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THE RELATIONSHIP BETWEEN SCIENCE PROCESS SKILLS AND 21ST CENTURY SKILLS IN SCIENCE LEARNING: SYSTEMATIC LITERATURE REVIEW

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Abstract :
The purpose of this study was to explore and analyze the relationship between science process skills and 21st-century skills in science learning through the Systematic Literature Review approach. Data collection was carried out using a reference manager application, namely Publish or Perish. The search strategy used keywords developed from the main concepts, namely science process skills and 21st-century skills in science education. The collected data were then stored in *.ris format for further analysis using VOSviewer software. Bibliometric analysis was used to assess opportunities for future scientific research. This study used metadata from 400 articles. This metadata was extracted from the Scopus and Google Scholar databases. Metadata was evaluated using Vosviewer to build its visualization. This mapping process consists of three types of visualizations, namely network visualization, density visualization, and overlay visualization. The results of the study indicate that science process skills are closely related to 21st-century skills, especially in terms of critical thinking, computational thinking, and inquiry-based learning. The novelty of this study lies in the in-depth analysis of the relationship between science process skills and 21st century skills in the context of science learning, which can provide new insights for designing a more integrative and applicable curriculum. The impact of this study is that it is able to improve the effectiveness of science education by preparing students to develop skills that are not only relevant in academic contexts, but also in facing the challenges of an increasingly complex world of work.

Keywords: 21st Century Skills, Science Learning, Science Process Skills, Systematic Literature Review

INTRODUCTION

21st-century skills are becoming a major focus in today's education world due to the importance of preparing the younger generation to face the challenges of globalization and technological advancement. Skills such as critical thinking, creativity, collaboration, and digital literacy are essential in various areas of life (Irawan, 2023; Saputra, 2024; Setianingrum et al., 2024). With these skills, students are expected to not only be able to master academic knowledge but also be able to adapt to rapid changes in society. Therefore, education needs to place more emphasis on developing 21st-century

skills so that students can contribute effectively in an ever-evolving world (Fakhri, 2023; Santoso et al., 2023).

The Merdeka Curriculum, which is implemented in Indonesia, is one effort to address these challenges. This curriculum provides flexibility for schools and teachers to organize the learning process according to student needs and local contexts (Fadillah & Wahyudin, 2024; Ginanjar et al., 2024). Through a more contextual and personal approach, the Independent Curriculum encourages the development of students' competencies and characters, including 21st-century skills (Lase & Murniarti, 2023; Thana & Hanipah, 2023). Thus, students do not only focus on theoretical knowledge, but also on mastering skills that are relevant to real life and the future.

In the context of science learning, science process skills such as observation, experimentation, and data analysis are closely related to 21st-century skills (Sultanni, 2023). Science process skills help students develop critical thinking, problem-solving, and innovation skills—all of which are part of 21st-century skills (Eralita, 2023). By combining science process skills and 21st-century skills, science learning becomes more meaningful and effective, and is able to produce students who are ready to face challenges in the real world.

The Systematic Literature Review (SLR) method offers advantages in systematically compiling and evaluating various existing studies (Anidhea & Sulaiman, 2024; Za et al., 2024). SLR allows researchers to identify trends, patterns, and gaps in the literature in an objective and structured manner (Akbar et al., 2024; Ardiana et al., 2023). This approach provides a more comprehensive understanding of the topic being studied and ensures that the analysis is based on strong and relevant evidence. These advantages make SLR an appropriate method to explore the relationship between science process skills and 21st-century skills.

The importance of using SLR in this study lies in its ability to reveal a significant relationship between science process skills and 21st-century skills in science learning. By analyzing various studies that have been conducted, this study can provide a clearer picture of how these two types of skills are interrelated and how they can be effectively integrated in the learning process. This is important to ensure that the learning strategies implemented can truly support the development of skills needed for the future.

This study is expected to provide a meaningful contribution to the development of more effective curriculum and learning strategies in Indonesia. By understanding the relationship between science process skills and 21st-century skills, teachers and educators can design teaching methods that are more innovative and relevant to students' needs. In addition, the results of this study can also be a basis for policy makers in designing educational policies that better support the development of 21st century skills.

The previous study conducted by Van Laar et al., (2020) and the current study have different focuses, although both discuss 21st-century skills. The first study focuses more on factors that influence 21st-century skills, specifically digital and technical skills needed by workers in the industrial world, while the second study explores the relationship between science process skills and 21st-century skills in the context of science education. The gap between the two studies lies in their contexts—the first focuses on workforce readiness in the industrial sector, while the second focuses on student skill development in science learning. Although both use systematic literature reviews, they could complement each other by further examining how skills developed in school can be applied in the workplace, as well as how technical and social skills in the educational context can contribute to future worker readiness.

This research has high novelty and urgency considering the importance of integrating 21st century skills in science education to prepare students to face the challenges of an increasingly complex and technology-based world. Amidst the rapid development of technology and changes in the dynamics of the world of work, skills such as critical thinking, problem solving, communication, and collaboration are becoming increasingly essential. By examining the relationship between science process skills and 21st century skills, this research makes a significant contribution to the development of more relevant and effective curricula and learning methods, which can improve students' abilities not only in the field of science but also in their professional lives. The urgency of this research lies in its ability to create more contextual and applicable learning, facilitating students in developing skills that are much needed in the modern world of work.

The formulation of the problem that is the focus of this study is how the relationship between science process skills and 21st century skills in the context of science learning. The purpose of this study is to explore and analyze the relationship between science process skills and 21st century skills in science learning through the Systematic Literature Review approach.

RESEARCH METHOD

This study focuses on science process skills and 21st-century skills in science education. The systematic review was conducted in accordance with the PRISMA guidelines, as all analyses for this study were based on published literature (Manoppo & Huriah, 2022; Parums, 202; Page et al., 2021). Therefore, the search strategy, study selection, quality assessment, data extraction, analysis, and synthesis process are described in the following sections.

The most crucial stage in conducting a systematic review is to ensure that all relevant studies can be found appropriately (Chauhan et al., 2022; Schröer et al., 2021). Data were obtained from various large databases such as Scopus and Google Scholar, due to their relevance to the topic of this study. Data collection was carried out using a reference manager application, namely Publish or Perish, to obtain articles that were in accordance with the theme being studied (Ansori et al., 2024; Al Husaeni & Al Husaeni, 2022; Suharti, 2022). The search strategy used keywords developed from the main concept, namely science process skills and 21st-century skills in science education. The collected data were then stored in *.ris format for further analysis using VOSviewer software.

The articles collected and analyzed came from the time span of 2015 to 2024, with search criteria focused on titles, keywords, and abstracts that were relevant to the theme of 21st century skills, science process skills, and science learning. Meanwhile, articles that did not meet these criteria were excluded. The selection process involved duplicate screening and abstract review steps (Muka et al., 2020).

The quality of the included articles was assessed based on the research design, publication outlet, and study impact. The research design was evaluated to ensure that each study included a comprehensive description of the research objectives, methodology, and results. Relevant attributes such as year of publication, title, outlet details, keywords, methodology, and study focus were extracted and analyzed using Vosviewer software. The results of the analysis were then synthesized to answer the research questions.

The purpose of this study was to create a map of attributes related to science process skills and 21st century skills in science education. Bibliometric analysis was used to assess opportunities for future scientific research. This study used metadata from 400 articles. This metadata was extracted from the Scopus and Google Scholar databases. Metadata was evaluated using Vosviewer to build its visualization. This mapping process consists of three types of visualization, namely network visualization, density visualization, and overlay visualization (Rahmawati et al., 2022; Sidabutar et al., 2022).

RESULTS AND DISCUSSION

Results

The VOSviewer output obtained in this study is as follows:

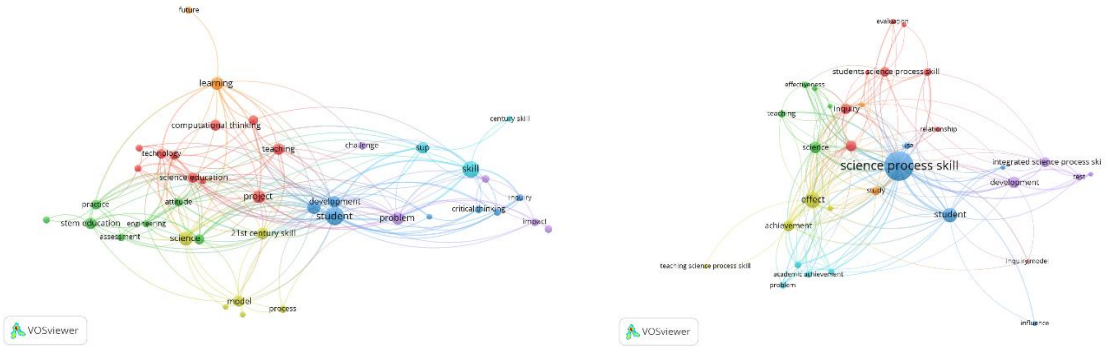

Figure 1. Network Visualization

Based on the results of the VOSviewer visualization related to 21st century skills and science learning, several key concepts that emerged in this study are learning, computational thinking, science education, 21st century skills, and critical thinking. These terms indicate a research focus on developing skills relevant to the 21st century, such as critical thinking and computational thinking, which are widely used in the context of science learning. The relationship between these concepts is clearly visible through the thick connecting lines, which indicate the frequency of co-occurrence in the articles analyzed. For example, computational thinking has a close relationship with science education, indicating the importance of applying computational thinking in science learning. In addition, concept clusters such as STEM education, engineering, and science show a strong relationship, indicating a research focus on STEM education that is closely related to 21st century skills. Lighter colors in the visualization indicate newer research, while darker colors reflect older research. This shows that some topics such as learning and computational thinking have received more recent research attention. Overall, this visualization shows the importance of critical and innovative thinking skills in science learning to prepare students for the challenges of the 21st century.

The keyword science process skill is located at the center of the network and is connected to many other concepts, indicating the importance of this skill in the context of science education. Keywords such as student, inquiry, and achievement are closely connected to science process skills, indicating that the development of these skills is often associated with inquiry-based learning and student academic achievement. The connection with the keywords use and study indicates that the use of and research on science process skills is a major focus in the literature.

In addition, words such as effect, development, and relationship indicate a focus on the impact of science process skills on learning outcomes and the relationships between these variables. The terms evaluation and test point to the importance of evaluation and testing in assessing science process skills. The network also shows that science process skills are often discussed in relation to integrated science process skills, which are essential for a more in-depth science education. Overall, this visualization illustrates the complexity and interconnectedness of the various aspects of science process skills in education, from their impact on students to how they are taught and assessed.

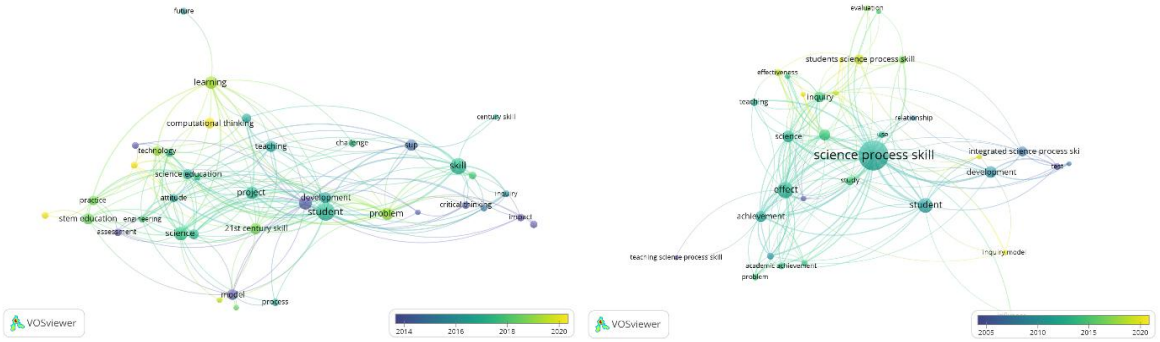

Figure 2. Overlay Visualization

Based on the figure above, it shows the relationship between various concepts in STEM (Science, Technology, Engineering, and Mathematics) education and 21st century skills from 2014 to 2020. Keywords such as student, kill, learning, problem, and science occupy a central position, indicating that these topics often appear together in the literature. 21st century skills such as critical thinking and computational thinking are closely related to the concept of project-based learning and student development, indicating that this approach is increasingly relevant in modern education. Concepts such as STEM education, science education, and technology highlight the importance of technology and science in learning. Some keywords, such as future and inquiry, indicate a future orientation and an inquiry-based learning approach. The colors in the graph represent the time of emergence of these concepts, where newer concepts such as computational thinking and STEM education are shown in yellow, indicating increased attention to these topics in recent years.

The keyword science process skill has the largest node, indicating that it is a central and most frequently researched topic. Other nodes that are closely related to science process skills include student, effect, inquiry, eaching, and achievement, indicating that these studies often discuss science process skills in the context of students, teaching effectiveness, and academic achievement. The color of the nodes and lines indicates the year the studies were published; yellow nodes indicate more recent studies (around 2020), while blue nodes indicate older studies (around 2005). For example, the keywords integrated science process skill and development appear more recent, indicating that studies related to the development and integration of science process skills have become more dominant in recent years. The relationships between keywords are indicated by connecting lines indicating the frequency of co-occurrence. The thicker the line, the more frequently the keywords appear together in the literature. This map illustrates that science process skills are not only related to student effectiveness and achievement, but are also closely related to inquiry-based teaching models and the development of these skills.

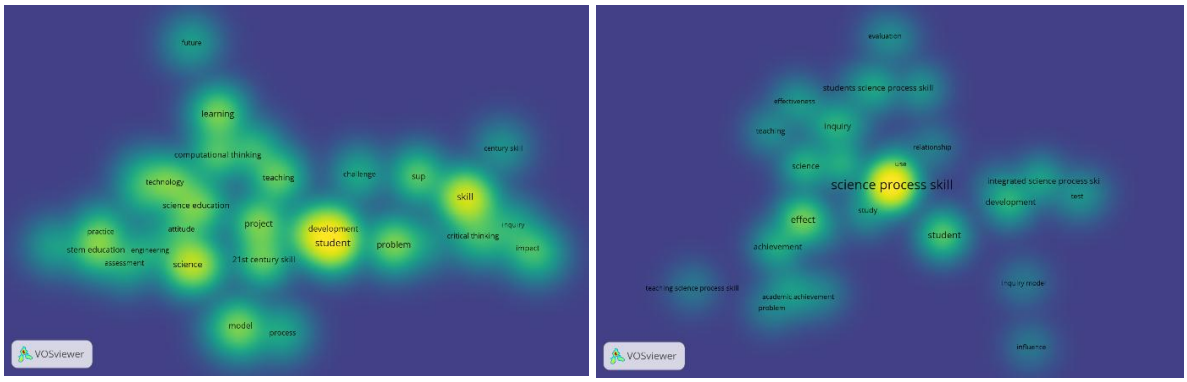

Figure 3. Density Visualization

Based on the figure above shows the density and frequency of keyword occurrences in the literature related to STEM education and 21st century skills. The lighter areas (yellow) indicate keywords that appear frequently or receive greater attention, while the darker areas (blue) indicate lower frequency of occurrence. Keywords such as student and skill have a very high density, indicating that

the main focus of research or literature is on student skill development. In addition, concepts such as learning, science, computational thinking and problem also stand out, indicating that these are topics that are often discussed in the context of STEM education and skill development.

Other words such as project, 1st century skill, critical thinking, and science education also appear quite prominent, emphasizing the importance of critical thinking skills and problem-based projects in modern education. Dimmer areas, such as model, practice, and assessment, indicate that these topics are also relevant, although not as popular as other keywords in the literature. This visualization provides a clear picture of the main focus of research related to 21st century education and STEM. The keyword science process skill is located in the center and has the brightest color intensity (yellow), indicating that this topic is the most discussed and the main focus of research. The keywords student, effect, inquiry, and achievement also have quite high intensity, indicating that these topics appear frequently and are relevant to science process skills.

Areas with lighter colors indicate higher frequency of occurrence and stronger relationships between these keywords. Conversely, areas with darker or spread out colors indicate keywords that appear less frequently or have weaker relationships. For example, keywords such as integrated science process skill and developmentt are on the right side and have medium intensity, indicating significant but not as high relevance as the main keyword. This map illustrates that science process skills in research are often associated with teaching effectiveness, student achievement, inquiry learning models, and the development of these skills. This image helps identify the main topics as well as more specific or less explored areas in science process skills research.

Discussion

Based on the results of the VOSviewer visualization of various literature related to 21st century skills and science education, it appears that the focus of research is mostly on the development of critical thinking skills and computational thinking in the context of science learning. Key concepts such as learning, computational thinking, science education, and critical thinking indicate that the literature tends to highlight the importance of integrating these skills to prepare students to face challenges in the 21st century. Network visualization shows a close relationship between these concepts, especially between computational thinking and science education. This indicates that computational thinking is an important element in science teaching to improve students' analytical and problem-solving skills.

In the overlay image, it is also seen that keywords such as STEM education and inquiry have an important role in the development of science process skills. These topics often appear in the latest literature (marked in yellow), indicating that inquiry-based approaches and technology integration are increasingly relevant in modern education. This is in line with global trends that emphasize the importance of implementing STEM to facilitate more contextual and applicable learning. The strong relationship between critical thinking, computational thinking, and project-based learning reinforces that the current literature is moving towards integrating these approaches into science learning, thereby enriching students’ skills and learning experiences.

The density visualization provides a clear picture of the frequency and intensity of key keywords in the literature. Keywords such as student, skill, and science process skill have high density and bright color intensity, indicating that these topics are widely discussed and are the focus of attention in the literature. The strong focus on students and their skills, especially science process skills, confirms that the main goal of science education today is to develop practical skills that are relevant to real life and can improve academic achievement. The high-density areas also show that the development of science process skills is often associated with the effectiveness of teaching and inquiry-based approaches, indicating that active and participatory teaching methods are very influential in the development of these skills.

However, there are several areas with lower density, such as models, practice, and assessment, indicating that these topics have received less attention than other key topics. However, effective teaching and evaluation models are essential to ensure that the skills taught can be measured and improved systematically. This visualization suggests that while the literature has been extensively discussing the importance of 21st-century skills and science processes, there is still a need to further explore relevant evaluation methods and instruments to measure the success of implementing STEM-based learning and science process skills.

Overall, this visualization suggests that modern science education literature focuses on developing critical and innovative skills needed to address the challenges of the 21st century. Furthermore, recent research increasingly points to the integration of STEM approaches and project-based learning to facilitate these skills. By considering these aspects, educators can develop more effective curricula and teaching strategies in developing critical and real-world-relevant science process skills.

The impact of this study is significant in increasing the understanding of how science process skills can contribute to the development of students' 21st century skills, which in turn can improve the quality of science learning and prepare students for the challenges of the professional world. This study can provide a basis for the development of a more skills-based curriculum, enhancing learning approaches that are more practical and relevant to the needs of the 21st century. However, this study also has several limitations, such as the reliance on existing literature, which may not cover the full range of educational contexts across countries or education systems. In addition, the methodology used a systematic literature review is limited to published sources and may not include recent research or relevant unpublished findings.

CONCLUSION

The results showed that science process skills are strongly related to 21st century skills, especially in terms of critical thinking, computational thinking, and inquiry-based learning. Data visualization highlights that topics such as student skills, teaching effectiveness, and science skill development are the main focus. STEM integration in science education supports the development of students' practical and critical skills, so that they are better prepared to face future challenges. Further research is recommended to develop empirical studies that directly test the influence of science process skills on students' 21st century skills across educational contexts, as well as identify the most effective instructional strategies for integrating both skills in the science curriculum.

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