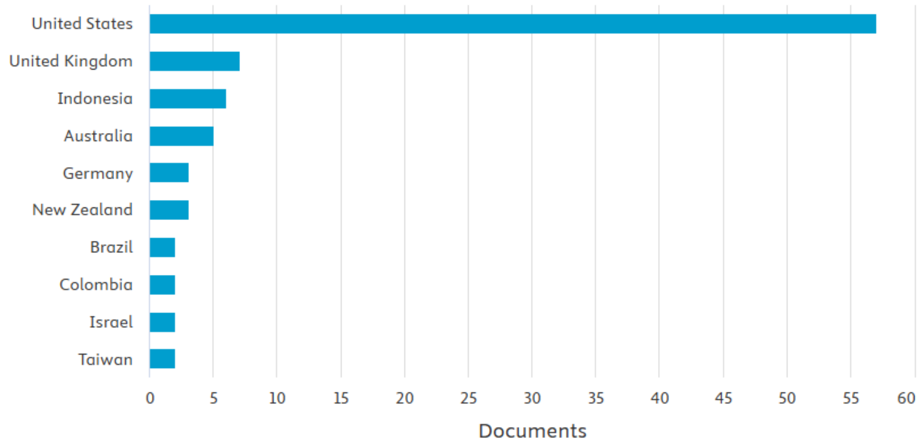

Figure 1. Distribution of articles by country.

The year 2020 saw the highest number of publications related to faded examples and scientific reasoning. However, authors' interest in researching this topic appears to have declined until 2025. More details on the distribution of articles can be seen in Figure 2.

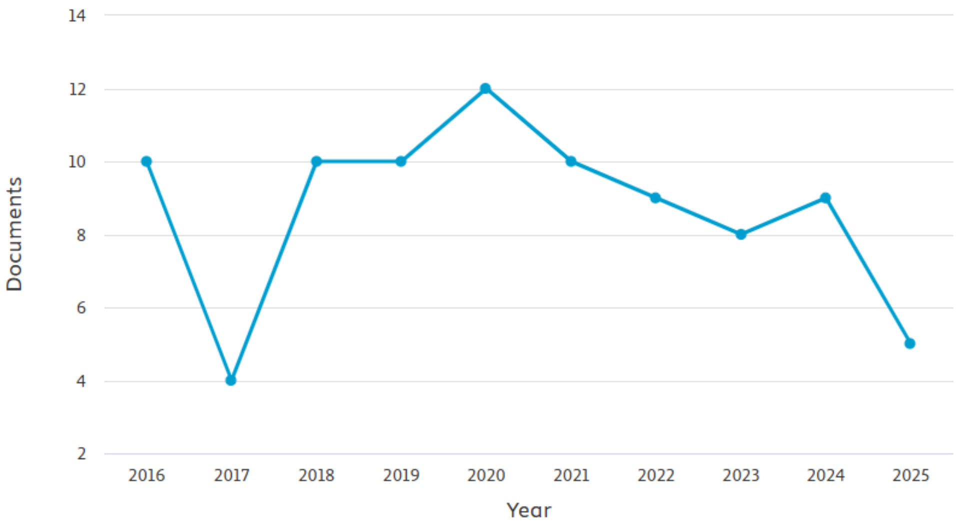

Figure 3. Distribution of articles by year.

Figure 4 is an image of the "network visualization" of the keyword index of the selected article, while Figure 5 is an "overlay visualization," and Figure 6 is a "density overlay visualization."

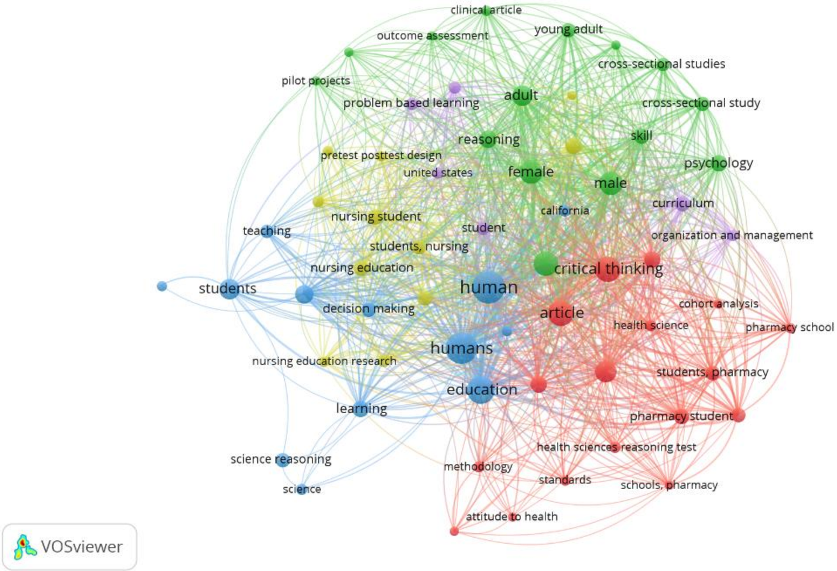

Figure 4. Network visualization.

From Figure 4, it can be seen that the topic of education is discussed quite extensively in the selected articles. Furthermore, the topic of education is linked to science reasoning and problem solving. Meanwhile, faded examples/worked examples are linked to problem solving. This suggests that faded examples are linked to science reasoning even though this is not explicitly discussed in the articles. These findings indicate that further research is needed on these two variables.

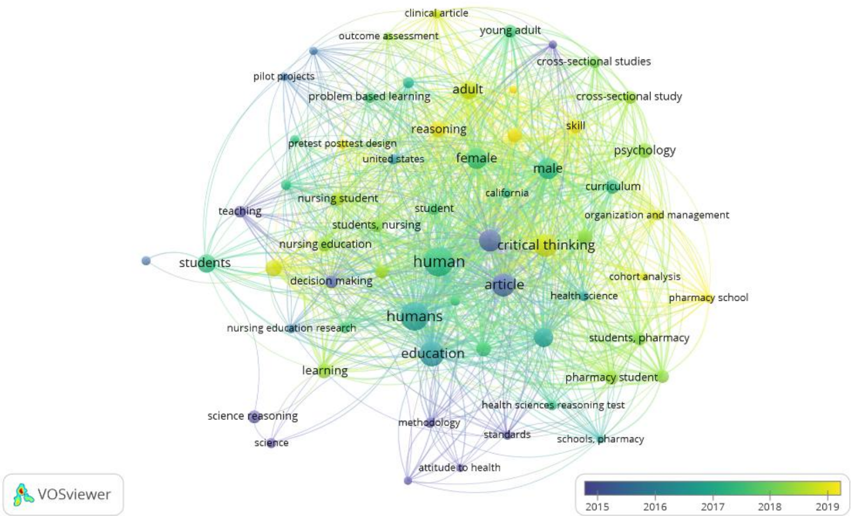

Figure 5. Overlay visualization.

Based on Figure 5, research related to science reasoning is also shown in purple. This indicates that research related to this topic has been conducted for quite some time, around 2015 and 2016.

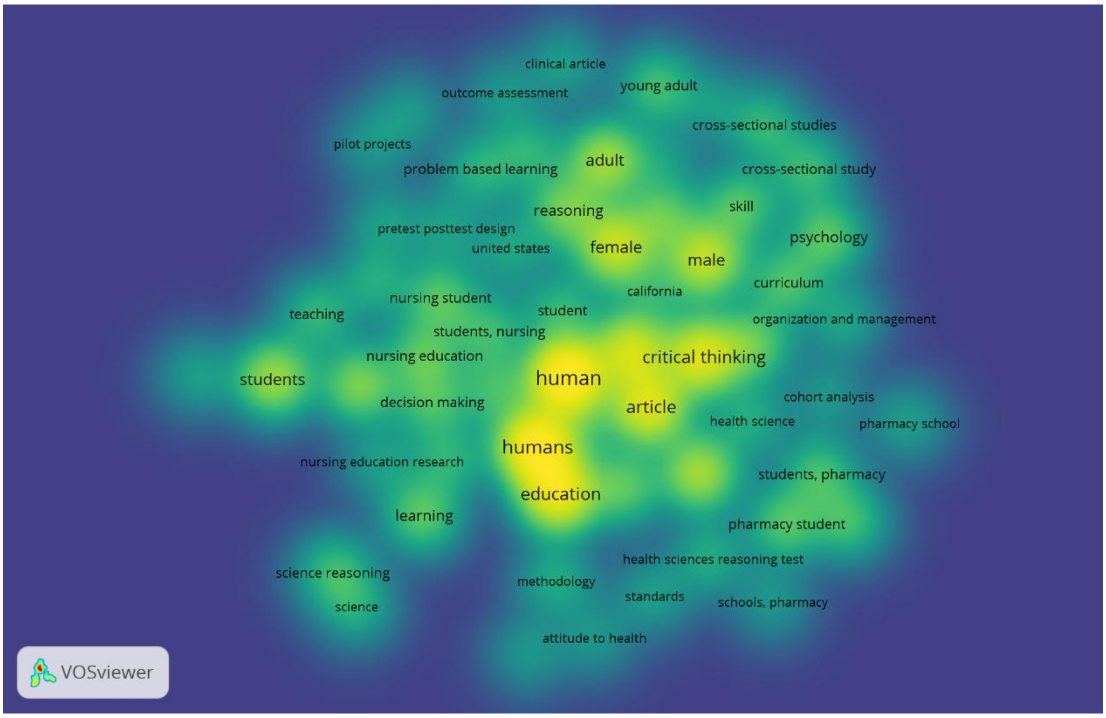

Figure 6. Density visualization.

Based on the results of the visualization of the density of findings, there appears to be a large gap in research related to scientific reasoning. Several topics such as scientific reasoning, students, and reasoning assessment in health sciences have been extensively studied and are marked in bright yellow. Meanwhile, topics that have received little attention, such as critical thinking, inter-variable relationships, and the role of teachers, are marked in green. This gap indicates that there are vast opportunities for researchers to deepen their studies in these fields in the future.

Overlay analysis and density visualization are used to identify the main topics that emerge from various studies or collections of information. This process involves calculating the frequency of co-occurrence of keyword pairs, and is carried out with the help of the VOS Viewer application. The formation of each cluster of interrelated keywords indicates a close relationship in the development of research on that topic. This common bibliometric technique, namely co-author analysis, is used to evaluate collaboration between authors in a field of research.

To provide a more systematic overview, the results of this bibliometric analysis are divided into three main groups. First, studies that focus on the faded example strategy, which specifically highlight the role of the worked example technique with gradual reduction of assistance in improving problem-solving skills. Second, studies that measure science reasoning ability, which represent broader research related to the assessment and development of scientific reasoning in science education and health fields. Third, studies that indicate the potential connection between the two, although they do not explicitly examine both simultaneously. This division is intended to clarify the position of current research findings while identifying gaps that could be the direction of further research.

3.1. *Studies focusing on faded example strategies*

There are seven articles that directly discuss faded examples. Based on existing empirical research evidence, learning that uses problem-solving strategies will increase students' cognitive load during the learning process, especially for novice students. The faded example strategy is chosen when students already have some initial skills but are not yet experts and still need scaffolding to master the material [11]. Faded examples should not be used and should be avoided when students are just learning new concepts [14]. In addition, faded examples are good for “learning declarative concepts” [15]. The faded strategy should be provided adaptively depending on students' prior knowledge and needs. With adaptive and appropriate strategies, novice students will learn faster than those who do not receive adaptive strategies [16].

Another article explains the types of faded examples. There are two types of faded examples, namely forward faded examples and backward faded examples [9,13]. In the forward fading method, students are required to find the solution in the first step. In the second question, students are asked to find the solution in the first and second steps, and so on, so that the last question must be completely solved by the students. Meanwhile, the backward fading method is the opposite. Kusuma & Retnowati [9] also describe how to design faded examples in mathematics, especially in algebra.

Learning to use faded examples also requires attention to technique. This strategy tends to be more effective when learned individually rather than collaboratively [12]. The effectiveness of collaborative learning decreases when using the faded example strategy. In other words, faded example-based learning can facilitate individual learning, especially for students with weak collaborative skills.

Overall, research in this category supports the claims of Cognitive Load Theory, although its application is still dominated by the field of mathematics. This opens up opportunities for research to test the relevance of this strategy in the context of science learning, which places greater emphasis on the development of science reasoning.

3.2. *Studies that measure science reasoning skills*

The second category covers the majority of articles in the dataset, namely 53 articles (60.9%) that explicitly use the terms science reasoning or scientific reasoning. These articles focus primarily on assessing scientific reasoning abilities and their relationship to critical thinking skills, science literacy, and academic outcomes.

Research in the field of health education has found that critical thinking skills, which are a core component of scientific reasoning, are closely related to student academic achievement [17–19]. In addition, several studies emphasize the importance of valid assessment instruments to measure scientific reasoning. One recent study developed and tested the reliability of a more comprehensive scientific reasoning test, so that it can be used to evaluate the effectiveness of various learning interventions [20]. Other studies show that a lack of science reasoning skills can create uncertainty in decision making [21].

Publications on scientific reasoning experienced a significant increase, reaching their peak in 2020, before subsequently declining. This indicates the dynamic nature of researchers' interest in this topic, which is likely influenced by trends in STEM education and the need for higher-order thinking assessments. However, the majority of these studies still focus on assessment [22–24] and have not yet examined specific instructional strategies that can directly develop scientific reasoning. In other words, there is still room to test the effectiveness of instructional approaches, including faded examples.

3.3. Studies indicating a potential relationship between the two

The third category does not directly address faded examples or scientific reasoning, but it has conceptual relevance to both. Scientific reasoning relies heavily on hypothetical thinking, which is a cognitive process that involves forming and testing hypotheses to understand scientific phenomena [25]. CLT research suggests that emotional content can increase cognitive load, thereby affecting science reasoning performance. This indicates that managing cognitive load is critical to effective science reasoning abilities [26].

Another article highlights the importance of scaffolding in supporting the development of students' critical thinking skills. Improving critical thinking skills will enhance students' ability to master scientific reasoning [18,19]. This concept is in line with the faded example principle, which provides gradual support until students are able to learn independently. There is also research discussing the improvement of transfer abilities through the worked example approach, which shows the potential of this strategy to strengthen higher-order thinking skills [27]. In addition, studies on the assessment of higher-order thinking skills in science classes indicate the need for instructional methods that can help students develop scientific reasoning [19].

These findings show that although no articles explicitly link faded examples with science reasoning, there is a fairly strong thematic proximity. The keyword faded examples is associated with problem solving and cognitive load, while science reasoning is often associated with assessment and critical thinking. This indirect relationship opens up new research opportunities to empirically test the integration of these two approaches in science learning.

4. Conclusion

Based on the existing literature synthesis, the faded example strategy shows effectiveness in improving problem solving and mathematical reasoning. Although there have not been many studies that explicitly test the direct relationship with science reasoning, this approach has strong potential to support the development of scientific reasoning, especially when integrated in the context of inquiry-based science learning.

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