JURNAL UPI

Indonesian Journal of Multidisciplinary Research

IJOMR Indonesian Journal of Multidiciplinary Research

Journal homepage: http://ejournal.upi.edu/index.php/ IJOMR/

Literature Review and Bibliometric Mapping Analysis: Philosophy of Science and Technology Education

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ABSTRACT

The research objective is to conduct a literature review regarding the philosophy of science views on science and technology, especially in the field of Education. Bibliometric analysis was carried out through mapping visualization using VOSviewer. The research method is Systematic Literature Review (SLR). Bibliometric analysis mapping has 4 stages: data search, data processing, data mapping, and data analysis. The keywords used are "Philosophy of Science" AND "Technology" with a range of 2018 - 2022. The number of articles obtained was 184 articles. The number of articles used for the literature review is 10 articles. The results show that research development has decreased from 2018 to 2020 and has increased from 2020 to 2022. Philosophy of science in the field of science and technology has many opportunities in various fields and studies within the scope of science and technology. Issues related to the philosophy of science are still quite widespread, especially for Science, Technology, Engineering, and Math (STEM) students, due to the lack of confidence in STEM students in the philosophy of science. The link strength value of the connection between philosophy and science is stronger when compared to the connection between philosophy and technology. This means that more researchers are linking philosophical research to science than technology. This research is expected to be a consideration in determining the research theme to be carried out, especially those related to the field of philosophy of science.

ARTICLE INFO

Article History:
Submitted/Received 16 Dec 2022
First Revised 26 Jan 2023
Accepted 17 Mar 2023
First Available online 18 Mar 2023
Publication Date 01 Sep 2023

Keyword:
Education,
Philosophy of science,
Science,
Technology.

1. INTRODUCTION

Philosophy of science is a branch of philosophy that studies and questions the nature of science systematically (Guo, 2014). The philosophy of science deals with philosophical and fundamental problems that exist in science in achieving scientific knowledge. Philosophy of science is a philosophy that is concerned with the subject matter of science as the core question to seek the truth. Philosophy of science is a critical review of recent scientific opinions through a comparison of criteria developed from certain opinions. The philosophy of science is very important to know. The philosophy of science helps a person distinguish between scientific issues and non-scientific issues (Blachowicz, 2009). The philosophy of science provides a clear value and orientation for each discipline.

There are several previous studies on the philosophy of science including research on the development of learning media to develop a philosophy-based nature of science (Asmara *et al*., 2022), research on adapting practice-based philosophy of science to teach science students (Green *et al*., 2021), research combination of history and philosophy of science implemented in energy teaching in high schools (Bächtold & Munier, 2019), research on professionally significant interdisciplinary connections on the history and philosophy of science (Korzhuev *et al*., 2018), research on several perspectives on the relationship between philosophy, philosophy of science, and law (Aspan & Adnan, 2021) and research on the use of philosophy of science in supporting the specially developed nature of understanding science teachers (Kampourakis, 2020). However, there has been no research regarding the philosophy of science literature review in science and technology, especially in the field of education.

Therefore, this study aims to conduct a literature review regarding the views of the philosophy of science on science and technology, especially in the field of education. This study focuses on a literature review using the Systematic Literature Review (SLR) method regarding the philosophy of science in science and technology. The novelties of this study are (i) the research is a literature review using the SLR technique; (ii) The research focuses on previous studies regarding the philosophy of science in the field of science and technology, especially in the field of Education; (iii) The process of analyzing the literature review is assisted by visualization of research bibliometric mapping using VOSviewer. This research has the intention of being an evaluation and development material for further research.

2. METHODS

2.1. Literature Review Method

This study uses the Systematic Literature Review (SLR) method in conducting a literature review. The SLR procedure used consisted of six stages, namely (i) Designing research questions; (ii) Determination of research criteria; (iii) searching for research data; (iv) Selection of research data; (v) Research quality assessment; and (vi) Analysis of the results of the synthesis of research questions. **Figure 1** shows the stages of the research carried out by observing the SLR research procedure.

The search for publication data in this study used the publish or perish application 7. The data search was carried out on December 7, 2022. The data search was carried out on published data in the 2018 – 2022 range in publication databases, namely Google Scholar and Scopus. The keywords used in searching data on the publish or perish 7 applications are "Philosophy of Science" AND "Technology". Keyword searches are carried out by matching the titles and abstracts of related articles. The number of articles obtained from the search results is 184 articles originating from the Scopus database for data processing for bibliometric analysis using the VOSviewer mapping visualization. The number of articles

DOI: http://dx.doi.org/10.17509/xxxx.xxx
p- ISSN 2776-608X e- ISSN 2776-5970

found for literature study after experiencing article selection based on the suitability of the title of the article with the research objective, namely 10 articles used for literature review.

Figure 1. Research stages.

2.2. Bibliometric Analysis Mapping Method

Bibliometric analysis mapping has 4 stages, namely data search using the publish or perish 7 application, data processing using the Microsoft Excel application, data mapping using the VOSviewer 1.6.16 application, and data analysis from the VOSviewer mapping visualization results. The published or perish 7 search result data is stored in .csv and .csv formats. ris. Data in .csv format is processed using Ms. Excel to get data on the number of articles per year and see the research that has been done by researchers regarding the keywords used. Data stored in *.ris format is used in data mapping using VOSviewer. The data that has been mapped is then analyzed to see the development of research on the "Philosophy of Science in Science and Technology Education". The data from this mapping is analyzed to obtain existing research trends and the results of terms that are often used as study material to find novelty for further research.

3. RESULTS AND DISCUSSION

3.1. Search Results Matrix

Based on the search results for articles on the Philosophy of Science in Science and Technology Education, 184 articles were found in the Scopus database. **Table 1** shows the research matrix from the results of the search conducted. Based on the data in **Table 1** shows that the total number of citations of all articles regarding the philosophy of science in science and technology education is 468.

Table 1 shows the number of citations in 2 types, namely 117.25 citations per year and 2.54 citations per article. Articles on the philosophy of science in the fields of science and technology have an h-index of 12. The h-index shows the author's level of metrics in measuring the productivity and impact of citations from publications (Dinis-Oliveira, 2019). The higher the h-index value, the better the research in that field (Mingers *et al.*, 2012). Research on the philosophy of science in the field of science and technology has an h-index of 12 can be said to be not very good and not widely cited by many people. The publication

DOI: http://dx.doi.org/10.17509/xxxx.xxx
p- ISSN 2776-608X e- ISSN 2776-5970

of Adsorption Biomaterials has a g-index value of 4.25. **Table 2** shows the ten articles with the highest number of citations. Based on **Table 2**, the article entitled "The social responsibility of a scientist: Philosophical aspect of contemporary discussions" published in 2019 has the most citations with a total of 43 citations.

Table 1. Research matrix.

Paper	184
Citations	469
year_first	2018
year_last	2022
Cites/Year	117,25
Cites/Paper	2,54
Authors/Paper	0,99
h-index	12
g-index	16

Table 2. 10 articles with the highest number of citations.

No	Number of Citations	Title	Year	Ref
1	43	The social responsibility of a scientist: Philosophical aspect of contemporary discussions	2019	Saenko *et al*. (2019)
2	28	Crowdsourced science: sociotechnical epistemology in the e-research paradigm	2018	Watson & Floridi (2018)
3	24	What do energy modellers know? An ethnography of epistemic values and knowledge models	2020	Silvast *et al*. (2020)
4	24	Quantitative data from rating scales: An epistemological and methodological enquiry	2018	Uher (2018)
5	20	A Framework for Epistemological Discussion on Integrated STEM Education	2020	Ortiz-Revilla *et al*. (2020)
6	19	The roles of ethics in gene drive research and governance	2018	Thompson (2018)
7	14	Why attention is not explanation: Surgical intervention and causal reasoning about neural models	2020	Grimsley *et al*. (2020)
8	14	Teaching and discussing about risk: seven elements of potential significance for science education	2019	Schenk *et al*. (2019)
9	14	Conceptual definition of technology emergence: A long journey from philosophy of science-to-science policy	2019	Burmaoglu *et al*. (2019)
10	14	Why science's crisis should not become a political battling ground	2018	Andrea (2018)

DOI: http://dx.doi.org/10.17509/xxxx.xxx
p- ISSN 2776-608X e- ISSN 2776-5970

3.2. Research Development

Figure 2 shows the development of publications regarding the philosophy of science in the field of science and technology in the range of 2018 and 2022. **Figure 2** shows that the development of research has decreased from 2018 to 2020, namely 38 articles in 2018, 35 articles in 2019, and 2020 in year 33. Whereas in 2020 the development of research has increased, namely 38 articles in 2021 and 41 articles in 2022. The most research took place in 2022, namely 41 articles, and the lowest research occurred in 2020, namely 33 articles.

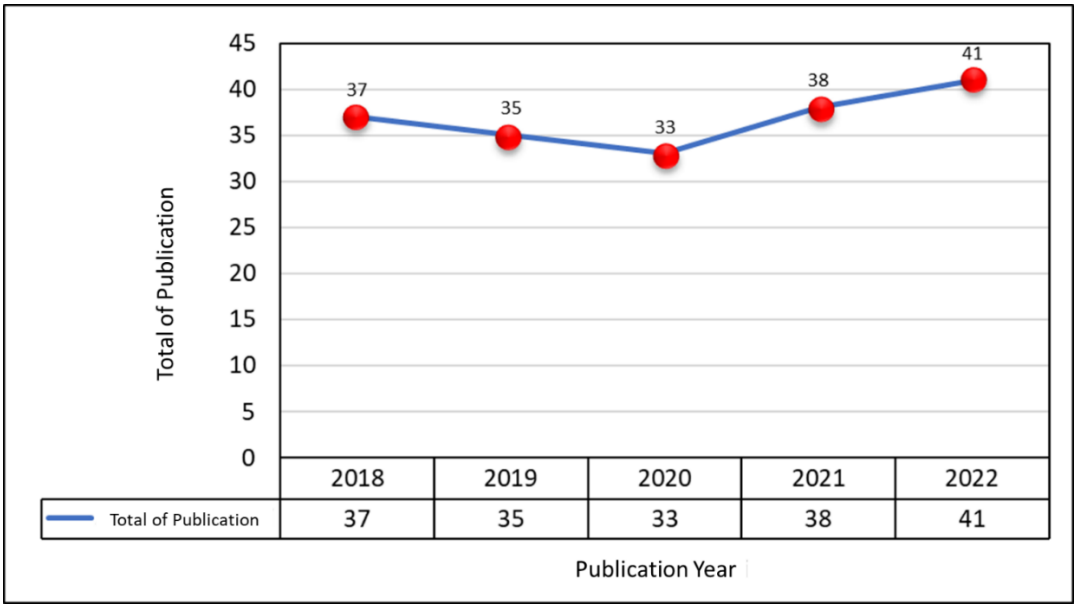

Figure 2. The development of research on the philosophy of science in the field of science and technology.

3.3. Current Studies on Philosophy of Science in Science and Technology

Table 3 shows details of research on the philosophy of science in the current field of science and technology. **Table 3** shows the title, year, objectives, methods, and findings of the research. Based on several research findings in **Table 3**, positive findings were obtained regarding the philosophy of science. Some of the findings in more detail are discussed as follows:

The relationship between the philosophy of science, the philosophy of technology, and the fields of Science, Technology, and Society (STS) have been very broad. An analysis of the approach taken from philosophy to the study of STS shows that new scenarios of new and constructive encounters between these fields have emerged from several philosophical perspectives (Moreno & Vinck, 2021). The analysis of the encounters made between the aforementioned philosophical perspectives and the field of STS can serve to stimulate and invite the development of other possible encounters such as those presented in this thematic file (Moreno, 2021).

Philosophers of science rely more on inductive inference (Mizrahi & Dickinson, 2022). However, induction may not be as fundamental to the philosophy of science as it is thought to be for science, given that philosophers of science make far more deductive arguments than inductive ones. Philosophers of science rely less on abductive arguments, although philosophers of science consider abduction to be a cornerstone of scientific methodology.

DOI: http://dx.doi.org/10.17509/xxxx.xxx
p- ISSN 2776-608X e- ISSN 2776-5970

Table 3. Studies on the philosophy of science in the field of science and technology.

No	Ref	Year	Objective	Method	Findings
1	Moreno & Vinck, (2021)	2021	The study aims to analyze the relationships established by several philosophers of science and technology with the development of STS, to show how some philosophical approaches and investigations, which are still neglected by most, have opened up rich interactions with STS and used them to build alternative conceptions of science and technology that are important;	Literature Review	The relationship between the philosophy of science, the philosophy of technology, and the fields of STS has been vast and varied over the past five decades, despite distance, controversy, and disagreement. The study of experimental work is a field that enriches conceptual frameworks, analytical schemes, and language for understanding science in general. Philosophy and STS have different methodological orientations which presuppose different normative viewpoints.
2	Chesher & Andreallo , (2021).	2021	The research aims to identify the contribution of different knowledge communities (Science, Arts, and Philosophy of Science) to the transdisciplinary understanding of faces.	Kajian Teori; Literature Review; analisis visual kualitatif;	• Our visual analysis of this type of robot, and making cross-connections between philosophy, science, and art. • The robot's face establishes the identity of the robot as a quasi-subject; • The robot's face and body display affective and emotional expressions; • The robotic face marks (or unmarks) the distinct stylistic, technical, gender, and racial identities that place it in a cultural and historical setting; • Robots can be read simultaneously as subjects, gadgets, material artifacts, works of art, performers, and parts of technological systems; • Human-robot interaction can be experienced as a collaborative performance with the framing of context, narration, sound, speech, and images.

DOI: http://dx.doi.org/10.17509/xxxx.xxx
p- ISSN 2776-608X e- ISSN 2776-5970

Table 3 (Continue). Studies on the philosophy of science in the field of science and technology.

No	Ref	Year	Objective	Method	Findings
3	Cabrera (2021).	2021	The purpose of this study is to describe the strategy for teaching the introductory philosophy of science course to Science, Technology, Engineering, and Mathematics (STEM) students through the second philosophy approach.	In the Second Philosophy approach, the sample is STEM students	The "Second Philosophy" approach, suggests, as far as possible, that the problems that concern the philosophers of science are inspired by the concrete questions that arise.
4	Nagatsu *et al.* (2020)	2020	The research aims to start a mutually enriching conversation between philosophers of science and sustainability scientists, thus responding to the latter's recent calls for more inclusive engagement with the humanities and social sciences.	Studi Literature, Literature Review, Study Teori	Based on this research there are brief sketches of three main areas where previous insights can contribute to the development of sustainability science. The first concerns epistemology and methodology: (a) inferential strategies such as analogical reasoning, (b) new practices such as inter- and transdisciplinary research, and (c) social and institutional conditions such as science policies that encourage new research practices. The second concerns conceptual issues: (a) making key concepts in sustainability science clear and precise, (b) identifying ambiguous and condensed evaluative concept functions, and (c) developing new concepts that are useful for applying sustainability science for practical sustainability purposes. The third area concerns normative and ethical issues, and the researcher highlights the importance of (a) making the role of values in scientific conclusions explicit and valid, (b) identifying and unraveling the tension between epistemic and ethical values, and (c) developing context-specific ethical frameworks for complex and urgent decision making.

DOI: http://dx.doi.org/10.17509/xxxx.xxx
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Table 3 (Continue). Studies on the philosophy of science in the field of science and technology.

No	Ref	Year	Objective	Method	Findings
5	Plaisance *et al.* (2021)	2021	The aim of this research specifically is to increase researchers' understanding of how philosophers of science can and do scientific practice, policy, and public engagement with science.	• The respondents are 35 philosophers of science. • Quantitative, qualitative, and mixed methods research. • Triangulation method	Tem Research studies show that direct, interpersonal, and often face-to-face interactions are associated with greater impact outside the discipline. Furthermore, the interviews conducted in this study indicate that many philosophers of science highly value the impact they have on scientists, policymakers, and other relevant stakeholders. Researchers have used the research data to come up with several recommendations about how philosophers can enhance their broader impact and what kinds of changes may be needed at the institutional and disciplinary levels.
6	AyÄ±k & CoÅŸtu, (2020).	2020	The research objective was to examine the effect of presenting content based on the HPS lacatosian perspective on pre-service science teachers' understanding of NOS and scientific progress.	• The research respondents were 34 science teachers • A quasi-experimental method with pre-test, intervention, and post-test. • Surveys • Mixed Method approach • Semi-structured interview technique	• The results showed that the demonstration of atomic theory from HP's perspective had a positive effect on pre-service science teachers' understanding of NOS. • The quantitative findings of the study revealed that, in the experimental group, content preparation from an HP's perspective had a positive effect on the understanding of NOS and the progress of science because the descriptive results produced more significant changes in the ex-outcomes. experimental group, while no significant changes were observed in the results of the control group.

DOI: http://dx.doi.org/10.17509/xxxx.xxx
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Table 3 (Continue). Studies on the philosophy of science in the field of science and technology.

No	Ref	Year	Objective	Method	Findings
7	Supena *et al*. (2021).	2021	The research objectives: (i) to analyze the effect of the 4C learning model on student learning outcomes in the philosophy of science course; (ii) the effect of academic ability on student learning outcomes in the philosophy of science courses, and (iii) the interaction between the 4C learning model and academic abilities on student learning outcomes in philosophy of science courses.	• Quasi-experimental research with 2x3 factorial design • Data collection techniques are multiple choice tests, essay tests, observation, and documentation. • Post-test only non-equivalnet research design • descriptive statistical analysis and inferential statistical analysis.	• The 4C learning model influences students' psychomotor and affective learning outcomes, • Students' academic abilities do not affect student learning outcomes, and • • Interaction between the 4C learning model and student learning outcomes. Academic ability had no effect on first year students
8	Pieterman-Bos & van Mil, (2022).	2022	The research objective was to identify the five aspects of conducting research and the four dimensions of learning, and why paying attention to the fourth dimension is important.	Study of literature	This research shows that research objectives are aligned and can reinforce each other when taught together. Integrated knowledge, skills, and abilities can better prepare students to understand and research increasingly complex biomedical data with the aim of creating knowledge about human life, health, and disease.
9	Lusk (2022).	2022	The research aims to present the results of a survey of students majoring in STEM whose education contains a significant component of history, philosophy, and sociology (HPS).	• Surveys • Multiple choice questions 5-point Likert scale questions, open response questions.	• There is a perception that STEM students are not interested in HPS and believe that the subject does not have much to offer them. The HPS Experience Survey assessed whether these perceptions were accurate, and they were not. After taking an HPS course, students retrospectively feel the value in it; they generally show that they are learning. • The HPS Experience Survey shows that if STEM students are initially resistant, that resistance goes away after experience in the HPS course.

DOI: http://dx.doi.org/10.17509/xxxx.xxx
p- ISSN 2776-608X e- ISSN 2776-5970

Table 3. Studies on the philosophy of science in the field of science and technology.

No	Ref	Year	Objective	Method	Findings
10	Mizrahi & Dickinson (2022)	2022	This research aims to do philosophical reasoning about science through quantitative digital studies	• Use the types of arguments abductive, deductive, and inductive • Quantitative method • Data Mining and Text Analysis methods	The results show that philosophers of science do rely on inductive inference. But induction may not be as fundamental to the philosophy of science as it is thought to be for science, given that philosophers of science make far more deductive arguments than inductive ones. The results of this study also show that philosophers of science do not rely too much on abductive arguments, even though philosophers of science regarding abduction as the foundation of scientific methodology.

3.4. Problems Current Issues of Philosophy of Science Research in the Field of Science and Technology

In further studies, we conduct studies on issues or problems that form the basis of several previous studies. Current issue issues based on literature studies of several previous studies on the philosophy of science can be summarized as follows:

Some specific philosophical perspectives on science and technology are not well known. The relationship is still distant between Science and Technology Studies (STS) and the philosophy of science and technology (Moren & Vinck, 2021). Based on the research of Chesher and Andreallo (2021) taking the research issue that is important in describing a technology that is connected with several sciences, one of which is the philosophy of science. Chesher and Adreallo (2021) explained that a depiction of a robot's face requires transdisciplinary literature on faces from the perspective of several sciences, namely science, art, and philosophy of science.

There is a critical engagement between scientists in developing and linking sustainable technology and the philosophy of science concerning engaging in scientific activity in a complex domain and many serious philosophical issues in sustainability science when combined with the ethical dimension of sustainability, giving rise to many problems in the philosophy of science. and technology. This is one of the issues in the philosophy of science research presented by Nagatsu *et al*. (2020).

In the field of education, specifically, the current problem or issue regarding the philosophy of science is the need to emphasize aspects of knowledge and understanding, whereas in reality aspects of application, analysis, synthesis, and evaluation are only carried out in a small part of learning (Supena *et al*., 2021). The philosophy of science can be used as a stimulus for students to think critically (Supena *et al*., 2021). In Science, Technology, Engineering, and Math (STEM) Education itself, students still doubt that the philosophy of science has a connection and usefulness to the field of science so there are obstacles that arise in involving STEM students in learning philosophy of science (Lusk, 2022).

DOI: http://dx.doi.org/10.17509/xxxx.xxx
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3.5. Current standards of Philosophy of Science Research in the Fields of Science and Technology

The latest standards used in several studies regarding the philosophy of science in the field of science and technology have been seen from the research approach that is often used is the mixed method approach. Many studies use qualitative and quantitative methods in data analysis, one of which was carried out by Lusk (2022), Supena *et al*. (2021), AyÄ±k, & CoÅŸtu (2020), and Plaisance *et al*. (2021).

Surveys, Questionnaires, and Interviews are the most used data collection techniques for qualitative analysis (Plaisance, 2021; AyÄ±k, & CoÅŸtu, 2020; Lusk, 2022; Mizrahi & Dickinson, 2022). Pre-test and post-test and quasi-experimental group designs (control class and experimental class) are widely used for the needs of data analysis using a quantitative approach (Plaisance, 2021; AyÄ±k, & CoÅŸtu, 2020; Supena *et al*., 2021). Research using literature review techniques was also carried out on the philosophy of science research theme by Pieterman-Bos & van Mil (2022). In this case, there are still few researchers who examine the philosophy of science based on a literature review.

3.6. Mapping Bibliometric Analysis of Philosophy of Science Research in the Field of Science and Technology

Bibliometric analysis mapping was carried out using the VOSviewer application. Several provisions are made, namely, the minimum value of the appearance of the term is 2 times so that 44 terms are found. **Figure 3** shows the network visualization between terms. Network visualization shows the connectedness between terms (Al Husaeni & Nandiyanto, 2023). The circle in the figure is a node. The node describes a term found in the philosophy of science research in the field of science and technology (Al Husaeni & Al Husaeni, 2022). Based on the cases in **Figure 3**, it is known that the size of the color nodes indicates the number of occurrences of a term (ie the number of times the keyword appears) (Nandiyanto *et al*., 2021). The greater the circle of a term, the higher the number of occurrences, and the thicker the links between nodes, the greater the total link strength between these terms (Al Husaeni & Nandiyanto, 2022).

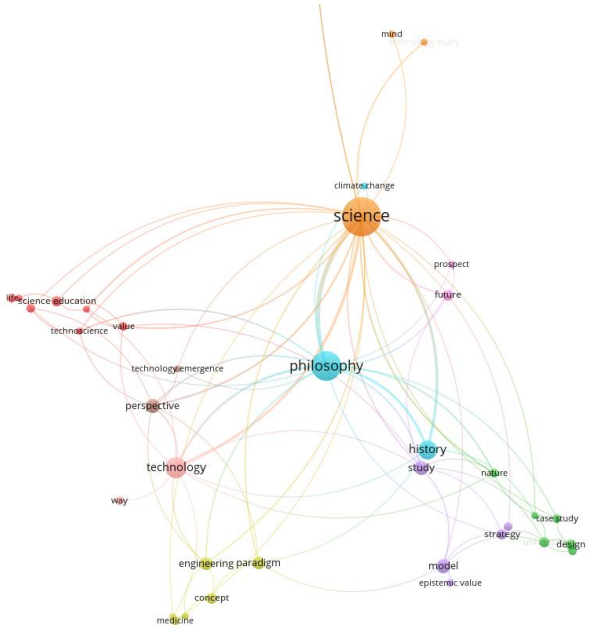

Figure 3. Network visualization of philosophy of science research in science and technology.

DOI: http://dx.doi.org/10.17509/xxxx.xxx
p- ISSN 2776-608X e- ISSN 2776-5970

Figure 4(a) shows the connection between the terms philosophy and science. Based on the picture, it is known that until now there are researchers who connect the terms philosophy with science. The link strength between the terms science and philosophy is 23. Meanwhile, **Figure 4(b)** shows the linkage between the terms philosophy and technology with a link strength value of 8. The link strength indicates the strength of the relationship between the two terms, the higher the value indicates the stronger the relationship between the two terms (Derrick *et al*., 2014). Based on the link strength value, the connectedness of philosophy and science is stronger when compared to the connectedness of philosophy and technology. This means that more researchers are linking philosophical research to science than technology.

(a) (b)

Figure 4. Connectivity of philosophical terms; (a) philosophy and science; (b) philosophy and technology.

As for several other terms are connected with philosophical terms besides science and technology, namely climate change, prospects, future, history, study, nature, case study, strategy, engineering, perspective, technology emergence technoscience, and ethics (**Figure 5**). Bibliometric mapping analysis of research on the philosophy of science in the field of science and technology is carried out to assist and become a consideration for further research in determining the research theme to be carried out, especially related to the field of philosophy of science.

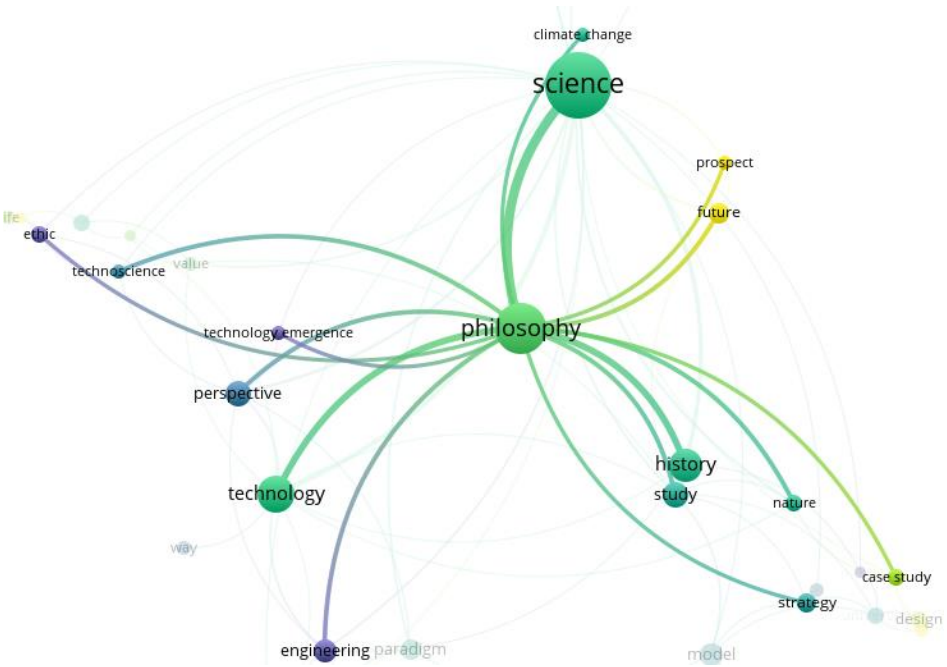

Figure 5. Network visualization of philosophical terms.

DOI: http://dx.doi.org/10.17509/xxxx.xxx
p- ISSN 2776-608X e- ISSN 2776-5970

4. CONCLUSION

Based on the results of a literature review that has been conducted on the philosophy of science in the field of science and technology, it can be concluded that the choice of research on the philosophy of science in the field of science and technology still has many opportunities in various fields and studies within the scope of science and technology. The relationship between the philosophy of science, the philosophy of technology, and the fields of Science, Technology, and Society (STS) have been very broad, but inversely proportional to the number of research which tends to be small. The number of studies on the philosophy of science in the field of science and technology is 184 publications with details: 37 in 2018, 35 in 2019, 33 in 2020, 38 in 2021, and 41 in 2022.

Problems with related issues regarding the philosophy of science in the field of Education, namely the need to emphasize the philosophy of science on aspects of knowledge and understanding, whereas in reality the aspects of application, analysis, synthesis, and evaluation are only carried out in a small part of learning. In Science, Technology, Engineering, and Math (STEM) Education itself, students still doubt that the philosophy of science has a connection and usefulness to the field of science. Thus, obstacles arise when involving STEM students in learning philosophy of science.

Based on the results of a bibliometric network visualization analysis of research on the philosophy of science in the field of science and technology, it is known that the link strength value of the connection between philosophy and science is stronger when compared to the linkage of philosophy and technology. This means that more researchers are linking philosophical research to science than technology.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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