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Project-Based Learning (PjBL)-STEM: Bibliometric Analysis and Research Trends (2016-2020)

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Abstract

This study aims to analyze research trends related to PjBL-STEM topics in 2016-2020 through bibliometric analysis with the Scopus database. Based on the criteria, it obtained 1,169 documents. Microsoft Excel was used to analyze data and *VOS viewer* as a data visualization. The results showed that PjBL-STEM research is increasing every year. The USA contributes the most research in the world, Indonesia ranks second. Universitas Pendidikan Indonesia, Universitas Negeri Malang, Universitas Sebelas Maret, and Universitas Negeri Semarang are among the top affiliates in PjBL-STEM research in the world. Visualizing the trend of PjBL-STEM research in 2016-2020, there are three clusters, namely 1.) PjBL-STEM as a framework, 2.) PjBL-STEM as self-development, and 3.) Effects of PjBL-STEM research. The results of this study can help researchers related to PjBL-STEM research trends in the world and provide direction in further research.

Keywords: Bibliometric Analysis Physics Learning; PjBL-STEM; Research Trends

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INTRODUCTION

The development of technology demands the development of the human mindset, among others, through education. In Indonesia, not all schools have implemented the paradigm of 21st-century learning due to the lack of human resources and technology facilities. The development of the times requires a change in the educational paradigm that can provide 21st-century skills to face aspects of life (Tuan Soh et al., 2010).In the 21st century, education has become an important factor in ensuring the skills of the 21st century (Andrian & Rusman, 2019). 21st-century learning applies 4C competency, *critical thinking*, *communication*, *collaboration*, and (Patrick Griffin and Esther Care, 2015). 21st-century skills are expected to prepare students to master various real-life, relevant skills (Jayadi et al., 2020).

One of the learning models that can be applied in physics learning is *Project-Based Learning* which provides students with the opportunity to learn actively (Çakici, 2013). PjBL is a learning model that provides meaningful experiences and produces a project in the learning process (Afriana et al., 2016). Previous research has shown that PjBL can be a learning model that trains a variety of skills in students, including critical thinking skills (Mutakinati et al.,

2018), creative thinking (Widyasmah et al., 2020), science literacy, and problem-solving (Parno et al., 2020).

The application of PjBL can be combined with the STEM approach because its characteristics emphasize more on the design process with a systematic approach to solve problems (Bicer & Capraro, 2017; Erdogan et al., 2016; Lee et al., 2019). STEM learning can practice conceptual and procedural skills to find solutions to real-world problems. STEM is associated with the development of learning in promoting 21st-century skills (Hernandez et al., 2014)

The bibliometric analysis uses descriptive statistics to map trends in a sphere of knowledge (Hallinger & Kovačević, 2019). Research on bibliometric analysis on STEM learning topics has been conducted by many researchers, such as:(Ha et al., 2020). The results showed that STEM education began in 2007 and improved periodically but only progressed in the last three years (Gil-Doménech et al., 2020), in line with previous research publications on STEM Learning topics increased in the period 1991-2016. (Ali, 2018) in his research mentioned that the number of publications from 1980-2018 increased by 75.4% and is expected to increase. The country with the highest number of publications in the USA. (Yu et al., 2016) using *the Social Science Citation Index* (SSCI) database from 1992-2013, STEM research has increased, the largest distribution of publications is USA (52%).

Previous research has provided an overview of PJBL-STEM research. However, few have analyzed *the state of the art* of bibliometric research. (Yu et al., 2016) and (Hallinger & Kovačević, 2019) used *the co-citation* method in their research to describe key references and citations together concerning various sciences on STEM education research. Uses the *co-word* method to detect interrelationships between themes based on text subjects. Stem research covers a wide range of aspects, including science (Effendi et al., 2021), administration (Hallinger & Kovačević, 2019), management (Zupic & Čater, 2015), and computational science (Yu et al., 2016).

The main purpose of this study is to explore the current state of PjBL-STEM research using bibliographic data extracted through the Scopus *database* in 2016-2020. This research is used to answer the following questions: (1) How will publications on PjBL-STEM topics in 2016-2020? (2) What is the pattern of disseminating PjBL-STEM research publications based on the source? (3) What is the pattern of spreading PjBL-STEM publications across regions (countries)? (4) Who are the top affiliates in PjBL-STEM research? (5) Who are the top authors for PjBL-STEM research? (6) How do Indonesian researchers contribute to PjBL-STEM research? (7) How to visualize the results of PjBL-STEM research trends?

METHOD

This study uses a general bibliometric analysis step consisting of five stages (Figure 1), including 1). Study design; 2) Data collection; 3) Data analysis; 4) Visualization of data; 5) Interpretation (Zupic & Čater, 2015). Data collection was conducted in April 2021 based on the criteria obtained 1,169 documents, including article and conference paper. The journal's sources are dominated by the Journal of Physics Conference Series, Journal of STEM Education, and Journal of Science Education and technology. The software used is Microsoft Excel to analyze data and *VOS viewer* as a data visualization on research trends with PjBL-STEM topics in the range 2016-2020.

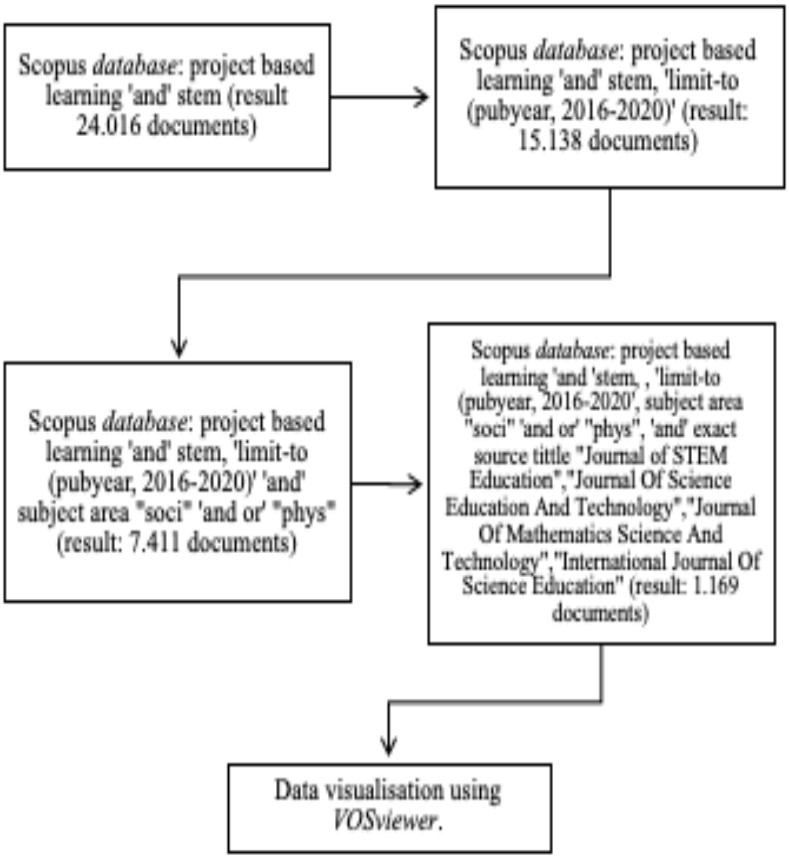

Figure 1 Research Scheme

RESULTS AND DISCUSSION

Publication results, document type, and number of publications by journal

The following is the number of PjBL-STEM publications for 2016-2020 which is presented in Figure 2.

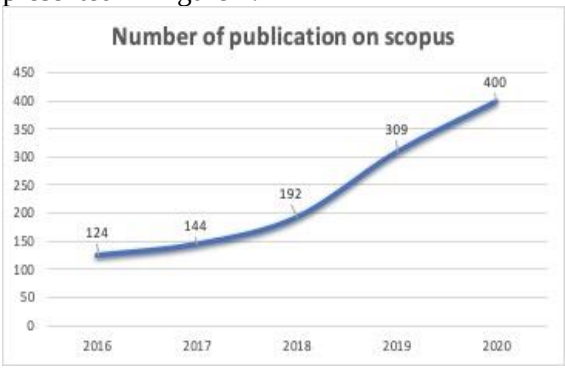

Figure 2 The Number of PjBL-STEM Publications in 2016-2020

Based on Scopus *database* search results obtained 1,169 documents related to the topic of PjBL-STEM research. In 2016 a total of 124 documents were published. In line with the results of research (Triwahyuningtyas et al., 2021), (Santi et al., 2021), and (Vuong et al., 2021), the number of publications has increased periodically, proven in 2020 the number of publications four times (400 documents) from 2016. PjBL-STEM research trends are predicted to increase in 2021. The results of PjBL-STEM publications in 2016-2020 are demonstrated in Figure 2.

Figure 3 showed most published document types are articles (882 documents).

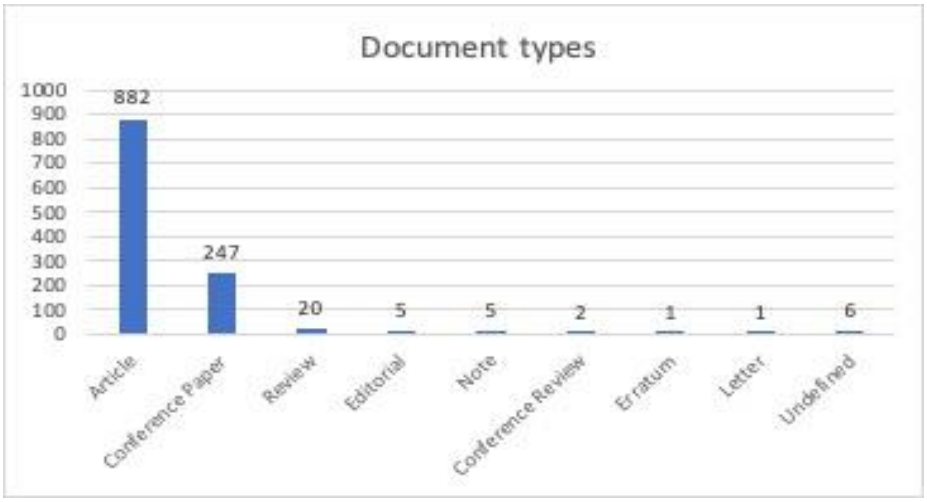

Figure 3 Distribution of Publications by Document Type

Based on Table 1, during the period 2016-2020, the number of publications by the journal is dominated by *the Journal of Physics Conference Series* as many as 203 articles.

Table 1 Top 10 Journals with PjBL-STEM Publications (2016-2020)

Source (journal)	sum
Journal Of Physics Conference Series	203
Journal Of Stem Education	87
Journal Of Science Education and Technology	87
Eurasia Journal of Mathematics Science And Technology	80
International Journal of Science Education	74
Research In Science Education	71
Physical Review Physics Education Research	60
Journal Of Research in Science Teaching	59
International Journal of Science And Mathematics Education	50
Science Education	48

Distribution of publications by country and institution

Figure 4 describes the number of PjBl-STEM by country from 2016 to 2020. The USA found the top spot (Chomphuphra et al., 2019) with 459 publications on PjBL-STEM, second place being Indonesia with 249 documents. Based on Scopus data, it can be concluded that Indonesian researchers are actively involved in PjBL-STEM research in international coverage.

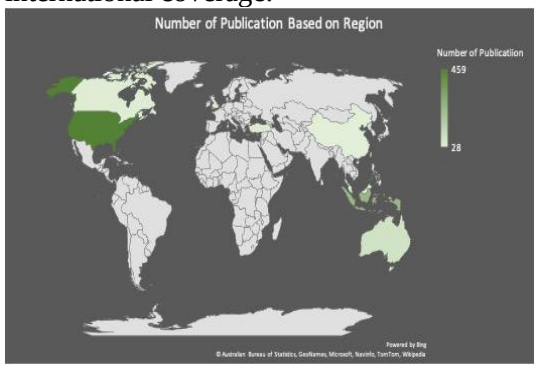

Figure 4 The Number of PjBL-STEM Publications by Country (2016-2020)

Top affiliates by institution

Top affiliation on PjBL-STEM research from 2016 to 2020 showed in Figure 5. dominated by Indonesia. The first position is represented by Universitas Pendidikan Indonesia (UPI) (50 documents), Universitas Negeri Malang (27 documents) in third place, Universitas Sebelas Maret (22 documents), and Semarang State University ranked Ninth (20 documents). University of Colorado, USA found second place with 28 documents.

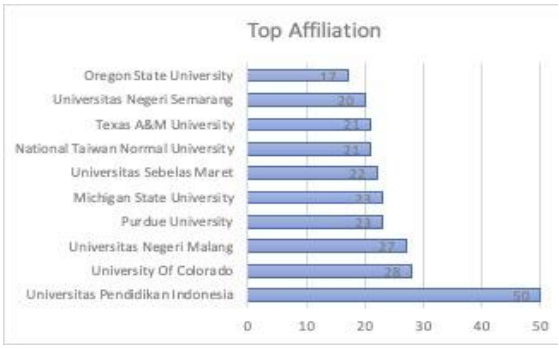

Figure 5 Top Affiliated PjBL-STEM Publications by The Institution (2016-2020)

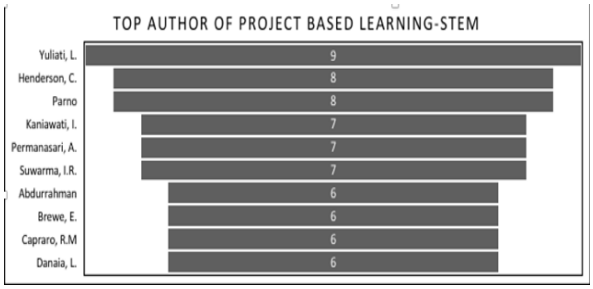

Figure 6 Top authors of PjBL-STEM publications (2016-2020)

Top authors of PjBL-STEM publications (2016-2020)

Researchers from Indonesia dominate as many as six out of ten Top authors; this shows Indonesia's contribution to PjBL-STEM research globally. Research topics conducted by authors from Indonesia include PjBL-STEM learning in physics and science, which aims to train critical thinking skills, problem solving, creative thinking, and cooperative attitudes between students. The following are the results of the top authors of the PjBL-STEM publication (2016-2020) presented in Figure 6.

Visualization of PjBL-STEM research trend results

PjBL-STEM research on the Scopus database was visualized through VoSViewer. This stage aims to analyze the novelty of the research, topic interrelationship, and influence of research results (Putri et al., 2021). Through (Figure 7) During the 2016-2020 PjBL-STEM research conducted by world researchers showed associations such as STEM and students, STEM learning and self-efficacy, learning processes, and computational-based learning (use of technology) (Zeng et al., 2019).

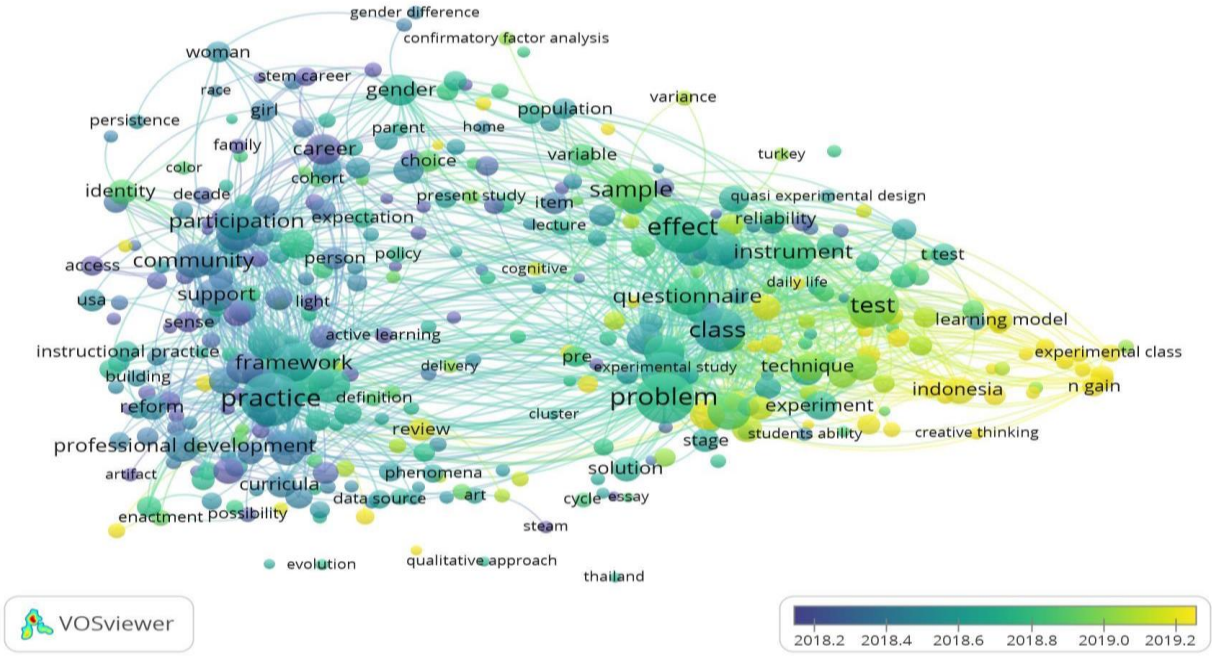

Figure 7 Visualization of PjBL-STEM research in 2016-2020

The 2018 research trend (illustrated with purple and blue balls) suggests that PJBL-STEM is related to science teaching and learning, scientific discovery, qualitative method research, descriptive analysis, and problems solving learning, and science literacy. In 2019 (pictured with a green and yellow ball), the world's researchers developed PjBL-STEM research on aspects of *technology (education computing)*, learning process with the integration of curriculum, communication skills, problem-based learning, and types of quantitative research, descriptive studies.

Based on the research paradigm used, in the period 2016-2020, the research trend for PjBL-STEM focuses on several aspects, including the PjBL learning model, STEM teaching, STEM integrated physics learning, STEM education curriculum (Chai, 2019), and student aspects in STEM education. In line with research (Kennedy & Odell, 2014), aspects of PjBL-STEM learning with a learning context integrate this STEM knowledge through project-based learning strategies (Figure 8a).

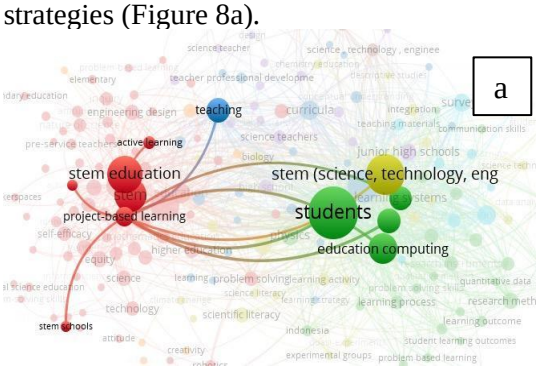

Figure 8(a.) Relationship Aspects of Learning with PjBL and STEM Learning

The teaching aspect (Figure 8b) is expected to promote the process of inquiry, question, and conduct investigations to develop a deep understanding of teaching materials (Kennedy & Odell, 2014). In PjBL-STEM physics learning, students play an important role where learning leads to student-centered. Integrating STEM aspects is expected to train 21st-century skills, one of which is the use of technology, problem-solving skills. The teacher aspect in physics learning with PjBL-STEM is related to the development of professionalism and the school curriculum.

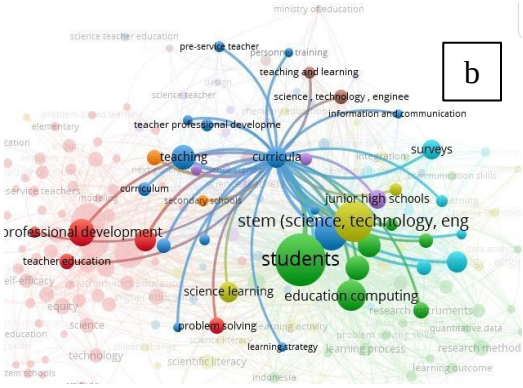

Figure 8(b.) Teaching STEM

The results of the VosViewer visualization (Figure 8c) show that PjBL-STEM can be associated with physics learning and relates to several other aspects, including the learning process, students, gender, and learning outcomes. The curriculum design on STEM learning focuses on the world's problematic situations and adopts project learning to spark students' interest in stem domains (Fan et al., 2020).

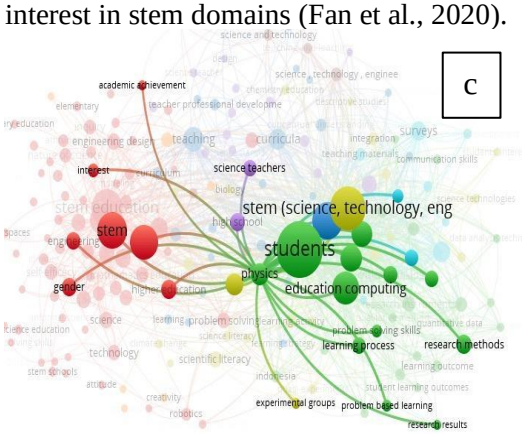

Figure 8 (c.) STEM Integrated Physics Learning

Figure 8d, physics teachers, are expected to provide authentic learning by provoking students' understanding of stem discipline concepts, so teachers need interdisciplinary training (EL-Deghaidy et al., 2017; Larkin & Jorgensen, 2017).

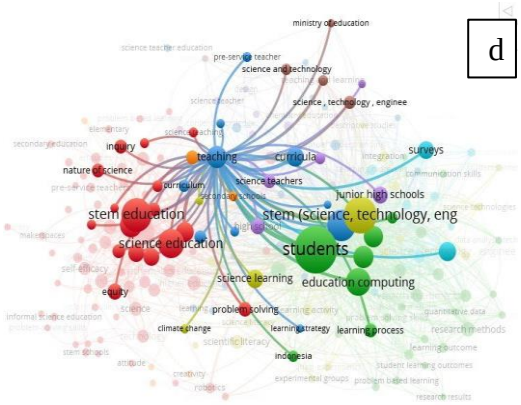

Figure 8(d) Integration of Curriculum in STEM Learning

Figure 9 shows the overall picture of PjBL-STEM research resulting in three visualized primary clusters and several colors (red, blue, and green). The red cluster describes PjBL-STEM as a *framework* associated with students' practice, community, participation, and learning. The Blue Cluster states that PjBL-STEM research relates to gender, career, and self-efficacy (Hasbullah et al., 2020). Green cluster explained that in PjBL-STEM research that has been conducted by the researchers two there are related to the problems faced during learning, the effects of learning PjBL-STEM include improving the ability of creative thinking and learning in daily life (Parno, Yuliati, Munfaridah, et al., 2020), and instruments used in the study in the form of questionnaires and tests.

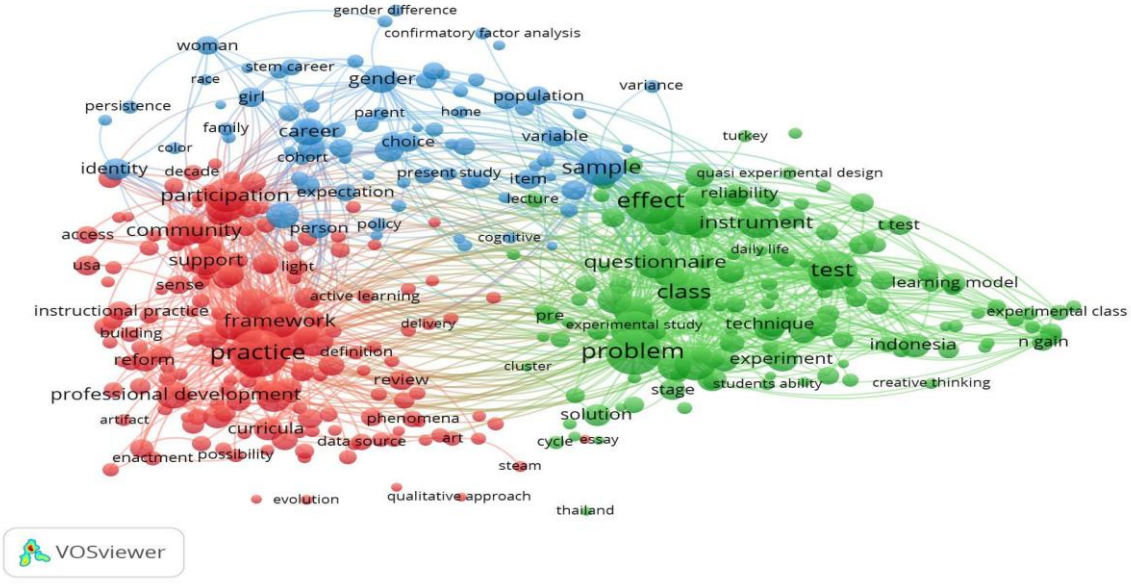

Figure 9 PjBL-STEM Research Cluster

PjBL-STEM research has been related to several aspects, including (Figure 9 a) showing that PjBL-STEM research's effects are related to practice and framework and affect career, self-efficacy, and gender. The PjBL-STEM model can solve learning problems in the classroom. In terms of frameworks, PjBL-STEM learning requires participation and support from participants and the community (Figure 9 b). PjBL-STEM learning practices relate to problems in the classroom, curriculum, and case studies, and the impact that comes after research can be in the form of improved problem-solving skills (Figure 9 c).

In (Figure 9a), Physics learning with PjBL-STEM affects gender and race. In line with the results of the study (Blackburn & Heppler, 2019; Goy et al., 2018; Rainey et al., 2019; Song & Zhou, 2020) Reports that white students consider teachers to be more concerned and provide an active learning

environment, while students of color consider teachers to be less attentive when learning, especially male teachers. PjBL-STEM affects the level of self-efficacy of teachers and students is supported by the results of research (Espinosa et al., 2019; Geng et al., 2019; Zakariya, 2020) mentions that there is a gap between gender and student self-efficacy in STEM disciplines. These gaps are measured in four dimensions: conceptual understanding, problem solving, practicum, and collaborative work. The rate of self-efficacy of female students increased significantly, whereas male students showed no change.

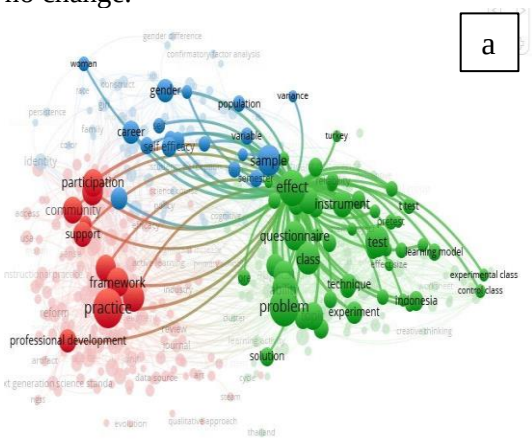

Figure 9(a) PjBL-STEM Research Relationships in Effects Aspects

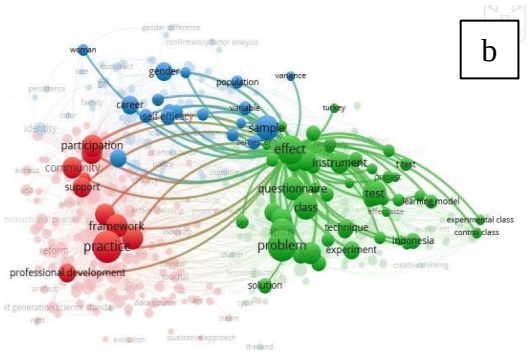

Figure 9 (b) PjBL-STEM in Practical Aspects

In practice (Figure 9b), PjBL-STEM in physics learning supports student involvement in further and student-centered investigations (Struyf et al., 2019). Research conducted by (Tomkin et al., 2019) mentions that STEM is an approach that supports the development of teachers and students in forming an active learning practice community. (Tam et al., 2020) His research reported that STEM is considered effective for developing students' ability to use technology and reduce gender stereotypes in learning.

Figure 9(c) is the result of visualizing the trend of PjBL-STEM research in physics learning practice, relating to problems in the classroom and the impact of the application of PjBL-STEM learning. The findings of this study are supported by previous research, including: (Sulistiyowati et al., 2018) mentioned that STEM learning through worksheets can improve the ability of science literacy. (Astuti et al., 2019) explains that PjBL-STEM learning improves students' concepts and learning activities (Knowles et al., 2018; Laforce et al., 2017; Reiss & Mujtaba, 2017). Their research explained that the effectiveness of STEM supports teachers' awareness of STEM careers. The selection of learning models and STEM curricula can help increase students' interest and self-efficacy in choosing a career in STEM fields.

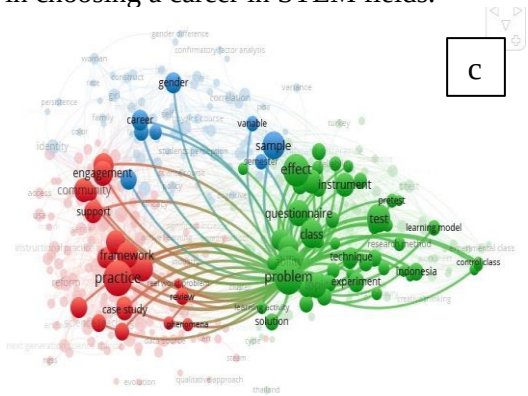

Figure 9 (c) PjBL-STEM Research and Its Relation to Problems Encountered During Physics Learning

CONCLUSION

Several important points related to PjBL-STEM research trends in 2016-2020 have been presented through bibliometric analysis. The number of publications

increases each year and is dominated by research articles. The Journal of Physics Conference Series is the journal that publishes the most PjBL-STEM publications. The USA is the country with the most publications, while Indonesia placed second. Indonesian Universities are among the top world affiliates in PjBL-STEM research including, Universitas Pendidikan Indonesia, Universitas Negeri Malang, Universitas Sebelas Maret, and Universitas Negeri Semarang. Visualizing the trend of PjBL-STEM research in 2016-2020, there are three clusters, namely 1.) PjBL-STEM as a framework, 2.) PjBL-STEM as self-development, and 3.) Effects of PjBL-STEM research.

This research only discusses the research trends of PjBL-STEM learning models on physics learning within the world by using the Scopus database as metadata resources. The results of this study can help researchers related to PjBL-STEM research trends in the world and provide direction in further research. Further research advice in the form of PjBL-STEM research trends in the scope of countries or continents, focusing on one level of education (elementary school, secondary school, or higher education), and has certain topics (fields of study) including physics, biology, and various other STEM disciplines.

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