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Project-Based Learning-STEAM Model on Students' Critical Thinking and Scientific Literacy: A Bibliometric Analysis

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Abstrak
This study analyses the application of the Project-Based Learning-STEAM (PjBL-STEAM) learning model to improve students' critical thinking skills and scientific literacy, especially in Indonesia, so the latest trends and research opportunities on these topics can be obtained. This study uses a quantitative bibliometric approach. The number of publications analyzed was 142 publication documents in 2015-2020, metadata was obtained from the Scopus database and analyzed using VOSviewer software. The results of metadata extraction show that there are 5 clusters with keywords that appear the most students, engineering education and STEM education. In addition, only 0.5% of authors have more than two publications, so further research from previous publications on this topic is still minimal. Based on the ranking results, the United States ranks 1st, Indonesia ranks 2nd, and Australia ranks 3rd. Indonesia is excellent in research development and collaboration on this topic compared to other countries. It can be concluded that research and publications related to this topic have made relatively little progress in the last five years.
Keywords: bibliometric, PjBL-STEAM, critical thinking, science literacy, Indonesia

Model Project Based Learning-STEAM terhadap Kemampuan Berpikir Kritis dan Literasi Ilmiah Siswa: Kajian Bibliometrik

Abstract
Penelitian ini menganalisis penerapan model pembelajaran Project-Based Learning-STEAM (PjBL-STEAM) untuk meningkatkan kemampuan berpikir kritis dan literasi sains siswa khususnya di Indonesia, sehingga dapat diperoleh tren dan peluang penelitian terbaru tentang topik tersebut. Penelitian ini menggunakan pendekatan bibliometrik kuantitatif. Jumlah publikasi yang dianalisis adalah 142 dokumen publikasi tahun 2015-2020, metadata yang diperoleh dari database Scopus dan dianalisis menggunakan software VOSviewer. Hasil ekstraksi metadata menunjukkan terdapat 5 cluster dengan kata kunci yang paling banyak muncul adalah mahasiswa, pendidikan teknik, dan pendidikan STEM. Selain itu, hanya 0,5% penulis yang memiliki lebih dari dua publikasi, sehingga penelitian lanjutan dari publikasi sebelumnya tentang topik ini masih minim. Berdasarkan hasil pemeringkatan, Amerika Serikat menempati peringkat 1, Indonesia peringkat 2, dan Australia peringkat ketiga. Jika dibandingkan dengan negara lain, Indonesia unggul dalam pengembangan penelitian dan kolaborasi dalam topik ini. Dapat disimpulkan bahwa penelitian dan publikasi yang terkait dengan topik ini relatif sedikit mengalami kemajuan dalam lima tahun terakhir.
Kata Kunci: *bibliometrik, PjBL-STEAM, berfikir kritis, literasi sains, Indonesia*

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INTRODUCTION

The era of disruption and the industrial revolution that increase massively affect the technological and social aspects, including education. This includes changes in learning styles, learning systems, and curricula oriented to 21st-century skills. In this learning system, students must engage in critical thinking, be innovative, solve problems, collaborate, have information technology literacy, and be socially responsible (Mayasari et al., 2016). These various abilities are needed in education to produce a generation that can answer the challenges of globalization in the competitive world of work with various new professions. Therefore, STEM (Science, Technology, Engineering, Mathematics)-based interdisciplinary learning approaches have become the latest trend in the last few decades (Suprapto, 2016). Various countries in Europe, America, and Asia have implemented STEM in their curriculum (Yata et al., 2020).

In 2011, the Ministry of Education, Science, and Technology of South Korea proposed the addition of a fifth interdisciplinary "Art" in STEM so that it became STEAM (Science, Technology, Engineering, Arts, Mathematics) (Santi et al., 2021). This addition was made based on several studies showing that creativity can improve students' scientific abilities (Burnard, 2016). Furthermore, the addition of "Arts" can increase learning motivation and help connect learning activities with real-life problems (Zhbanova, 2017). Through the STEAM approach, students can be encouraged to explore their abilities, create innovative works, collaborate, cooperate, and take personal and intrapersonal responsibilities (Haifaturrahmah et al., 2020; Mu'minah & Suryaningsih, 2020; Nurfadilah & Siswanto, 2020). This is certainly very relevant to the capabilities of the 21st century, so STEAM is important to be applied to the learning system.

The STEAM approach can be applied through various learning models, such as Project-Based Learning (PjBL). This is because PjBL is a learning model that provides a learning experience for students by designing and creating a project to produce a product (Samsudin et al., 2020). The application of PjBL has various purposes, but this research will focus on students' critical thinking skills and scientific literacy (Adriyawati et al., 2020; Daniel, 2017). This is in line with previous research by Baran et al. (2021); Suryandari et al. (2018); Tati et al. (2017); Triana et al. (2020), which revealed that the implementation of PJBL-STEAM was declared effective in improving students' critical thinking skills and scientific literacy. Critical thinking is one of the skills needed in the 21st century that allows a person to think rationally and logically (Trisnawati & Sari, 2019). At the same time, scientific literacy can give students the ability to understand scientific concepts, phenomena, and processes necessary to participate in society in the 21st century (Karampelas, 2021; Pertiwi et al., 2018).

Since 2015, research on STEAM has developed very rapidly to date. A simple thing that can be done to prove it is to search Scopus with the keyword "STEAM Education", in 2015 there were 49 documents, while in 2021, there were 251 documents. So there is a very rapid increase of up to five times. According to (Y. Li et al., 2020) research, there needs to be an effort to initiate the status and trend of research on a topic so that strategy development and support can be appropriately identified. Bibliometric studies can be used to understand the status and research trends in PjBL-STEM to contribute to the development of knowledge in this field at a low cost (Alsharif et al., 2020; Park & Yoon, 2018; Zakhiyah et al., 2021).

Previously, (Santi et al., 2021) had conducted research on STEAM bibliometric research in the environment and science education in 2013-2020. But this study only focuses on the STEAM. Another research by (Reis et al., 2017) on Project-Based Learning bibliometric research in engineering education in 2000-2016. This research is only limited to the implementation of PjBL. In addition, a similar study has also been carried out by (Solihin et al., 2021) on bibliometric analysis of PjBL integrated STEM in physics learning in 2017-2021. However, this research only focuses on learning physics, not students' critical thinking skills or scientific literacy. Until now, there has been no bibliometric research on PjBL-STEAM and its relation to critical thinking skills and scientific literacy.

Therefore, it is necessary to conduct a bibliometric analysis of the topic to describe the extent of the research studies and research opportunities. This bibliometric study will specifically discuss and map research on STEAM-PjBL and its relationship to students' critical thinking and scientific

literacy, especially in Indonesia. Through bibliometric analysis, keyword groups, research trends, main research topics, and good research recommendations in the STEAM-PjBL research field can be identified (Gil-Doménech et al., 2020; Ha et al., 2020; Nagariya et al., 2020; Santi et al., 2021).

METHOD

This research is a type of quantitative research with a bibliometric approach to map research trends regarding STEAM-PjBL on students' critical thinking skills and scientific literacy (Hudha et al., 2020; J. Li et al., 2019; Suprapto et al., 2021). The bibliometric approach will use the Scopus database from 2016 to 2020. This study adopts five stages of bibliometric analysis (Hudha et al., 2020; Tranfield et al., 2003), as shown in Figure 1.

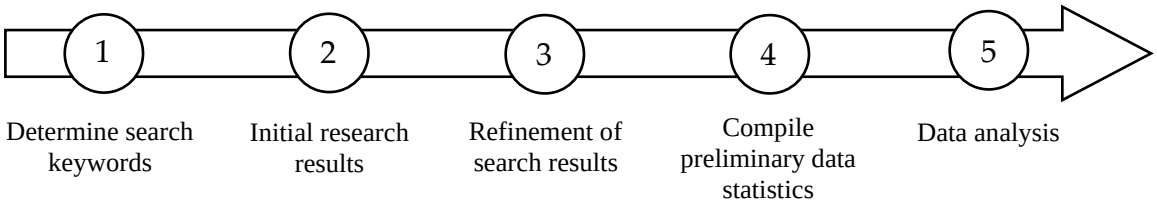

Figure 1. Five stages of bibliometric analysis

Keyword determinan

The The literature search was carried out in April 2021 using the search keywords "*project AND based AND learning AND steam AND critical thinking AND literacy AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016))"*. Metadata collection is done on Scopus' database source (www.scopus.com). The Scopus database were choosen because it is one of the databases that has the highest quality, reputation, and good index with the curated largest number (Baas et al., 2020). We also did not choose another database because of limitations in having an account and extracting its metadata.

Initial search results

The search was carried out specifically on "title words" and "2016-2020". Based on the initial search results, 141 documents were found.

Refinement of search results

The search results were refined without limiting the categories so that journals, seminar proceedings, editorials, and books were included in the bibliometric analysis. Search results are saved in *.ris* and *.csv extensions*. The file is *.ris* used for the stage of compiling further statistical data. In contrast, the file is *.csv* used to analyse more detailed information about the article title, author name, affiliation, abstract, keywords, and references in each article.

Compile preliminary data statistics

Statistical data compilation is done by entering metadata in a .ris extension file into the *VOSviewer* application to analyse and map research data on STEAM-PjBL. *VOSviewer* was chosen because this application produces visualizations that are easy to understand, compatible with various computer operating systems, open access, and work efficiently on large databases (Bornmann & Haunschild, 2016; Hudha et al., 2020).

Data analysis

The data analysis phase was carried out using the *VOSviewer* application to analyse and visualise the bibliometric network regarding STEAM-PjBL to improve students' critical thinking skills and scientific literacy (Meng et al., 2020; Xie et al., 2020). Data analysis can be seen through the size

of the nodes formed on the network map that is formed. The larger size of the node, the greater number of publications on the topic written on that node. In addition, the strength of the relationship between two topics or items can also be seen from the closeness between the two items and the line connecting them. This also applies to network mapping based on authorship. The analysis will also look at the extent to which Indonesia has implemented the STEAM-PjBL concept.

RESULT AND DISCUSSION

Result

The results of the Scopus metadata extraction obtained a total of 142 article publications in 2015-2020. This shows that research on this topic is still little done by researchers around the world. Further details on the results of *mapping* data will be explained in the following sub-chapters.

Mapping based on co-occurence

Based on the extraction of bibliographic data on the type of *co-occurrence* analysis with the full counting type, 558 keywords were obtained. Suppose the minimum number of occurrences of keywords is set to 3. This is because if keywords are set to only 1 or 2, then the keywords that appear are too general, so that the data obtained will be too much, and the mapping is also too large. In that case, 14 keywords meet the minimum threshold by mapping, as shown in Figure 2. It can be seen that there are 5 clusters formed based on visualization network with each keyword item. In cluster 1 with red nodes containing 9 items, cluster 2 with green nodes containing 6 items, cluster 3 with blue nodes containing 6 items, cluster 4 with yellow nodes containing 6 items, and cluster 5 with purple nodes containing 4 items. In addition, there are several keywords with the most occurrences, namely '*students*' n = 13, '*engineering education*' n = 12, '*stem education*' n = 10, '*stem*' and '*steam*' n = 9.

Other keywords with fewer occurrences are listed in Table 1.

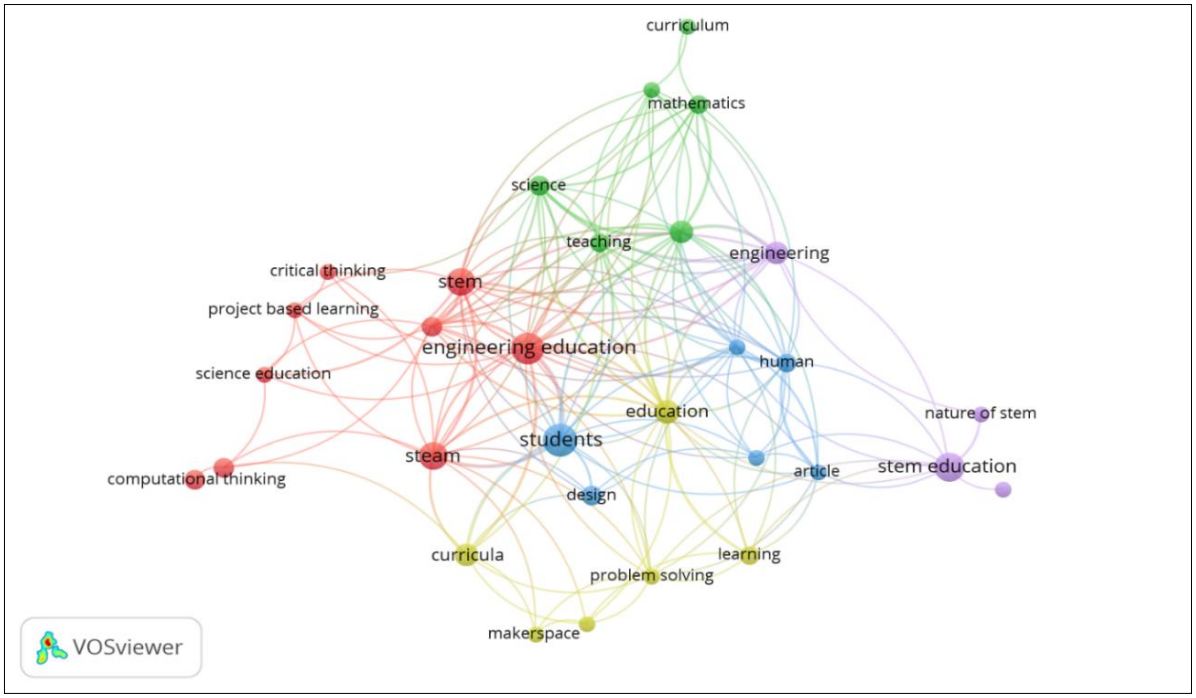

Figure 2. Mapping of keywords in research on STEAM-PjBL

Mapping based on co-authorship

Based on bibliographic data extraction on the type of co-authorship analysis with the full counting method and the minimum number of documents author is 1, it is found that 369 authors published articles on this topic, as shown in Figure 3. The figure shows that several clusters of authors from around the world discuss this topic. In the first cluster with red nodes with a total of 15 items.

The second cluster with green nodes with a total of 11 items. The third cluster with blue nodes with a total of 10 items. While some other clusters have documents of less than 10 items.

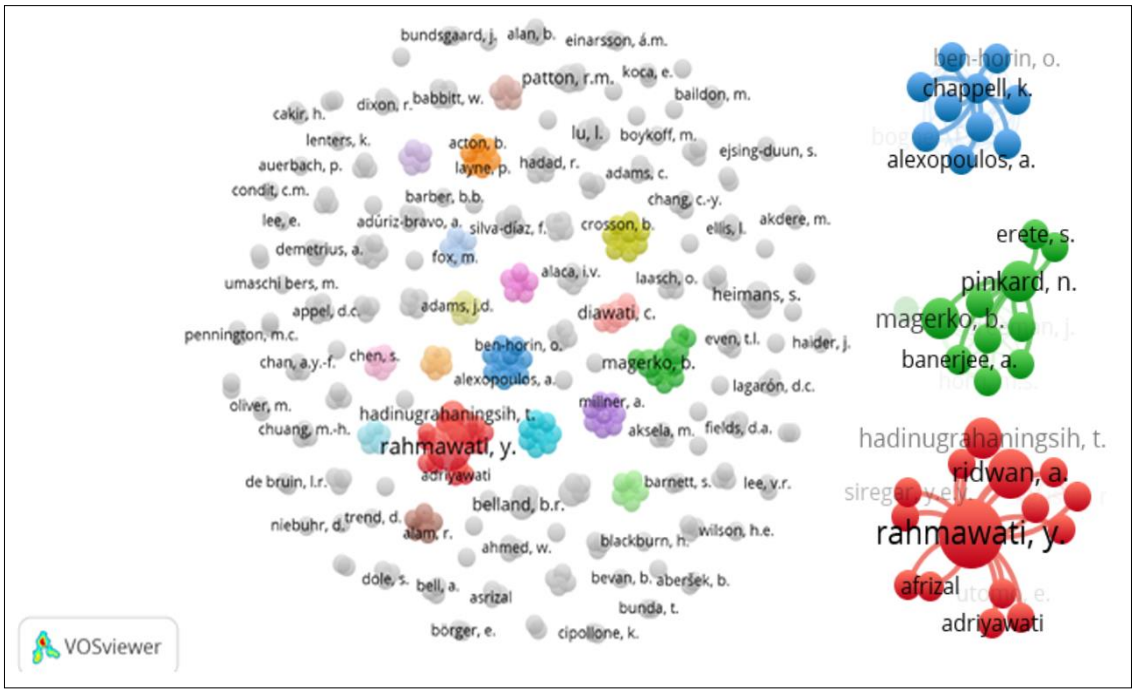

Figure 3. Mapping co-authorship with a minimum number of 1 document

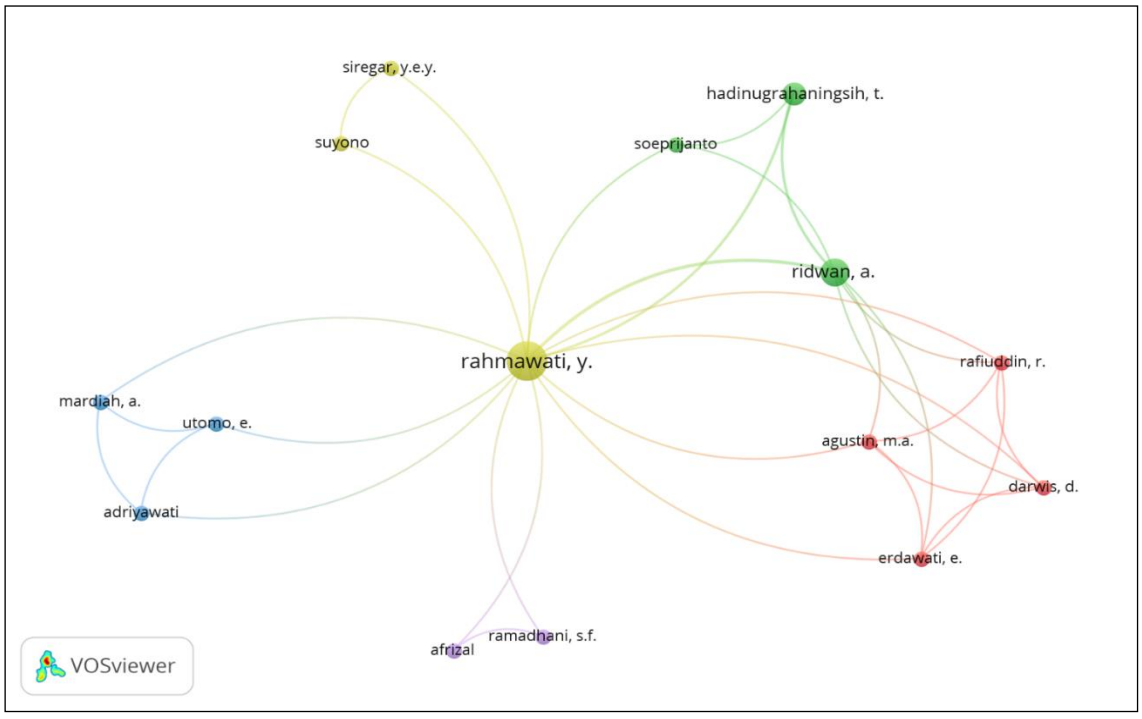

Figure 4. Mapping co-authorships of interconnected each other

However, if all the authors are connected to each other, 15 authors are connected to each other, as shown in Figure 4. Based on the figure, it can be seen that there are four clusters with the top author “rahmawati, y” from the Universitas Negeri Jakarta, Indonesia, with a total of 6 documents. The author has connections with all the other authors on the map, which are also from Indonesia.

Table 1. *Recent Research Themes Regarding STEAM-PjBL with Fewer Occurrences*

Project-based learning	Learning outcomes	Curricula	Human experiment
Critical thinking	Steam education	Makerspace	Creativity
Science education	Design	Higher education	Engineering
Computational thinking	Article	Technology	Nature of stem
Computer science education	Human	Science	Curriculum
Curricula	Problem-solving	Learning	Mathematics
Education			Teaching

Mapping by country

Based on the extraction of bibliographic data on the type of co-authorship analysis and countries unit analysis with the full counting method and the minimum number of documents in each country is 1, 38 items of data obtained by mapping as in Figure 5. The figure shows 19 clusters, with the main cluster being the United States which is coloured red. In addition, cluster 1 also has a relationship line with several other clusters such as the United Kingdom (yellow colour, cluster 4), Germany (green color, cluster 2), United Arab Emirates (blue colour, cluster 3), and Spain (purple colour, cluster 5). Apart from these clusters, several other clusters only stand as independent, and there is no relationship between another cluster.

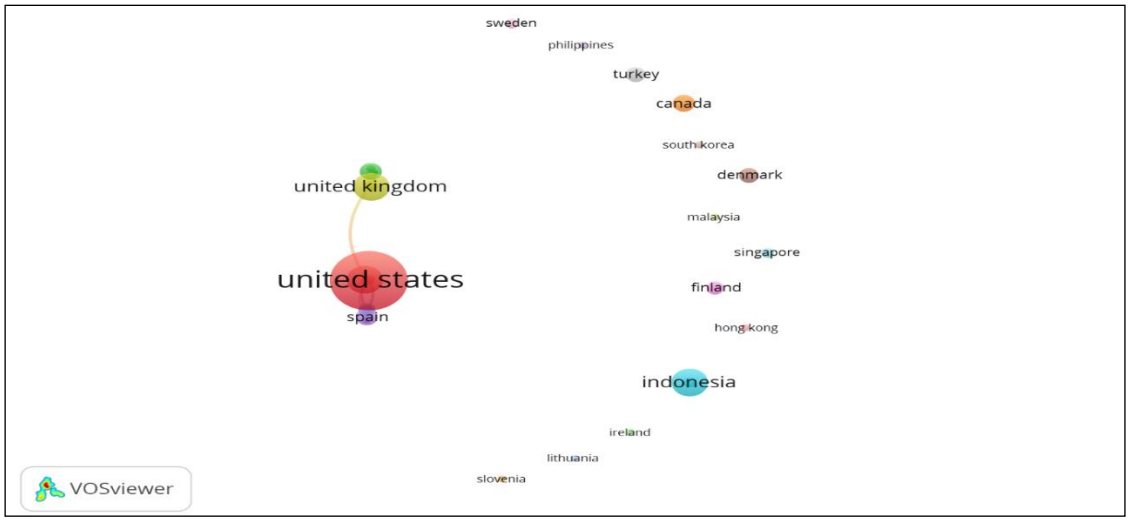

Figure 5. Mapping results by country

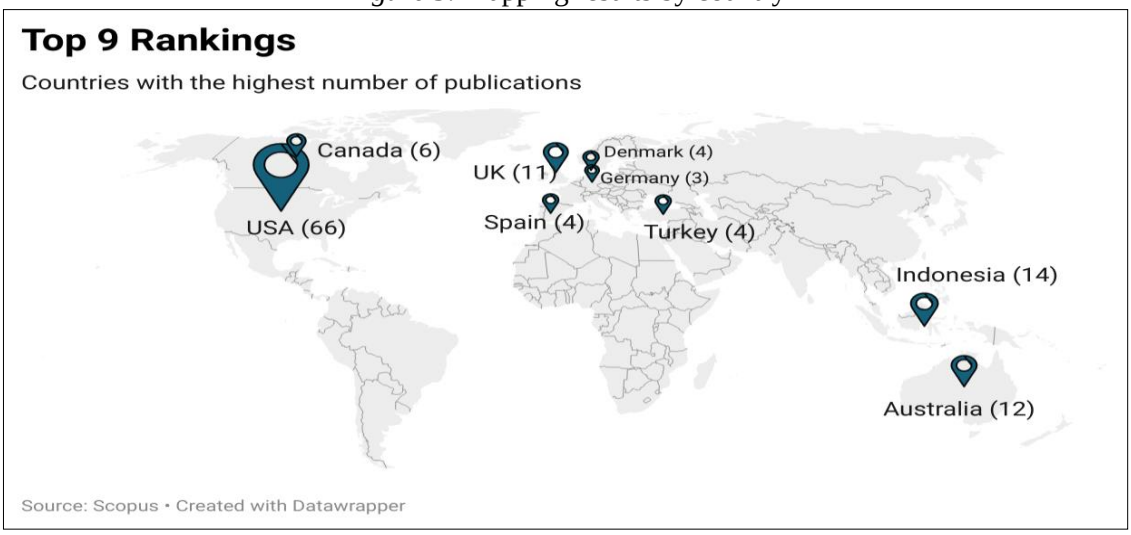

Figure 6. Top 9 ranking of countries with the highest number of publications regarding the implementation of PjBL-STEAM on critical thinking skills and scientific literacy

If the ranking is carried out for all countries, it can be seen that the top 9 countries with related research on STEAM-PjBL learning are shown in Figure 6. The figure shows that the United States ranks first with 66 publications, followed by Indonesia with 14 units. Australia is in third place with 12 publications, and England is in fourth place with 11 publications. In addition to these countries, the number of publications is less than 10.

Application in Indonesia

Research trends regarding the application of PjBL-STEAM to improve students' critical thinking skills and scientific literacy in Indonesia are pretty good. It can be seen in Figure 7 that Indonesia ranks second with the highest number of researches on this topic. In addition, the two authors with the most number of research documents came from the Universitas Negeri Jakarta, Indonesia, namely Rahmawati, Y. with six documents and Ridwan, A. with three documents. So that the results shown mapping in the Co-Authorship category, Indonesia becomes cluster 1 as in Figure 4 and becomes the only country if the minimum number of documents mapped is two items as shown in Figure 5.

Advanced research

We offer advanced research on PjBL-STEAM, which focuses on its implementation in improving students' critical thinking skills and scientific literacy with a mapping model as shown in Figure 7. Based on this figure, there are 7 clusters formed. The main cluster with red nodes consists of students, steam, curriculum, literacy, design, critical thinking skills, and project-based learning models. The second cluster with green nodes consisting of steam components, namely science, technology, engineering, arts, mathematics and several other keywords such as teaching and scientific literature. The third cluster with blue nodes consists of science education, project-based learning, critical thinking, and STEM, which is the origin of STEAM. The fourth cluster with yellow nodes consists of education, learning, steam education, and problem-solving, which are critical thinking applications. The fifth cluster with purple nodes consists of stem education, creativity, problem-solving skills, and an interdisciplinary curriculum. The fifth cluster with cyan-coloured nodes consists of science learning, scientific literacy, and STEAM-PjBL. The last cluster with orange nodes consisting of human and image analysis is one component of scientific literacy.

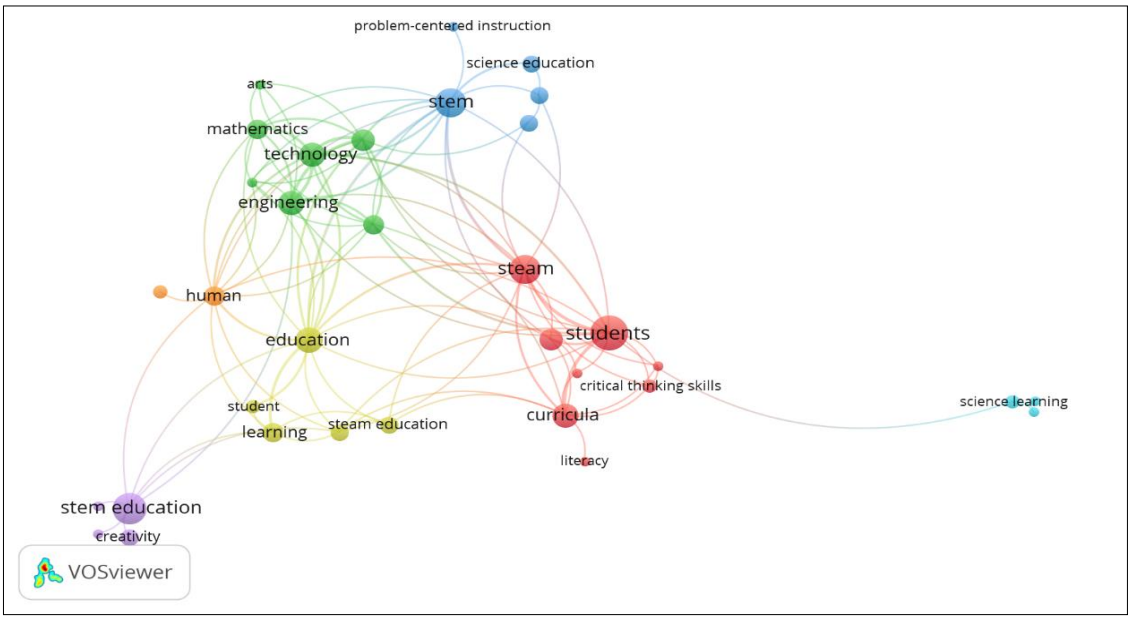

Figure 7. An advanced research model related to the topic

Discussion

Based on bibliometric studies, research profile on PjBL-STEAM focuses more on students and technical education. This is in line with research by (Ha et al., 2020) that the current trend of

STEM research is more focused on students and technical education. So, researchers who want to find novelty can try to research PjBL-STEAM in teachers, science education, or curriculum with fewer occurrences of keywords.

Based on the overlay results using the *VOSviewer* application, we can see research development every year. Data related to research on STEAM-PjBL in the last 5 years shows that relatively little progress has been made regarding this research. Whereas the concept of STEAM in education was proposed in 2011. This is a research opportunity regarding the implementation of STEAM-PjBL, considering that STEAM can improve problem-solving students', critical thinking, and scientific literacy skills. Moreover, reflecting on Indonesia's PISA score is ranked 74th out of 79 countries (OECD, 2019). So there is a need for development research to the implementation of the application of STEAM-PjBL in learning.

Co-authorsip mapping visualization shows that the number of documents written by "rahmawati, y" is the most among other authors, so that the strength of the relationship with other"authors is a"so large. Mapping results show that as many as 96.7% of authors only have 1 article public"tion; 2.7% o" authors have 2 published articles; 0.5% of authors have more than 2 published articles. This shows that very few authors have follow-up research from previous publications on PjBL-STEAM and its relationship to students' critical thinking skills and scientific literacy.

When mapped by country, it is clear that western countries, especially America have rapid development of STEAM. This finding is in line with research by (Marín-Marín et al., 2021) which shows that the USA has the most documents. This is because STEM was first initiated in that country, so it is clear that research production continues to grow and increase. However, Indonesia is also no less lagging behind the field of this research because currently through the driving school curriculum, which emphasizes STEAM-project based learning (Faiz et al., 2022).

Research of PjBL-STEAM collaboration is national in Indonesia has been very good even though the number of Indonesian publications is still far from the United States. However, Indonesia should collaborate with several other countries such as the United States or Australia with very high research trends. This is very important because research collaboration can allow researchers to share knowledge, experiences, approaches, and resources to produce research outputs of higher quality (Freshwater et al., 2006; Kim, 2006; Rolfe et al., 2004). The research results on the PjBL-STEAM model in Indonesia should also be applied directly to the curriculum and education system. This model can improve students' scientific literacy to improve Indonesian PISA scores.

Overall, this bibliometric study finds a need for international collaboration and increased research capacity on applying the PjBL-STEAM model in education. In line with research by (Ha et al., 2020; López et al., 2021; Santi et al., 2021; Solihin et al., 2021; Thu et al., 2021) who revealed that research on STEAM in Indonesia needs to be developed and collaborated so that it can improve students' critical thinking skills and scientific literacy. This is very important because the model provides learning outcomes relevant to 21st century skills, some of which are critical thinking and scientific literacy (Hadinugrahaningsih et al., 2017; Musa et al., 2012; Rahmawati et al., 2019; Rochmawati & Ridlo, 2020).

However, this study has some limitations, namely the refinement of search results where the search process does not limit the types of documents analysed. The search of keywords should be done by limiting only the types of scientific journals. The bibliometric analysis will be more credible and the information provided by the journal is of higher quality (Ruiz-Real et al., 2018). This is because the author has limitations on the Scopus account used in metadata extraction.

CONCLUSION

This bibliometric study discusses and maps research on STEAM-PjBL and its relationship to students' critical thinking and scientific literacy, particularly in Indonesia. The study results show that research on STEAM-PjBL in the last five years shows that relatively little progress has been made regarding this research. In addition, as many as 96.7% of authors only have 1 article publication; 2.7% of authors have two published articles; 0.5% of authors have more than two published articles. The country with the most research is the United States with 66 publications. Indonesia ranks second, with 14 publications, and has the strongest research collaboration compared to other countries. This research

recommends international collaboration on the research topic. The implication of this research for future researchers is to find research trends based on keyword mapping so that novelty in PjBL-STEM research can be known. The research limitation is that no filter is performed when searching so that some unreviewed documents such as books or editorials are included in this research. In addition, this research is still using only one database, namely Scopus. We recommend using more than one database (such as Google Scholar or Web of Science) so that the results of mapping research trends are more comprehensive.

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