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# Mapping Research Trends on 21st-Century Problem-Solving Skills in Science Learning: A Literature Review from 2014 to 2023

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**Abstract:** Problem-solving skills are among the most important competencies of students, especially in the area of science education in the 21st century. Problem-solving skills enhance critical, logical, and creative thinking skills, which are necessary to solve complex real-life problems. This study is intended to identify and analyze research trends with regard to problem-solving skills in science learning from 2014 to 2023. A qualitative bibliometric approach has been used, and the data was collected using Publish or Perish and Dimensions.ai. In total, 200 documents indexed by Google Scholar were analyzed. Research trends, key keywords, and publication patterns were mapped and visualized using the VOSviewer software. The findings indicated that research on problem-solving skills gained consistent interest over the last decade, with the highest number of publications in 2023. Journals were the most common type of publication, followed by proceedings, chapters, and books. Among all publication venues, the Journal of Physics: Conference Series turned out to be the most important, publishing 784 articles and receiving 2567 citations. The most frequent keywords accompanying research in problem-solving are "critical thinking," "science learning," "motivation," and "teacher," which point to the interdisciplinary nature of the topic. Bibliometric visualization shows the emergence of new research clusters: student skills development, teaching strategies, and assessment methods. The conclusion from this study is that, while the research on problem-solving skills has grown steadily in science education, the implementation of practical teaching strategies in a classroom to enhance these skills remains fragmented. The future direction for research should encompass experimental studies through the integration of problem-based learning approaches that are important in the development of critical and creative thinking among students. Such findings have an important basis for educators, policymakers, and researchers to devise evidence-based practices that enhance the outcomes of science education.

**Keywords:** problem-solving skills, 21st-century competencies, science learning, bibliometric analysis, critical thinking.

## ▪ INTRODUCTION

The scientific and technological advancements achieved by a nation are critical benchmarks for assessing its overall development and global competitiveness. In the 21st century, these advancements are increasingly linked to the quality of human resources, which are shaped fundamentally through education. Education, particularly science education, plays a pivotal role in fostering intellectual growth and critical thinking abilities. These skills are indispensable for addressing the complexities of the modern world (Hanushek & Woessmann, 2012; Schleicher, 2019). To cultivate essential competencies such as problem-solving, creativity, and critical thinking, the quality of science education must be continuously improved (Trilling & Fadel, 2009; Bybee, 2013).

Science education is primarily aimed at helping students understand and explain natural phenomena. However, effective science teaching transcends rote memorization;

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it encourages learners to observe, analyze, and apply their knowledge to real-world challenges (Osborne, 2014; Jonassen, 2011). This approach aligns with inquiry-based learning principles, which promote critical and creative thinking while fostering a deeper understanding of scientific concepts (Hmelo-Silver, 2004; Lazonder & Harmsen, 2016).

The need for developing 21st-century competencies cannot be overstated in today's globalized environment. Skills such as critical thinking, problem-solving, collaboration, and communication are in growing demand across industries and society (Voogt et al., 2013; Fullan & Langworthy, 2014). Despite their significance, many education systems continue to struggle with implementing science learning approaches that prioritize problem-solving. For example, Indonesia's 2018 Programme for International Student Assessment (PISA) results ranked the country 71st out of 79 participating nations, signaling critical deficiencies in students' critical thinking and problem-solving abilities (OECD, 2019). Traditional instructional methods that emphasize rote learning over active problem-solving only exacerbate these challenges (Taber, 2010; Areepattamannil et al., 2011).

To address these issues, educators must adopt innovative teaching strategies that promote problem-solving skills. Research has shown that approaches such as problem-based learning (PBL), inquiry-based learning (IBL), and collaborative learning effectively enhance students' problem-solving and critical thinking abilities (Barron & Darling-Hammond, 2010; Hmelo-Silver, 2007). These strategies actively engage students in the learning process, enabling them to develop solutions to authentic problems while encouraging cognitive growth (Hmelo-Silver, 2004; Yager & Akcay, 2008).

Problem-solving is particularly crucial in science education, as it allows students to systematically analyze issues, develop strategies, and implement solutions. Jonassen (2011) emphasizes that problem-solving bridges the gap between theoretical knowledge and practical applications. Developing these skills not only enhances scientific literacy but also equips students to tackle challenges in a rapidly evolving, technology-driven world (Osborne, 2014; Bybee, 2013).

Despite its recognized importance, research on problem-solving skills within science education remains fragmented. While numerous studies have explored teaching models that promote problem-solving, comprehensive analyses of trends and themes in this field are still limited (Aria & Cuccurullo, 2017; Chen et al., 2019). Bibliometric analysis serves as an effective tool for addressing this gap by identifying research trends, prominent keywords, and underexplored areas. It provides a clear visual representation of the research landscape, enabling scholars to pinpoint emerging themes and opportunities for future study (Chen et al., 2019).

This study aims to bridge this gap by conducting a bibliometric analysis of research on problem-solving skills in science education between 2014 and 2023. Specifically, the study seeks to address the following research questions:

1. What are the publication trends in problem-solving research within science education from 2014 to 2023?
2. What dominant themes, keywords, and research clusters emerge during this period?
3. What gaps exist in the current literature, and what areas should future research explore to advance the understanding of problem-solving skills in science learning?

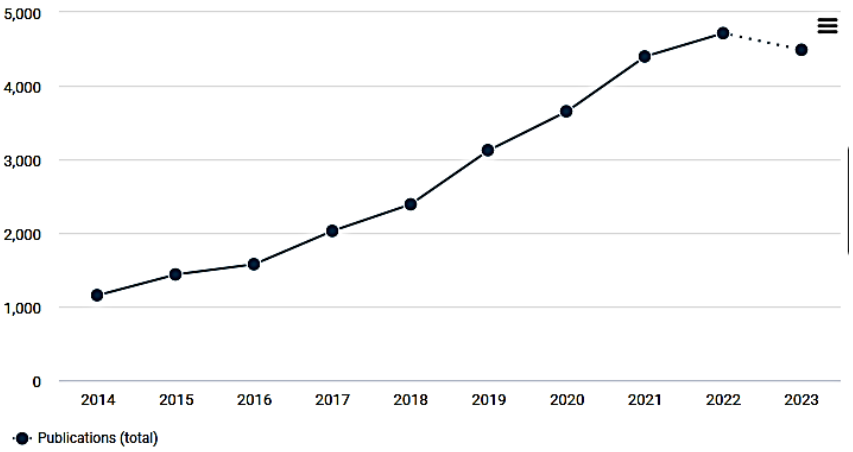


**Figure 1**. Problem solving ability research trends (2014-2023) (app.dimensions.ai)

By answering these questions, this study offers a comprehensive overview of research trends related to problem-solving in science education. The findings are expected to guide educators, researchers, and policymakers in identifying emerging themes and addressing gaps, ultimately contributing to the development of more effective teaching strategies. Furthermore, the study underscores the significance of problem-solving skills in achieving 21st-century educational goals while advancing critical thinking and scientific literacy among students (Trilling & Fadel, 2009; Fullan & Langworthy, 2014).

## ▪ METHOD

### Research Design

This study adopted a bibliometric analysis research design to explore trends in problem-solving skills within science education between 2014 and 2023. Bibliometric analysis is a quantitative method that systematically maps research outputs to identify relationships, trends, and emerging themes within a specific area of study (Aria & Cuccurullo, 2017; Chen et al., 2019). By employing this approach, the study offers an objective and structured understanding of how problem-solving skills research has evolved in the context of science learning. Special focus was placed on analyzing publication trends, prominent keywords, and research clusters using bibliometric tools and visualization techniques.

### Search Strategy

The literature search was carried out systematically using reliable academic tools and databases, including Google Scholar, Publish or Perish, and Dimensions.ai. These platforms were selected for their broad coverage of indexed publications across disciplines, particularly in science and education research (Harzing & Alakangas, 2016; Hallinger & Chatpinyakoop, 2019).

The search process employed carefully selected keywords such as "problem-solving skills," "science learning," "21st-century competencies," and "critical thinking." To refine and expand the results, Boolean operators like "AND" and "OR" were applied.

The search process was structured into four stages: Identification, a total of 900 documents were initially retrieved from the selected databases. Screening, titles and abstracts were reviewed for relevance, narrowing the results to 320 documents. Eligibility, full texts were carefully assessed to exclude studies that did not align with the

research objectives, resulting in 200 eligible publications. Inclusion, the final set of 200 documents met all criteria and was included for analysis. To ensure transparency in the selection process, a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart was utilized, as illustrated in Figure 1 (Moher et al., 2009). This framework provides a clear and systematic outline of the screening and selection process.

**Inclusion and Exclusion Criteria**

To maintain the quality and relevance of the selected studies, specific inclusion and exclusion criteria were applied: Inclusion Criteria: studies must focus on problem-solving skills in science education, Publications must have been released between 2014 and 2023, articles must be indexed in Google Scholar, Dimensions.ai, or similar reliable databases, Document types included peer-reviewed journal articles, conference proceedings, book chapters, and edited books, articles must be published in English to ensure accessibility to an international audience. Exclusion Criteria: studies that did not explicitly address problem-solving skills within science learning, duplicate publications identified across multiple databases, articles lacking sufficient methodological details, incomplete texts, or abstracts, non-peer-reviewed documents, such as theses, dissertations, or technical reports. The application of these criteria ensured that only high-quality and relevant publications were included, providing a reliable basis for the bibliometric analysis (Chen et al., 2019; Hallinger & Nguyen, 2020).

**Data Analysis**

The selected data were analyzed using bibliometric methods to quantitatively assess publication trends, citations, and keyword relationships (Aria & Cuccurullo, 2017). The bibliometric tool VOSviewer was used to visualize and map research themes, author networks, and keyword clusters. VOSviewer is a widely used software for bibliometric mapping, offering graphical representations that highlight connections among research topics, authors, and keywords (van Eck & Waltman, 2010; Chen et al., 2019).

The data analysis process was conducted in three stages: Descriptive Analysis: Descriptive statistics summarized key trends, including publication frequency, document types, and citation metrics. This provided a clear picture of research productivity and impact during the study period. Keyword Co-occurrence Analysis: Frequently appearing keywords were analyzed and grouped into thematic clusters. These clusters were visualized through network diagrams generated in VOSviewer, offering insights into dominant and emerging research themes. Overlay and Density Visualizations: Overlay maps were used to track the progression of keywords over time, while density maps highlighted areas of concentrated research activity. This approach revealed the chronological development of key themes and provided insights into research gaps and opportunities for future exploration (Chen et al., 2019; Moed et al., 2014).

By adopting this multi-stage bibliometric approach, the study achieved a comprehensive analysis of trends, relationships, and thematic developments in problem-solving research within science education. The findings offer valuable insights into current knowledge gaps and future research directions.

## ▪ RESULT AND DISCUSSION

This study aims to describe research trends on problem-solving skills conducted between 2014 and 2023. Problem-solving skills are crucial for students in science

education as they foster critical, logical, and creative thinking, enabling students to address complex scientific challenges effectively. Research in this area continues to grow, reflecting its importance in improving student learning outcomes and preparing individuals for 21st-century competencies (Jonassen, 2011; Lazonder & Harmsen, 2016). The results of this bibliometric analysis highlight several significant findings regarding the types of publications, citation impact, and emerging research themes.

**Publication Trends**

Table 1 presents the distribution of publication types for research on problem-solving skills. The data indicate that four primary publication types articles, proceedings, book chapters, and edited books dominate the literature on this topic.

**Table 1**. Problem solving research trends by publication type

| Publication Type | Publications |
|---|---|
| Article | 33071 |
| Proceeding | 3547 |
| Chapter | 4522 |
| Edited Book | 239 |

Table 1 reveals that journal articles constitute the largest proportion of research publications, accounting for 33,071 studies. This finding aligns with previous bibliometric studies, which emphasize that peer-reviewed journal articles are the preferred medium for disseminating research findings due to their rigorous review processes and higher accessibility (Chen et al., 2019; Aria & Cuccurullo, 2017). Proceedings, chapters, and books follow as alternative platforms, albeit with significantly lower publication counts. Similar trends were reported by Dovlatova et al. (2022) and Waltman (2016), who emphasized the increasing dominance of journal articles in educational research.

**Table 2**. Journal publication of research on problem solving ability from 2014 to 2023

| Journal | Publications | Citations | Citations Mean |
|---|---|---|---|
| Journal of Physics Conference Series | 784 | 2567 | 3.27 |
| AIP Conference Proceedings | 347 | 547 | 1.58 |
| Procedia - Social and Behavioral Sciences | 243 | 3106 | 12.78 |
| SSRN Electronic Journal | 242 | 592 | 2.45 |
| Advances in Social Science, Education and Humanities Research | 239 | 136 | 0.57 |
| Journal of Chemical Education | 194 | 2816 | 14.52 |
| AKSIOMA Jurnal Program Studi Matematika | 129 | 214 | 1.66 |
| The FASEB Journal | 126 | 30 | 0.24 |
| Jurnal Penelitian Pendidikan IPA | 89 | 81 | 0.91 |
| Journal of Educational Psychology | 77 | 8293 | 107.70 |

Table 2 shows that the most research on problem-solving ability was published in the Journal of Physics Conference Series with 784 publications. However, the most cited problem-solving research was a research article published in the Journal of Educational Psychology with 8293 citations. The lowest citation was in The FASEB Journal with 30

citations. This discussion will present a graphic visual mapping of articles on problem-solving ability. The results of this analysis become an interpretation of article publications based on research objects that are often studied and analyzed. Related to bibliometrics, mapping science is a method for visualizing objects of study from a field (Chandra, 2018; Chen & Song, 2019). Visualization is done by creating a landscape map that can provide visual information about the topic of study, namely problem-solving ability. The results of bibliometric mapping from the shared word map network for article publications can be seen in the following figure.

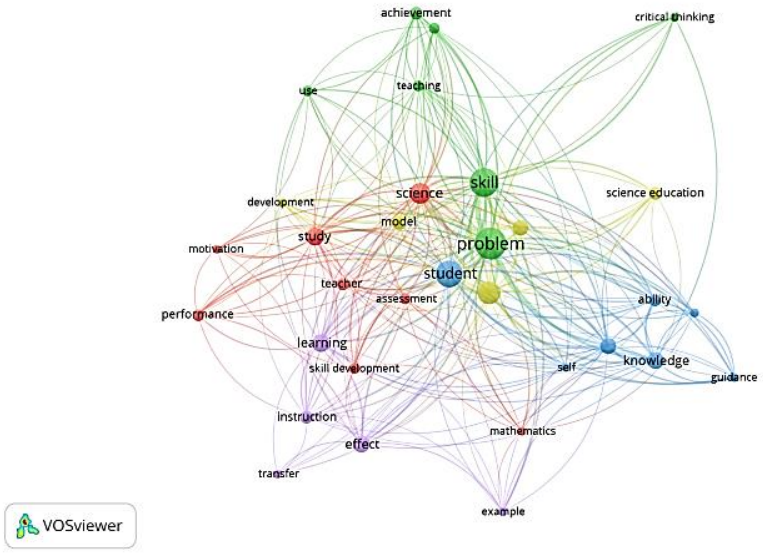


**Figure 1**. Circles network visualization

Figure 1 shows the results of bibliometric keyword mapping in research on problem-solving skills. The figure shows keywords that are often used in research on problem solving. Figure 1 shows several clusters, where the first cluster is marked in red which includes assessment, mathematics, motivation, science, skill development, study and teacher. The blue cluster includes achievement, critical thinking, problem, relationship, skill and teaching. The last cluster includes science learning, student, environment and others. The results of the clusters in the network visualization analysis are in line with the results of the analysis conducted by (Suprapto et al., 2021) which shows that there are six clusters in TPACK-based learning.

The keywords classified into 3 clusters are arranged in a color chart showing clusters that are connected to each other. The following are also presented keywords about problem solving by year.

Figure 2 shows the trend of article writing themes in journals indexed by Google Scholar by year. The trend in article writing themes related to problem-solving skills from the oldest to the newest is marked by the themes of purple, blue, tosca, dark green, light green and yellow. This means that the keywords of wisdom development, critical thinking, motivation and others are the latest themes related to research on problem solving. This can be a current reference for further research. Research on problem solving can be illustrated in the following figure.

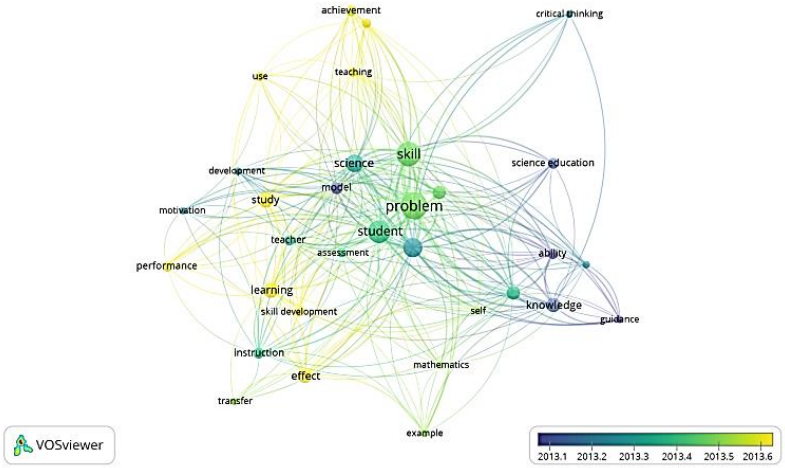


**Figure 2**. Frames overlay visualization

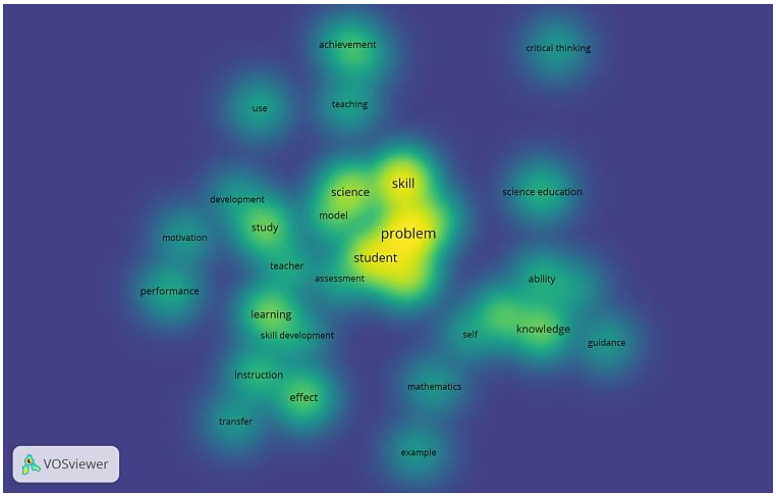


**Figure 3**. Density visualization

Figure 3 shows the density of research themes. The density of research themes is indicated by the bright yellow color. The brighter the color of a theme, the more research has been completed. The dimmer the color means that the theme is currently rarely studied, such as the environment. (Kaur et al., 2022; Liao et al., 2018) state that the yellow color indicates keywords that are currently and frequently used in research.

The results of this study reveal significant growth in research on problem-solving skills, driven by the increasing recognition of their importance in science education. The dominance of journal articles as the primary publication type reflects the academic community's preference for peer-reviewed research dissemination. However, disparities in citation impact highlight the need for greater efforts to enhance the visibility and accessibility of impactful studies (Harzing & Alakangas, 2016; Moed et al., 2014).

The bibliometric mapping underscores critical themes, such as the relationship between problem-solving and critical thinking, as well as the role of teaching strategies in fostering these skills. Despite significant progress, gaps remain in understanding how environmental factors and contextual variables influence students' problem-solving abilities. Future research should explore these areas using experimental and longitudinal designs to provide deeper insights (Hmelo-Silver, 2004; Osborne, 2014).

## ▪ CONCLUSION

Research on problem solving in the period 2014-2023 is not too fluctuating, the increase always occurs every year until 2023 as its peak. Based on the results of the analysis, several types of publications were found that have the theme of critical thinking which include journals indexed by SINTA or Google Scholar. Types of publications include journals, proceedings, chapters and books. Journals are one form of publication that contains the most articles on critical thinking skills. The journal that published the most with the keyword problem solving is the Journal of Physics Conference Series, namely 784 with a total of 2567 citations.

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