Research Trend of 21st Century Skills in Science Education Through Bibliometrics

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Abstract. Science learning plays an important role in facilitating the development of 21st century skills. Scholars have paid much attention to the topic in their research activities to gain a comprehensive picture of its role in science education. This study aims to provide an overview of research trends on 21st century skills, especially in science education, through a search for articles that have been published since 2000-2022. The articles consisted of 740 articles derived from the scopus and google scholar databases through searches using the publish or perish search engine. Bibliometric network mapping using visualization of similarities. This bibliometric research is based on stages based on the preferred reporting items for systematic reviews and meta-analyses and network meta-analyses method or abbreviated as preferred reporting items for systematic reviews and meta-analyses. The results showed that 21st century skills research in recent years has increased and occurs at various levels of education and scientific discipline areas and uses a variety of research methods. The findings are expected to provide an overview for other researchers regarding 21st century skills including the number of publications, country of origin, type of publications, research methods, research subjects, types of instruments used, disciplinary fields (science, chemistry, physics, and biology), and learning interventions.

Keywords: 21st century skills, Publish or Perish, VOSviewer, bibliometrics, PRISMA.

Introduction

Every individual should have the 21st Century skills that are essential in a knowledge-based economy (Kensicki et al., 2022) in order to have a reliable competitiveness. Research on 21st century skills has attracted researchers from various fields to study more deeply. Researchers are interested in conducting research because 21st century skills are basic skills that must be possessed in order to face competition. Individual skills in the world of work must be able to adapt to technological developments that cause changes in the way people live (Turiman et al., 2020). The 21st century is characterized by rapidly advancing technological developments (Chu et al., 2017) that can transform organizations and the workers within them (Beer & Mulder, 2020). Technological developments have an impact on the demands of the world of work which demand a variety of new skills. The changing times should be responded to by all
concerned to improve the skills needed in this century. Individuals who are able to adapt in this century must have life and career skills, learning and innovation skills, and information, media and technology skills. The competitiveness and innovation capacity of organisations must be continuously developed through the encouragement of 21st century digital skills (van Laar et al., 2017). All of these skills are needed for a dynamic world of work that keeps up with the times.

The key skills that individuals must master through education in formal and non-formal institutions are known as 21st century skills (Khan et al., 2019; Setiawati et al., 2020). The identification of the types of 21st century skills has been developed by many figures or institutions that focus on the development of these skills. These various 21st century skills become a reference in the development of resources both in the world of education or other institutions both public and private. 21st century skills are needed in education and the world of work (van Laar et al., 2020) so that we can have high competitiveness. In the era of globalization, the world of education must prepare students to have skills that can be used in facing competition (Afandi et al., 2019). Therefore, students must be given the opportunity to engage in contextual-based learning in solving real problems and building authentic professional knowledge (Guo et al., 2020).

The achievement of 21st century skills in education should also be emphasized when investigating the learning effects of pedagogy (Abaniel, 2021). The world of education makes the types of 21st century skills a goal that must be achieved by its graduates through the programs implemented in their respective institutions. Teachers and students have a mutually influential role in improving 21st century skills (Gürsoy, 2021). Some skills are not only related to material content, but there are other competencies in thinking, social interaction and mastery of technology in accordance with the demands of the times. Every graduate of an educational institution must have these skills to prepare for the world of work.

In particular, science education must play a role in developing 21st century skills through learning programs that are applied both in primary education to higher education. The integration of 21st century competencies in the curriculum has become an important issue worldwide (Wang et al., 2018; Wei et al., 2022). Curricula can integrate 21st century skills in science education (Zorlu & Zorlu, 2021) to develop skills by mapping skills in curriculum design as has been done by (Carracedo et al., 2018) for domain-specific and professional competencies. Amoah et al. (2023) found that the curriculum can produce citizens who are scientifically literate and able to face workplace challenges in a systematic and logical sequence. Academic achievement in science can be significantly predicted through 21st century skills (Kan’An, 2018) and are integrated both as an approach to learning and as an outcome of learning applied in the classroom.

Thinking skills are one of the abilities needed to compete in a globalised world (Herawati & Istiana, 2021). Thinking skills as a result of learning both metacognition and creative thinking skills are needed by students to face challenges in the 21st century (Yusnaeni et al., 2020). Students’ success in learning will be determined by their critical thinking skills (Ramadhani et al., 2023). Critical thinking skills are influenced by communication skills and digital literacy (Amin et al., 2023). Creative thinking is one of the important skills needed to produce innovation (Turiman et al., 2020) in the world of education or the world of work. In addition, the skills of critical thinking, creative thinking, communication and collaboration (4C) are one of the keys to success to be able to compete in entering the information and knowledge era (Fajrini et al., 2020) is not influenced by gender (Bahtiar et al., 2023) can be developed through a learning process that emphasizes 21st century skills (Susila et al., 2021). Research trends on 21st century
skills based on seven skills (Silber-Varod et al., 2019), namely collaboration, communication, creativity, critical thinking, information literacy, problem solving and social-emotional skills have been carried out.

The abundant number of scientific publications in the last decade (Prieto-Gutiérrez & Segado-Boj, 2019) and their easy accessibility allow us to analyze the development trend of a particular topic (Suwandi et al., 2023) as needed through bibliometric methods for research assessment (Ellegaard & Wallin, 2015; Wallin, 2005). Researchers can conduct studies to obtain an overview of 21st century skills development in science education to be analyzed and interpreted as needed. We can carry out the process of analyzing research trends in science education through bibliometric studies and visualize with the help of VOSviewer (Santi et al., 2021). Bibliometrics is a method to explore and analyze large amounts of popular and rigorous scientific data (Donthu et al., 2021) and to investigate a particular field of research based on measures of the relevance and impact of its publications (Lee et al., 2020) through combined mapping and clustering techniques (Waltman et al., 2010).

A framework for conceptualizing "21st century skills" in both school and career in the first two decades of the 21st century can be seen (Chen, 2021). In this study, it is necessary to examine the trends and get a clear picture for the application of 21st century skills in science learning, namely physics, chemistry and biology at various levels of education through a bibliometric study. This study will provide an overview of 21st century skills in science classroom learning. Several scientific publications of research results either in the form of journal articles or conferences will be further analyzed to find out the development of research on the topic of 21st century skills in science learning.

Researchers will conduct a deeper study including the number, type of research, types of 21st century skills that are most considered in learning and which countries are concerned with this topic in conducting this research, researchers will use the help of search software and several other supporting software to facilitate research. This study aims to provide an overview of 21st century skills research trends in science education that have been conducted by researchers for three years, from 2020-2022.

Methods

This research is a literature review study using the preferred reporting items for systematic reviews and meta-analyses and network meta-analyses method or abbreviated as PRISMA (Page et al., 2021; Rethlef sen et al., 2021; Sawyer et al., 2019). Systematic reviews aim to collate and synthesize all studies that meet pre-determined eligibility criteria using methods that seek to minimize bias (Higgins et al., 2011). Descriptive analysis techniques and literature studies supplemented by bibliometric analysis (Masalimova et al., 2023) were used to investigate research trends (Adi et al., 2021) through the utilization of publication databases (Zupic & Čater, 2015). The study focused on the profile of 21st century skills research that has been conducted in science education, the number of studies, country of origin, type of publication, research methods, research subjects, types of instruments used, areas of science (science, chemistry, physics and biology), and learning interventions.

The key stages in systematic review are: clarifying the objectives and methods in the protocol, finding relevant research, collecting data, assessing the quality of the research, synthesizing the evidence, and interpreting the findings (Pollock & Berge, 2018). The research began with a search for articles through the Publish or Perish (PoP)
application. The article search was conducted on March 6-25, 2023 through PoP. Database searches and determination of articles selected using criteria first based on a list of inclusions or exclusions against the criteria that have been compiled (Chalkiadaki, 2018; Ilma et al., 2023) can be seen in Table 1. The use of criteria is done to facilitate researchers in selecting a number of articles that have been found through PoP. Selection of several articles is important in order to get a good quality article for deeper analysis so that it can provide a comprehensive picture of the topic being studied.

<table>
<thead>
<tr>
<th>Type of Criteria</th>
<th>Inclusion</th>
<th>Exclusion</th>
</tr>
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<tbody>
<tr>
<td>Type of publication</td>
<td>Journals and Conferences</td>
<td>Books, Dissertations, others</td>
</tr>
<tr>
<td>Year of publication</td>
<td>2000-2022</td>
<td>Less than 2000</td>
</tr>
<tr>
<td>Data source</td>
<td>Scopus dan Google Scholar</td>
<td>Other than Scopus and Google Scholar</td>
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<tr>
<td>Area</td>
<td>Science, Physics, Chemistry and Biology</td>
<td>Outside of Science, Physics, Chemistry and Biology</td>
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<tr>
<td>Research method</td>
<td>Quantitative, qualitative, mixed methods, Research and Development</td>
<td>other</td>
</tr>
<tr>
<td>Study subjects</td>
<td>Elementary, junior high, high school and college students and teachers</td>
<td>other</td>
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<tr>
<td>Intervention</td>
<td>Approaches, models, strategies, media</td>
<td>other</td>
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<td>Research instrument</td>
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The stages of the prisma method are: identification, screening, eligibility and inclusion (Moher et al., 2009). At the identification stage, searching for articles and obtained 740 articles, namely: google scholar there are 695 articles, while from Scopus obtained 45 articles. Screening stage, 621 articles were obtained, because there were 104 inaccessible, and 12 documents that could not be accessed and multiple. The eligibility stage, excluded as many as 548, the results obtained as many as 73 articles. Included, 73 articles were used in this stage.

**Figure 1.** The flow of research stages using the prisma method.
Further analysis was carried out using the VOSviewer application which is a software tool for building and visualizing bibliometric networks. The application for bibliometric analysis VOSviewer (Abbas et al., 2021; Abdullah, 2022; Arruda et al., 2022; Effendi et al., 2021; Ha et al., 2020; Li et al., 2022; Limaymanta et al., 2021; Maryanti et al., 2023) will provide visualization (Al Husaeni & Nandiyanto, 2022; Zhang et al., 2021) of research trends using databases (Nordin, 2022) so as to form a network (Cheng et al., 2021) of areas or topics that are widely researched, current trends based on years of research, and areas or topics that have not received much attention in research. Bibliometric research needs to be done to provide an overview of a topic periodically in scientific publications (Pesta et al., 2018). Research data sources can be based on different databases (Arruda et al., 2022).

Results and Discussion

Systematic literature review was conducted in March 2023 to find and analyze articles through searching using the PoP application. The results of the search for published articles will then be analyzed more deeply to obtain information related to the research picture of 21st century skills in education. The information generated from the systematic review will provide an initial overview before conducting research on this topic. Researchers will get more updated information so that they can get an overview of the development of this research.

Research on the development of 21st century skills is the initial study conducted by researchers if they want to research further on this topic. Literature search through bibliometric studies will provide an overview for researchers who will conduct research (Muhammad et al., 2022; Pham et al., 2023; Sen, 2023). Based on the results of the research that has been carried out by researchers, several results were obtained that can provide an overview of the development of 21st century skills research.

Figure 2. Scientific publications on the topic of 21st century skills analyzed from 2000-2022 by number.
The number of articles analysed was 73 articles selected after going through a selection process from a total of 740 articles found. In 2020-2022 many articles were netted, meaning that the topic of 21st century skills is getting a lot of attention from researchers today. Educational researchers and practitioners are interested in developing these skills to improve the quality of learning (Kim et al., 2019). Increasing the number of scientific publications related to this topic will have a positive impact on the development of 21st century skills in science learning because learning 21st century skills cannot be separated from content (Aura et al., 2023).

In general, the topic of 21st century skills attracts the attention of researchers from all over the world as we can see from the research conducted by Ichsan et al. (2023) and Chalkiadaki (2018). The distribution of countries that produced articles from 2000-2022 can be seen in Figure 3. There are three countries that produced the most articles, including Indonesia, Turkey and the Philippines. In 2000-2013, and 2015 there were no articles analyzed in this study. Indonesia occupied the first position where many researchers conducted research on 21st century skills.

![Figure 3. Scientific publications on the topic of 21st century skills by country of origin.](image)

![Figure 4. Scientific publications with 21st century skills topics by type of scientific publication.](image)

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The study of relevant previous literature has an important role in the research that will be carried out regardless of the discipline (Snyder, 2019). Scientific literature will help researchers to design the research to be carried out (Subramanyam, 2013). Articles published from 73 documents, there are two forms, namely journals and conference results. The type of publication in the form of journals is more than the type of publication of conference results. The type of publication will give us information regarding the quality of the research. Published articles have generally gone through a good review and editing stage before the manuscript is published. Information obtained from journal articles is usually of better quality than some other scientific sources that have not gone through the review stage.

Researchers can utilise different types of research to identify educational issues. The research methods used consist of quantitative research, qualitative research, mixed methods research and development research (R&D). Many researchers used quantitative research as many as 42 articles, and the least used qualitative research as many as 9 articles. In addition, mix methods and R&D research were used to research topics related to 21st century skills. The diversity of the types of research used will enrich the findings of the topic being studied.

![Figure 5. Scientific publications with 21st century skills topics based on research methods.](image)

![Figure 6. Scientific publications on the topic of 21st century skills based on research subjects.](image)
Research subjects in 21st century skills can be elementary, junior high, high school students, university students and teachers. Research on 21st century skills is mostly applied to high school students as research subjects and the least to elementary school students. Skills in the 21st century must be instilled from the elementary school level so that as they move up to higher education levels they become more skilled. The development of 21st century skills should begin in childhood as these skills are essential for their transition to adulthood and meaningful contributions to the well-being of society (Tandika, 2022). In addition, research on teachers is important, because the role of teachers has a central role in classroom learning besides students of course.

Research targeting research subjects from various levels needs to be conducted to provide a more comprehensive picture of research trends on the topic of 21st century skills. Research subjects provide important information to give us an overview of how research has progressed on the topic. Researchers will get an idea of the topic areas that need further research based on the information that has been obtained. Based on the data in Figure 6 we can see how the distribution of the research subjects studied has not been evenly distributed. Teachers have an important role in developing the skills that students need as a result of learning in their classrooms to be applied in solving real-world problems. A learning environment where students’ daily experiences can support learning and participation needs to be developed (Furberg & Silseth, 2022) by teachers in schools in order to improve the quality of learning.

Research instruments that are widely used in research consist of tests, non-tests and a combination of both types of tests can be seen in Figure 7. Assessment instruments in the form of non-tests, such as Likert scales, assessment rubrics, interview guidelines and others are most widely used to measure 21st century skills. Assessment instruments using tests are least used, this is because some indicators in 21st century skills are suitable for assessment using non-tests. Non-test assessments need to be developed so that the assessment of 21st century skills can be measured precisely to assess their ability in a real-world context. Students' critical analysis of real-world problems can be measured through authentic assessment (Ghosh et al., 2020).

![Figure 7. Percentage of scientific publications with 21st century skills topics by test type.](image)

Quality research is determined by the instrument used to obtain data for research. Researchers use various research instruments that are tailored to the type of data or information needed. The accuracy of the selection of the form of research instruments will produce information will determine the quality of data or information that will be further analyzed by the researcher. Along with developments in the world of education, it is necessary to develop holistic research that is able to assess all aspects of learning.
outcomes. Assessment for comprehensive knowledge and higher-order skills, namely creativity, innovation, critical thinking, coordination, and communication, problem solving (Goyal et al., 2022).

![Figure 8](image_url)

**Figure 8.** Percentage of scientific publications with 21st century skills topics by area of science.

Based on Figure 8, the discipline areas that make 21st century skills achievements as learning targets, we can know that physics is an area of science that is widely researched. Chemistry is a discipline that is not very visible in scientific publications. Therefore, it is necessary for researchers in fields other than physics to focus more on their respective fields of science. It is not enough for 21st century skills to be integrated in one discipline, but it would be better if they are integrated in all disciplines.

Based on Figure 9, we can get an overview of the various forms of efforts made by researchers in developing 21st century skills. Generally, researchers choose the application of learning models, and the least use assessment as an effort in improving 21st century skills. Various forms of learning models are pursued by researchers to achieve the skills set. Teachers can make a significant contribution to developing children's 21st century skills from a young age through the use of appropriate teaching materials (Tandika, 2022).

The development of 21st century skills can be applied in various forms both in learning models, teaching materials and assessments. Some learning interventions in research that are applied as an effort to develop 21st century skills include project-based learning (Baran et al., 2021; Mohammad et al., 2019; Rochmawati & Ridlo, 2020), problem-based learning (Sekarini et al., 2020; Yanto & Enjoni, 2022), inquiry (Abdurrahman et al., 2019; Novitra et al., 2021; Widestra & Yulkifli, 2021). Research related to the use of teaching materials to develop 21st century skills including research by Asrizal et al. (2022), Zakiyah & Sudarmin (2022), Dilmen & Atalay (2021), Sawitri et al. (2021), Sarmi et al. (2020), Rusilowati et al. (2020), Vebrianto et al. (2016), Gürsoy (2021). Assessment as an intervention provided to improve 21st century skills was studied by Nurdini et al. (2020) and Nurhijah et al. (2020) in line with the function of assessment as it can be developed during the learning process to improve the teaching and learning process (Supahar & Rosana, 2018).
A pedagogical approach that places learning tasks in a real-world context (Herrington et al., 2014) for learning and assessment (Tumilty et al., 2022) can develop 21st century skills. Learning outcomes can be improved by using various forms of good assessment, especially in the form of formative tests. Formative test is a form of assessment that is given after teaching and learning activities are carried out so that absorption and learning development can be known. The development of learning outcomes is not only focused on the use of models or teaching materials, but assessment is also one form of action that can be given in science learning to improve critical thinking, scientific attitudes, and student self-efficacy in science learning (Suastra & Ristiati, 2019).

VOSviewer can perform bibliometric analyses to identify clusters of research themes that have been conducted (Abdullah & Khan, 2021) as well as bibliometric relationships between various variables (Kirby, 2023). Based Figure 10, on the visualization using Vosviewer, it can be illustrated that the 21st century skills research has six main clusters shown by different colors, namely: blue, red, green, purple, yellow and turquoise. Blue research clusters show the most researched research items, while turquoise blue items show the least researched research items. These themes will provide an overview for researchers who are designing a research project.

Figure 9. Percentage of scientific publications with 21st century skills topics by learning intervention.

Figure 10. Network visualization of 21st century skills research domains in science education in 2000-2022.
The development of 21st century skills research based on trends from past to present can be seen in Figure 11. The purplish color shows the network of research topics in the older years including topics on skills, projects, frameworks, and integration. The yellow areas show the network of areas or topics including influence, investigation, change and STEM. Based on the visualization in Figure 11, we can confirm that the yellow areas are the current areas or topics being researched in 21st century skills research.

**Figure 11.** Overlay visualization of 21st century skills research in science education in 2000-2022.

**Figure 12.** Density visualization of 21st century skills research in science education in 2000-2022.
Figure 12 gives us an idea if the areas or topics in yellow color get a lot of attention in 21st century research. Areas or topics with large letters and are in the yellow area including 21st century skills and skills get a lot of attention from researchers. The dark-colored area gives us an idea of the areas or topics that still have not received attention in this research topic. Some areas that have not received much attention include evaluation, investigation, projects, innovation, collaboration, and communication. The findings can provide educational researchers and practitioners with an overview of 21st century skills in science education so that they can find research areas or topics to improve the quality of science learning in the future.

Conclusion

Based on the results of research, it shows that research on 21st century skills has increased since 2019. Countries from various parts of the world have conducted research on 21st century skills and many have published through journals. The research was conducted using various research methods, including the most quantitative methods, the most research subjects were conducted in high schools. The instruments used in the research mostly combine tests and non-tests. Research on 21st century skills was conducted mainly in physics with learning interventions as a learning model. In addition, the results of using VOSviewer obtained information that there are six clusters of 21st century skills research areas, themes that have received the most researcher attention and topics that are still not widely researched. This research is needed to obtain an overview of 21st century skills research trends so that it can be taken into consideration for other researchers who will conduct research on the same topic.

References


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