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Bibliometric Map of STEM-Physics Research Evolution

Vivi Mardian*, Judhistira Aria Utama and Irma Rahma Suwarma

Department of Physics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

*vivimardian1111@gmail.com

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Abstract

STEM learning may increase students' engagement in the instructional process. STEM has a significant role in students' cognitive and skills development. STEM in the learning process is characterized as engaging and interesting actions that are structured in such a way. STEM research in physics has been conducted for the past two decades. However, the evolution of this research has not specifically explained the trend of STEM studies in learning, so a distribution map is needed from this research. A bibliometric research analysis was employed to determine research development in STEM learning on physics. The papers were collected from 2013 to 2022 by writing the title (STEM) and keywords (STEM, Physics) through Publish or Perish. In addition, the selected paper must also be in English and indexed by Scopus. The total number of final papers analyzed in this study was 169. In addition, VOSviewer shows that there are still many opportunities for future researchers to study STEM, especially those related to barriers, case studies, scientists, stem content, opinions, stem activities, stem fields, and programs. This study discovered that the topic of study of STEM has a good likelihood of being explored and that it can be combined with various fields to make the research unique.

Keywords: Bibliometrics Analysis; STEM Research; Trend

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INTRODUCTION

In the past few decades, the trend in research has been to tie science to other sciences such as biology, chemistry, engineering, technology, and mathematics (Van Vo & Csapó, 2023; Fang & Fan, 2022; Bindis, 2020). Researchers interact with researchers from other areas to develop superior research findings due to the necessity for cross-sectoral expertise (Garg et al., 2022; Hinton et al., 2021). STEM research has been conducted due to corporations' significant interest in STEM graduates (Lysenko & Wang, 2022; Skrentny & Lewis, 2022). STEM graduates are expected to be theoretically

and practically proficient in 21st-century skills (Stehle & Peters-Burton, 2019; Jang, 2016; Radloff & Guzey, 2016). STEM-based instruction offers students with relevant experiences. Therefore, it is crucial to investigate the most recent trends in STEM research.

STEM research is a fascinating area to investigate at this juncture. STEM research reveals topics in STEM education (Habig et al., 2020; Li et al., 2019). STEM education actively engages students in learning to enhance three dimensions: cognition (Wu & Rau, 2019), skills (Ng & Chu, 2021), and mindsets (Zhou et al., 2022). Students' cognitive abilities will improve greatly



with exciting learning that is not restricted to one topic (Auerbach & Andrews, 2018; Kim et al., 2020). Furthermore, students learn to generate ideas or answers to problems that exist in today's society (English, 2023; Merayo & Ayuso, 2022; Simeon et al., 2020). Finally, pupils become accustomed to problem-solving and scientific conduct. Therefore, this STEM study will be addressed utilizing publish or perish software and VOS Viewer to provide a bibliometric analysis.

Some studies on bibliometric analysis in education, Inclusive Education, scientific output in social science (Hajar & Karakus, 2022), electronic learning (Djeki et al., 2022), learning on the Covid-19 Pandemic (Sreenivasan & Suresh, 2023), Science Instruction (Marín-Marín et al., 2021), Artificial Intelligence in Education (Tlili et al., 2022), and STEM (Jamali et al., 2022) are available (Mahendra et al., 2022). Bibliometric is outfitted with a search algorithm for information and STEM research (Huang et al., 2022; Mahendra et al., 2022). In addition, bibliometrics has been utilized to investigate educational models (Mahendra et al., 2022; Phillips & Ozogul, 2020). The research of Triwahyuningtyas et al. (2021) focuses on the bibliometric analysis of STEM module keywords from 2015 to 2019. Similar research with the term STEM conducted by Ha et al. (2020) shows that from 2000 to 2019, the most STEM research in ASEAN was carried out from 2017-2019. Much of STEM research is contributed from the USA region, while topics that are often studied in STEM education relate to early childhood education, occupational education, and environmental education (Jamali et al., 2022). However, no developmental research bibliometric

studies in STEM, especially physics, have been done. A bibliometric study of Scopus-indexed papers produced between 2013 and 2023 was performed using the VOSviewer program. This study is meant to be one of our recommendations for choosing research subjects, notably in STEM physics instruction.

METHOD

The bibliometric analysis approach was applied in this study's research technique. This method was chosen because it accurately measures and analyzes articles in the specified database. This approach may locate, categorize, and evaluate published documents connected to the chosen subject (e.g. Chang et al., 2022; Kaushal et al., 2021; Mahendra et al., 2022). Scopus was recognized as one of the trustworthy indexing systems. The analytical tool supplied by Scopus was sufficient to obtain most of the findings sought for this investigation. The offered tool provides a detailed dynamic interpretation and determines publication features in the context of disciplines, the most dominant publication source of information, and the most well-known authors (Mahendra et al., 2022).

This study utilizes Harzing's Publish or Perish tool to collect data. Without Scopus access, PoP may be utilized simply. PoP can be downloaded and accessed by almost everyone, while the Scopus database requires access to obtain the required articles. Furthermore, PoP provides metric citations to make the information acquired more comprehensive. This software is a tool for doing a literature study on the specified subject of STEM. Figure 1 depicts the steps in this investigation.

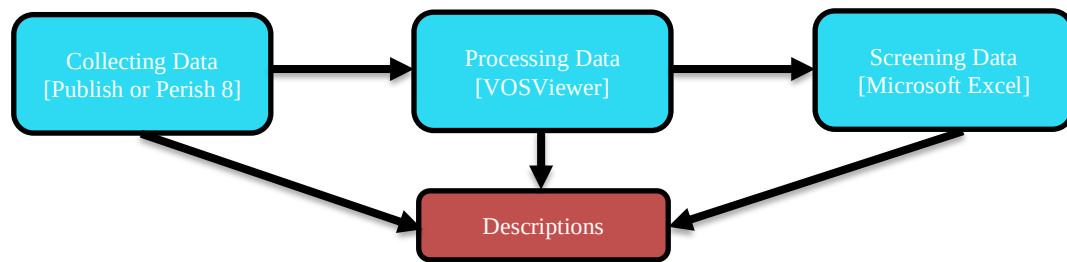


Figure 1 Research Steps

The first step is utilizing the Publish or Perish software to find articles. Data was collected from 2013 to 2022, including the keywords physics and STEM. There are 200 articles in the search results. Then there are numerous concerns, such as the title, which uses the word STEM in the sense of social studies rather than biology. Finally, the data category had just 169 items. There are several criteria to consider when submitting articles including: 1) containing the term STEM in the title, 2) using English, 3) papers in the form of research articles, and 4) papers published in Scopus-indexed journals. The data will then be processed using the VOS Viewer program. First, install the VOSviewer application for free from the VOSviewer web. Next, select the menu Create in the action panel column, then click Create a map based on text data. Set the data source to "read data from reference managee files". Input files that are already in RIS format. Finally, in the verify selected terms column, select relevant and irrelevant words to the research. Search results in Publish or Perish are saved in RIS format before being entered into the VOS Viewer. The file is imported into the VOS Viewer, and the display's color, shape, and size are customized before being saved in PNG format. The third stage is to choose articles based on the prior criteria. CSV files are quite useful for reviewing study data produced by POP. The final step is

to understand the VOS Viewer and Microsoft Excel results.

VOSviewer software was employed to display and assess the trend using bibliometric mapping (Krisnaningsih et al., 2021). The VOSviewer software may show bibliometric mapping in three ways: network visualization, density visualization, and overlay visualization based on the network (co-citation) connecting existing items. When developing the bibliometric mapping, it was agreed that the frequency of the keywords should be kept to a minimum of one time. This yielded 101 entries that were deleted based on the keywords.

RESULT AND DISCUSSION

Publications data search results

There are 200 articles appropriate for the study based on data collection on the term "Physics and STEM" from the Scopus database using Harzing's Publish or Perish. Author names, paper titles, publication year, journal name, publisher, number of citations, DOI, and URLs were obtained for articles. The data example utilized in this research's VOSviewer analysis is displayed in Table 1. The data sample consisted of the 34 top publications with the most citations. The total number of citations from all papers in this study was 3633, the total number of citations per year was 363.30, and the average number of citations per article was 18.17.

Table 1 Article finding from searches via Publish or Perish

No	Cites	First Authors, Year	Title
1	524	S. Cheryan, 2017	Why are some STEM fields ...
2	143	E. Makarova, 2019	The Gender Gap in STEM Fields ...
3	133	A. Eaton, 2020	How Gender and Race Stereotypes Impact the Advancement of Scholars in STEM ...
4	87	D. Miller, 2013	Can spatial training improve long-term outcomes for gifted STEM ...
5	75	F.R. Sullivan, 2016	Robotic construction kits as computational manipulatives for learning in the STEM ...
6	71	A.M. Zaniewski, 2016	Increasing STEM ...
7	70	T. Lancaster, 2021	Contract cheating by STEM ...
8	65	L. Mutakinati, 2018	Analysis of students' critical thinking skill of middle school through stem ...
9	59	H.M.G. Watt, 2017	Mathematics—a Critical Filter for STEM ...
10	57	R. Sagala, 2019	The effectiveness of stem-based ...
11	57	C. Chung, 2017	A study of creativity in CaC $\times$ steamship-derived STEM ...
12	56	M.C. Botia, 2015	The relationships among high school STEM ...
13	56	P.R. Bahr, 2017	Unrealized Potential: Community College Pathways to STEM ...
14	53	K. Altmeyer, 2020	The use of augmented reality to foster conceptual knowledge acquisition in STEM ...
15	53	N. Heilbronner, 2013	The STEM ...
16	40	V. Seyranian, 2018	The longitudinal effects of STEM ...
17	36	B. Aeschlimann, 2016	How to foster students' motivation in mathematics and science classes and promote students' STEM ...
18	35	Y. Ma, 2020	Mentorship and protégé success in STEM ...
19	31	D. Drane, 2014	Students as teachers: Effectiveness of a peer-led STEM ...
20	28	K.G. Talley, 2017	Women's interest development and motivations to persist as college students in STEM ...
21	27	N. Apkarian, 2021	What really impacts the use of active learning in undergraduate STEM ...
22	27	K. MacArthur, 2015	Optimal ADF STEM ...
23	26	Suyatna, 2019	Future Physics Learning Materials Based on STEM ...
24	26	S. Kanadli, 2019	A meta-summary of qualitative findings about STEM ...
25	22	M. Berkowitz, 2018	Which cognitive abilities make the difference? Predicting academic achievements in advanced stem ...
26	22	C. J. Craig, 2018	The influence of parents on undergraduate and graduate students' entering the STEM ...
27	22	R. Khatri, 2017	Characteristics of well-propagated teaching innovations in undergraduate STEM
28	21	M. Stella, 2019	Forma mentis networks quantify crucial differences in STEM ...
29	21	A. Deiglmayr, 2019	Beliefs in "brilliance" and belonging uncertainty in male and female STEM ...
30	21	M.E. Karim, 2016	A review: Can robots reshape K-12 STEM ...
31	20	A. Johnson, 2020	Culturally relevant pedagogy: A model to guide cultural transformation in STEM ...
32	20	D. Verdín, 2018	Stem ...
33	20	C. Cherqui, 2014	Combined Tight-Binding and Numerical Electrodynamics Understanding of the STEM ...
34	20	H.L. Xin, 2014	Is there a Stobbs factor in atomic-resolution STEM ...

Research development in the field of STEM

Figure 2 depicts the progression of research in the field of STEM. From 2013 to 2023, 169 papers were published in Scopus-indexed journals. There were

four articles in 2013 about STEM. There were ten papers published in 2014 and 9 in 2015. The year 2019 had the most published papers. There were 11 papers in 2016 and 17 papers in 2017. 2018, there were just 28 papers, while in 2019,

there were 35 papers. There were just 32 papers in 2020, while in 2021, there were 18, and only five papers in 2022.

Figure 2 depicts the development of STEM research during the previous ten years, from 2013 to 2022. Figure 2 depicts varying research developments throughout the first four years (2013-2016). It increased from four pieces in 2013 to ten the following year. From 2016 to 2019, research trends rose, with 35 papers published in 2019. These

findings are consistent with Triwahyuningtyas et al. (2021), who discovered that the most STEM module papers published between 2015 and 2019 totaled 283 in 2019. Beginning in 2020, the trend of STEM research continues to decline until only five publications are left in 2022. According to the statistics, the popularity of STEM research is volatile and expected to fall through 2022.

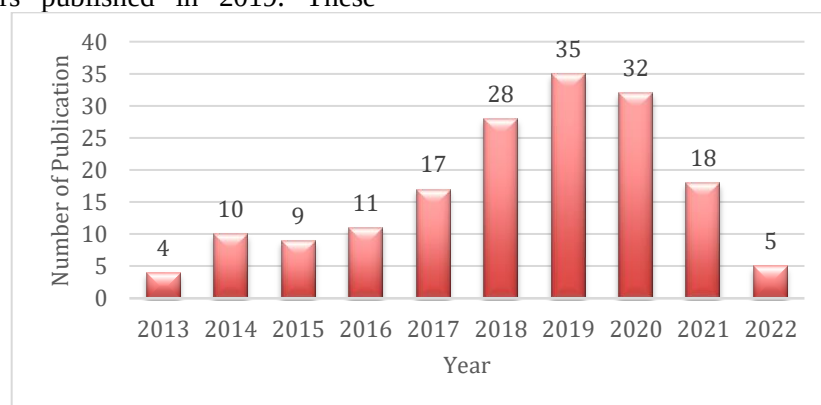


Figure 2. Distribution of STEM research in Indonesia between 2013-2022

The employee of VOSviewer generates articles' computational mapping on STEM. Every item is divided

into 36 clusters with a total of 461 items. The 16-cluster mapping was:

Table 2 Mapping of 16 clusters based on VOSviewer analysis

Cluster 1

Belonging, bias, biomedical engineering task group, classroom diversity philosophy, color, diversity, education, embodied physics, engagement, engineering stem workforce, feeling, gender balance, impact, international women, medical physics, mentoring, online teaching practice, physical isolation, resource, social connectedness, solution, stem fields, stem performance, stereotype, support, training, undergraduate student, utilizing.

Cluster 2

Analysis, attrition, blended learning, computational manipulative, course choice, critical thinking skill, cross-disciplinary skill, future physics learning material, higher rate, inequity, lower grade, male, middle school, robotic construction kit, sign, stem disciplines, stem education approach, stem education project, stem PBL implementation, students' perception, underrepresented minority student, values undergraduate students attribute, woman, workplace.

Cluster 3

Application, career information literacy a study, contact cheating, covid, damped harmonic motion, efficient terahertz radiation, emphases, employer, energy, ferromagnetic heterostructure, generation, inquiry stem, pandemic, pandemic perspective, physics concept understanding, science literacy ability, stem fields report, stem education, thermal inversion experiment, topic, undergraduate capstone unit, wimpbme task group, work

Cluster 4

Agreement, boy, company, country, explosion, gender role, girl, graduate student, individual, inequality, mentorship, nation, new wealth, parent, parental egalitarian attitude, perception, prosperity, school science, stem career, stem field, success

Cluster 5

Assessment stem, critical thinking, cultural transformation, development, evaluation study, hot, mathematics project, model, problem, relevant pedagogy, secondary student, skill, stem department, stem education method, stem education orientation program, stem PjBL, teaching material, technological pedagogical content knowledge, TPACK.

Cluster 6

Attitude, cac, classroom emotional climate, creative thinking skill, creative, cycle, electron vortex haadf stem beam image, frozen phonon simulation, gender difference, inf stemship, influence, investigation, nuclear quantum effect, physics career choice, Rasch analysis, stem pipeline, stem project, student stem self-efficacy, study choice.

Cluster 7

Additional profession, case, community, computer science education, engineer, evaluation, forma mentis network, initiative, international stem expert, learning prospective field, lesson, organization, room, school, school time framework, scientist, self, stem teaching

Cluster 8

21st century, building scientific literacy, concept achievement, criterium, essential prop component, focus, inquiry, intelligent problem solver, interdisciplinary conversation, knowledge representation method, light emitting diode, meta summary, motivational pattern, physics problem-solving skills, robot, secondary school level, self-determination perspective, stem education

Cluster 9

Active learning, beliefs, biology, chemistry, cultural factor, electromagnetic field, gender disparity, importance, integration mechanism, interest, mathematics, national survey, non-stem majors, physics class, physics instructor, stem preference, undergraduate stem education

Cluster 10

Academic achievement, advanced stem study, classroom experience, cognitive ability, deaf, difference, energy topic, hearing, note, opinion, postsecondary learners' retention, predictor, prospective teacher, situation, stem activity, stem content, tablet computer.

Cluster 11

Cern, declaration, experience, hand, hologram, lab, measuring innovative stem, middle school student, model engineering, near-peer, physical science, primary teacher, program, relationship, stem experiment, stem success, student intent

Cluster 12

Achievement, approach, context, effect, gamification element, high school physics student, introducing, lower secondary school, secondary schools, selected physics concept, self-efficacy, stem educational software, stem intervention, student attitude, teaching gravitational wave, unit, Vietnam tan cuong tea village

Cluster 13

Academic performance, competence, data, discipline, high school, module, need analysis, physics student book, role, science class, stem approach, student motivation, student stem career choice, student worksheet, sup, tertiary institution

Cluster 14

Computational physics, design, diverse views, e-learning, implementation, interdisciplinary stem instruction, opinions about preparing, physical movement, physics chemistry preservice teachers, stem lesson plan, student hots ability, synergy, teaching programming, teaching strategy, upper division stem course.

Cluster 15

Academy, and mathematics, class, engineering, field experiment, formative evaluation, link, performance-approach goal, phet medium, physics education student, profile, self-assembly, southeast high school interactive science, technology, test anticipation

Cluster 16

Challenge, choice, choosing stem, concept, experimental technique, media, perspective, qualified, stem learning, strategy, study, subject, unconscious influences, variation

Cluster 17

Advancement, Arab society, biased evaluation, counter-intuitive pattern, culture, difficulty orientation, gender, intersectional analysis, pathway, professor, race-ethnicity, race stereotypes impact, scholars, stem degree

Cluster 18

Chart gender difference, developmental trajectory, engineering student, factor, field, gender gap, gender stereotype, math, phenomenological study, science, secondary students' career, social cognitive theory framework, stem self-efficacy, theory.
Cluster 19
Activity, case study, comparison, conventional learning, high school student, integrated stem outreach, method, new educational tool, PBL, PBL stem education, scientific literacy competencies domain, urban setting, vertical jump measurement platform
Cluster 20
Conceptual power series knowledge, crucial difference, expert, gender representation, influences, network, novel stem summer bridge, selection process, stem major, stem perception, stem relevant, student, summer enrichment program.
Cluster 21
Acrl framework, bibliometric analysis, educational game, electromagnetic introduction phenomena integrated science, information, literature, magnetic field, research, stem area, sustainability thinking, teaching, transformative science stem step stepped education, value.
Cluster 22
Argumentation, computational model, creative critical thinking style, current teaching practice, epistemic belief, implication, integrated stem education, performance, physics teacher, scientific reasoning, stem agenda
Cluster 23
Biophysics, biosemiotics, Indonesian physics teacher, logical incompatibility, meaning, mixed methods analysis, motivation, teacher readiness, view, voice, women interest development
Cluster 24
Aberration, Bayesian analysis, cation intermixing vs, deep learning, ferroelectric domain wall, interface structure, polarization, stem data, stem technique, vortices
Cluster 25
Career path, certainty, college physics, first-generation college student, longitudinal effect, ontological perspective, possible self, school experience, stem identity, stem role.
Cluster 26
Education research, geometry optic learning material, interactive multimediu, maximizing, partnership, physics preliminary study, science outreach, summer program, teacher expectation
Cluster 27
Environment, functional mri data, girls' interest, higher education, individual difference, monitoring, reactive game engine programming, stem, student ideal, water transportation
Cluster 28
Advanced stem, aquatic robotics, electromagnetic induction project, roavee
Cluster 29
Analytical view, disparity, example, outcome, social gap
Cluster 30
Barrier, cognitive science research, educational computer game, undergraduate stem instruction, usage
Cluster 31
Academic procrastination, achievement goal, interactive effect, stereotype
Cluster 32
Card hand, curriculum module design
Cluster 33
Friction, tribological investigation, valve
Cluster 34
Effectiveness, peer, stem learning program
Cluster 35
Justice, linguistic privilege
Cluster 36
Laser propagation demonstration, outreach project

VOSviewer automatically displays the number of terms set in the occurrence column. In the VOSviewer action panel,

the column displays the number of clusters for that term. These clusters are sorted alphabetically, and each cluster

has a different number of occurrences depending on the algorithm from VOSviewer and is interrelated between notes in one cluster or with other clusters. Each cluster has one note that is the largest (showing that the term appears a lot in previous studies). According to Figures 3 and 4, the phrase STEM (cluster 27) is directly associated with the term environment (cluster 27) and scientist (cluster 7). However, these three phrases differ in node size, brightness of the connecting route, and brightness of the nodes. This cluster, together with other terms, assists the reader in detecting gaps for future study.

Each cluster is made up of many words. A bigger circle will be assigned to one of these terms than the other terms in the cluster, such as STEM, student, physics, and others (see Figure 3). This indicates that past scholars have

thoroughly explored the phrase, whereas terms with a tiny circle provide chances for additional investigation. In other words, there is still a sufficient gap in the phrase to be filled by future inventions.

Visualization STEM research area using VOSviewer

Each group depicts the relationship between one item and another. A colored circle denoted each phrase. The size of each circle varies according to its recurring appearance. The circle's diameter correlates strongly with the occurrence of the phrases in the title. When a word appears more frequently, the circle grows larger. Computational mapping representation was examined in network visualization (Figure. 3) and overlay visualization (Figure. 4).

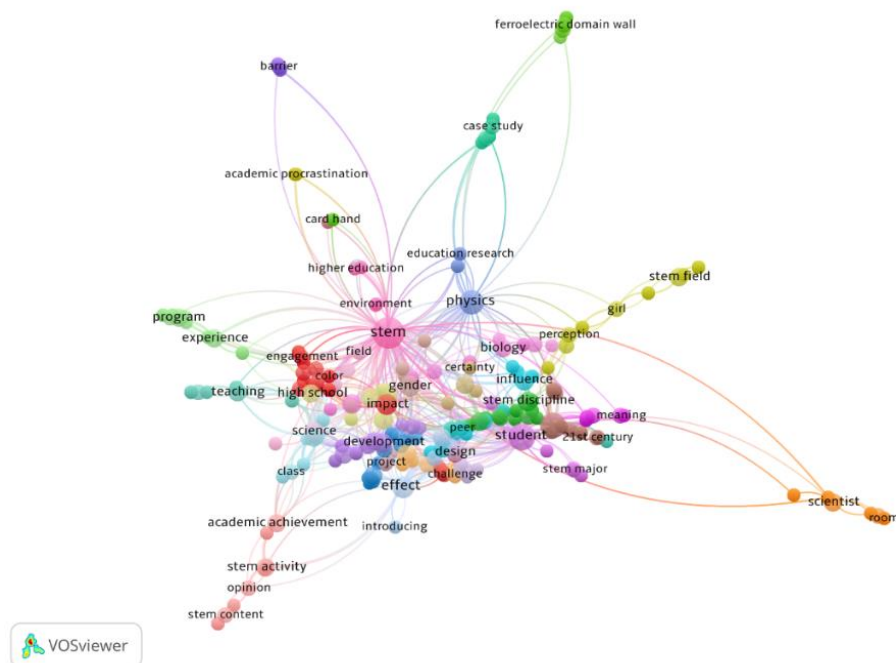


Figure 3 Network visualization of physics-STEM keyword

According to Figure 3, four terms appear more frequently: STEM (44 times), Student (21 times), STEM education (16 times), and Physics (14

times). STEM is a keyword in Publish or Perish during the previous ten years, and it is in cluster 27, as seen in Table 2. STEM items have larger labels than

others. The distance between STEM items and other items determines whether the two are closely related. Figure 3 shows that STEM is closely related to environment, field, engagement, gender, physics, and impact, and vice versa.

STEM items have a long distance with the following items: STEM content, room, STEM fields, case studies, and barriers. The distance between these two items is an opportunity for further research.

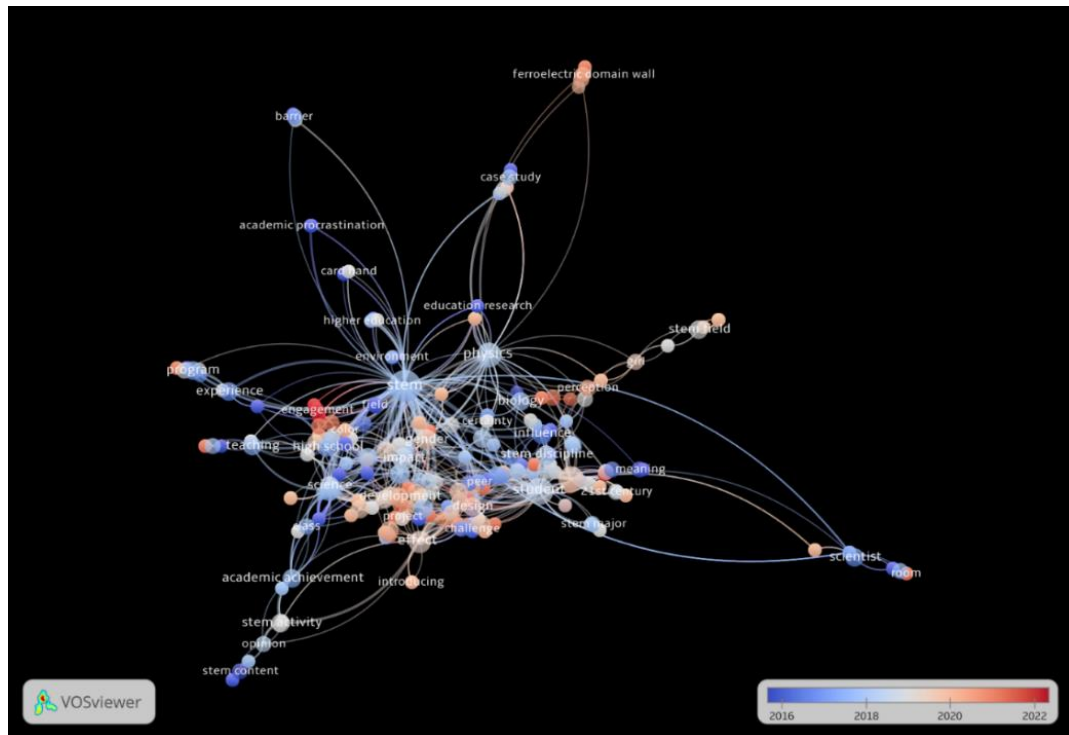


Figure 4 Overlay visualization of physics-STEM keyword

Figure 4 shows that much of the STEM research was done in 2018-2019, corroborated by the research trend graph in Figure 2. The stronger the red hue and the wider the diameter of the word label's circle, the more commonly the term happens (Kijkasiwat et al., 2022; Ellili, 2022; Li et al., 2018). Over the past three years, STEM research has been related to the terms STEM field, perception, girl, and gender. Many researchers have examined the gender gap regarding STEM enthusiasts. Many STEM enthusiasts are dominated by male students (Regan & DeWitt, 2014). This prompted researchers to examine further why female students have a low interest in STEM.

The second keyword that often appears is student. This phrase is in

cluster 20, which is light purple. The word student directly relates to other phrases such as design, STEM major, 21st-century skills, peer, STEM discipline, meaning, and challenge. Figure 3 displays the term student in orange and surrounded by yellow (Tosun, 2022; Koçak & Soylu, 2022). Like the term STEM, the phrase student has been carried out from 2018 to 2020. The third keyword is STEM education. But this term does not appear in the graph because another circle covers the circle. The fourth term that often appears is physics, according to keywords in article searches. VOSviewer analysis reveals that the term physics occurs 14 times. Terms directly related to physics include education research, perception, biology,

certainty, case study, influence, and others.

This research is very interesting and contributes to further research. There are two findings from the research that should be highlighted. First, STEM research in physics learning was mostly carried out in 2019, or a year before the spread of COVID-19. The second finding is about future research opportunities. The three VOSviewer visualization results show that there are still many opportunities to develop STEM. This is shown by Figures 3 and 4, where STEM barriers, programs, STEM scientists, STEM content, STEM activities, and STEM case studies have rarely been studied in the last 10 years. This finding also validates the efficiency of bibliometric analysis in examining and illustrating the present literature, which may be utilized in determining if more research should be conducted, as stated by other articles (Zhao et al., 2023; Khatib et al., 2022; Rahman et al., 2020).

CONCLUSION

This study aims to do a bibliometric analysis of research articles from the Scopus database. The theme chosen for this research is "STEM-Physics". Articles used in this research were harvested from the Scopus database using Harzing's Publish or Perish software. Based on the analysis, 169 relevant articles were published from 2013 to 2022. This study shows that research on STEM fluctuated in the first four years (2013-2016). The result of this study shows STEM topic still has a high chance of being researched and associated with other terms. Thus, there will be a novelty related to this research. This study's findings also clearly demonstrate that there are still several opportunities for STEM research. Several STEM studies, such as STEM content, STEM fields, and STEM activities, have received little attention. The following researcher can investigate

the design of a physics study with STEM activities for females.

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