

A Bibliometric Analysis of Entrepreneurial Thinking Research in Science Education from 2014 to 2023

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Abstract: This research aims to provide a bibliometric literature review regarding the trends of entrepreneurial thinking (ET) research in science education in 2014-2023. In this research, five main stages were carried out in bibliometric literature: determining topics and keywords, searching databases according to keywords, refining the database, compiling statistical data, and analyzing data. Search results from the scopus.com document database using the keywords "entrepreneurial thinking" and "science education" obtained 89 articles, which were then analyzed for completeness and statistical data. Data that have gone through the refinement stages are stored in the form of Research System Information (RIS) and analyzed using VOSviewer software to obtain visualization of the data. The results of the bibliometric review show that the entrepreneurial thinking research trend linked to science education continues to experience development with a focus on research studies on the integration of entrepreneurship in science and engineering, as well as the development of skills related to entrepreneurship through science, including entrepreneurial character, entrepreneurial intention, and entrepreneurial thinking. In more specific science education, entrepreneurial thinking has begun to be developed through STEM and design thinking since 2018. Another bibliometric review shows that research on ET still needs to be studied, especially in science teaching, which is linked to strategies, approaches, media, and teaching models. The results of the bibliometric review show that ET in science education has many opportunities for research development that can be studied further.

Keywords: bibliometric, entrepreneurial thinking, science education.

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INTRODUCTION

Science education in higher education aims to help students develop scientific knowledge and investigations with a scientific approach; quite a few students also have the desire to develop entrepreneurial skills related to the scientific understanding of science content (Chen et al., 2021; Shahali & Halim, 2010). Furthermore, science education aims to strengthen the relationship among science, creativity, entrepreneurship, and innovation (European Commission & Directorate-General for research and Innovation, 2015). In the context of 21st-century teaching, science education needs to emphasize and present a teaching process that develops entrepreneurial character (Achor & Wilfred-Bonse, 2013). The entrepreneurship skills can be acquired through science laboratory activities, workshop applications, and intra- and extracurricular activities (Deveci, 2016). Thus, this entrepreneurship can be developed in various fields, including science, so that the terms sciencepreneur and scientific entrepreneurship are known.

Scientific entrepreneurship is related to producing innovative products based on science to meet product needs that do not yet exist in society (Armstrong & Tomes, 2000). In its development, this

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entrepreneur is not only oriented towards producing a product but also more focused on developing an entrepreneurial way of thinking in students, which is known by several terms, namely entrepreneurial mindset, entrepreneurial intention, and entrepreneurial thinking. Entrepreneurial thinking (ET) is one of the thinking skills that students must have to face future challenges (Bacigalupo et al., 2016). These skills do not just shape someone into an entrepreneur but emphasize the intrinsic perspective and skills in exploiting opportunities and innovation (Diniaty & Atun, 2015; Siew & Ahmad, 2022).

Entrepreneurial thinking (ET) is an essential skill that can form the young generation with various skills that can be applied in facing global challenges, such as problem-solving, creativity with limited resources, being able to perceive feedback critically, and being able to work collaboratively (Peschl et al., 2021). Furthermore, there are three core competencies in ET, namely 1) high curiosity in responding to current developments, 2) ability to generate and connect problem-solving ideas with community needs, and 3) ability to create value from innovative ideas that can benefit society (Lavoine, 2022). Other literature explains that ET has an orientation toward exploiting opportunities, innovation, and experimentation (Konstantinos, 2022). Referring to the explanation regarding ET skills, ET relates to elements of the scientific process, such as curiosity, problem-solving, innovation, and creativity in creating and carrying out collaborative solutions.

The relationship between elements of entrepreneurial thinking and the scientific process indicates that ET can be developed through the scientific process in science teaching. Science education can develop entrepreneurial values through scientific inquiry in increasing understanding of social values, culture, and epistemic processes (Davis, 2022). Furthermore, eight scientific activities are relevant to developing ET (Konstantinos, 2022). The eight basic activities include asking questions based on scientific issues and phenomena, developing models, planning investigations, analyzing and interpreting data, using mathematical formulas and computational thinking, developing experiments and designing solutions, developing arguments based on evidence, and communicating results. Based on this explanation, research in the field of science education is starting to be linked to the development of ET skills, both of which have the same orientation toward problem-solving, innovation, creativity, and collaboration.

In science education research, ET is becoming a research topic linked to design thinking and STEM (Science, Technology, Engineering, Mathematics). In general, research focuses on developing ET through STEM implementation, such as implementing STEM projects for prospective STEM teachers to develop ET, developing STEM learning modules as an effort to increase ET (Siew & Ahmad, 2022), interdisciplinary integration of E-STEM to develop ET in high school students (Eltanahy et al., 2020) and the use of STEM with a design thinking approach in developing an entrepreneurial mindset (Bosman & Shirey, 2023). These studies illustrate that the STEM process impacts the development of ET. STEM is related to science education as part of an integrated approach and curriculum. The process in STEM has the same essence as the scientific process in science education so that science education has the same opportunity to develop ET. Based on this explanation, this article presents the results of a bibliometric analysis focusing on studying two things: 1) what are the trends in ET research in science education from 2014-2023? and 2) what are the future opportunities and potential for science education research to develop ET?

METHOD

In this research, bibliometric analysis consists of five main stages: determining search keywords, collecting initial search results, refining initial searches, compiling statistical data, and analyzing data (Tranfield et al., 2003). The following is explanation of the five bibliometric stages (Table 1).

In the first stage, the keywords used in this bibliometric research consist of ET and science education. These keywords are related to the two primary research focuses, namely mapping ET research in science education and opportunities for developing ET research in science education. Search for data uses scopus.com (<https://www.scopus.com/search>) so that the data obtained are scientific articles published on Scopus.

The second stage is collecting a database of search results based on a search on scopus.com. The Scopus database published 89 documents from 2014 to 2023. In the third stage, 89 articles were refined by checking the completeness of the article components, namely completeness of article information, availability of abstract, author's name, journal name, year, publisher, and others. The

checking results showed that the 89 articles met the criteria for completeness of information in the article so that all of the articles could be used for the next stage.

Table 1. The stages of bibliometric

Stages of bibliometric	Stages Explanation
Determining search keywords	Search keyword: Entrepreneurial Thinking, Science Education Scopus database shows: “entrepreneurial” AND “thinking” AND “science” AND “education”
Collecting initial search results	Search results on scopus.com collected 89 published documents. (N=89)
Refining initial searches	Publication document criteria for the process of refining initial search results: completeness of the article components, namely abstract, author's name, journal name, year, publisher, and suitability to the theme. all publication documents meet the criteria, so no documents are eliminated. (N=89)
Compiling statistical data	Compiling data based on statistical data on scopus.com
Analyzing data	Data analysis using Vosviewer

In the fourth stage, statistical data were compiled. The advantages of searching using the database from Scopus.com include the ease of reading statistical data from search result documents. In scopus.com, there is an analysis of search result feature that provides statistical data in the form of several papers based on year, document source (name of journal, type of conference, name of publisher), name of the author, original affiliation, country of origin, type of document (article, conferences, books, reviews), the subject area of the paper, to statistical data regarding sponsors of the research. In the fifth stage, the database of the 89 articles from scopus.com is stored as a Research Information System (RIS), which is then analyzed using VOSviewer. The analysis in VOSViewer uses the title and abstract as keywords in mapping results according to the keywords used. VOSViewer analysis results are presented in three primary forms: Network Visualization, Overlay Visualization, and Density Visualization.

FINDINGS AND DISCUSSION

Entrepreneurship Research Trends toward Science Education in 2014-2023

Research on entrepreneurial thinking (ET) in science education has yet to become famous and is still rare; this can be seen from the documents obtained from scopus.com in 2014-2023 showing that there were only 89 documents. The years 2022 and 2021 are the years that produce the most articles. Figure 2 shows statistical data on the number of articles from 2014-2023 relating to ET in science education.

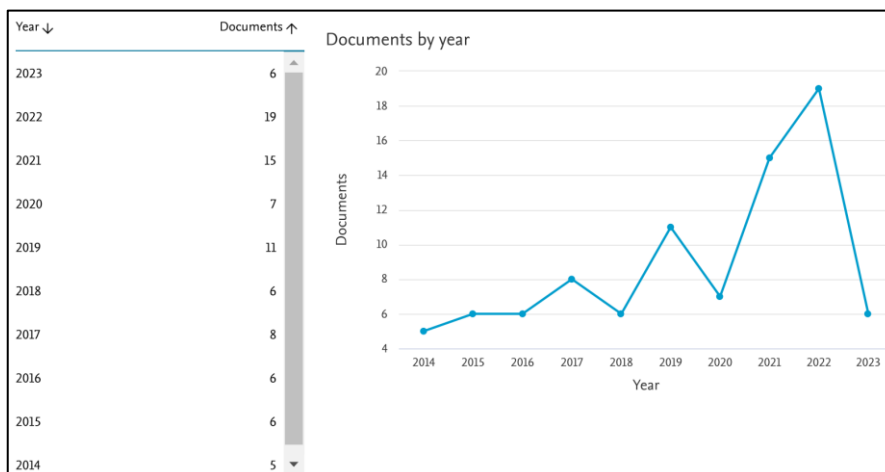


Figure 2. Statistics on the Number of Articles for 2014-2023 regarding ET in Science Education (Source: Scopus.com)

Based on the document database from 2014-2023, some articles have been cited. Table 2 show five articles related to ET in science education which have the most citations:

Table 2. Five articles related to ET in science education with the most citations

No	Title	Authors	Journal Name	Year	Number of citations
1	Combining technology and entrepreneurial education through design thinking: Students' reflections on the learning process	Lynch, M., Kamovich, U., Longva, K.K., Steinert, M.	Technological Forecasting and Social Change, 164, 119689	2021	57
2	Exploring entrepreneurial conceptions, beliefs, and intentions of Greek graduates	Kakouris, A.	International Journal of Entrepreneurial Behaviour and Research, 22(1), pp. 109–132	2016	36
3	How data analytics is changing entrepreneurial opportunities?	Sedkaoui, S.	International Journal of Innovation Science, 10(2), pp. 274–294	2018	19
4	Assessing the role of the teacher in introducing entrepreneurial education in engineering and science courses	Teerijoki, H., Murdock, K.A.	International Journal of Management Education, 12(3), pp. 479–489	2014	18
5	Curriculum development for technology-based entrepreneurship education: A cross-disciplinary and cross-cultural approach	Kazakeviciute, A., Urbone, R., Petraite, M.	Industry and Higher Education, 30(3), pp. 202–214	2016	16

According to bibliometric reviews, the trend of the research on entrepreneurial thinking (ET) in science education from 2014 to 2023 continues to increase, especially in 2022, with a significant increase. The analysis shows that ET is one of the skills starting to be researched and developed in various fields, including science. In 2014, there were four documents, with two specifically related to science education. The ET research trend in science education began with research regarding the role of teachers in introducing entrepreneurial education in engineering and science courses (Teerijoki & Murdock, 2014). This research has not studied ET as a skill students must possess and develop during college. Other research in 2014 related to developing innovation skills through science teaching oriented towards entrepreneurial problem-solving (Barnes et al., 2014).

In 2015, there were six documents, but only one record was directly related to science education. This research examines the development of educational entrepreneurship in applied science courses in universities (Päätaalo, 2015). In 2016, there were six documents that had themes related to entrepreneurship, but there were no articles that specifically discussed entrepreneur education and ET in science education. In 2016, the research trend emphasized more on the role and use of technology in entrepreneurship (Kazakeviciute et al., 2016; Scott et al., 2016). In 2017, there were eight documents whose research trends are toward the development of pedagogical innovation and design thinking in developing entrepreneurship mindset and entrepreneurial intention in the fields of science and technology (Tabrizi, 2017; Varghese & Philip, 2017; Wachira & Absaloms, 2017).

In 2018, the research trend decreased to only six documents. In 2018, only one paper specifically discussed entrepreneurship in science education, and measurements were starting to be taken regarding ET in prospective STEM teachers. In 2019, there were 11 documents with a research focus on developing entrepreneurial skills, namely developing entrepreneurial character through STEM (Sudarmin et al., 2019), entrepreneurship skills through project-based learning (Kunicina et al., 2019), entrepreneurial behaviour through innovative engineering lectures (Ten Caten et al., 2019), entrepreneurial mindset through engineering lectures (Pöder et al., 2019) and the development of ET through STEM (Xu et al., 2019).

In 2020, research on entrepreneurship in science education decreased, with only seven documents and no articles specifically discussing entrepreneurship in science education. Meanwhile, in 2021 and 2022, there was a significant increase in the trend of science education research related to entrepreneurship; research in 2021 and 2022 has led to the development of ET through the development of STEM curricula and the application of STEM in teaching at the elementary to higher education levels (Ahmad & Siew, 2021; Akrami, 2022; Barth & Muehlfeld, 2022; Lynch et al., 2021; Siew & Ahmad, 2022). Meanwhile, in 2023, on scopus.com, there were only six documents related to entrepreneurial thinking in science education. In 2023, the research focus began to develop the role of technology in STEM education to train ET skills (Bosman & Shirey, 2023; Eimler & Straßmann, 2023).

Statistical data show that there are articles that already have citations. Table 1 shows that the research by (Lynch et al., 2021) is the article with the highest number of citations; this is because the content of the article is relevant to the current and future needs and trends of science education research. The article explains that currently entrepreneurship is a need for everyone, so education graduates must think about how to develop it, including science education graduates. The article further explains that design thinking is an appropriate pedagogical strategy for introducing and developing entrepreneurship in engineering and science students (Lynch et al., 2021). Another article discusses several aspects of ET research in science education, namely exploring students' conceptions and beliefs regarding entrepreneurship (Kakouris, 2016), the role of data analysis in changing entrepreneurship opportunities (Sedkaoui, 2018), the role of teachers in introducing entrepreneurship education for engineering and science students (Teerijoki & Murdock, 2014), and research on entrepreneurship curriculum development in multidisciplinary, including science and engineering (Kazakeviciute et al., 2016).

The Relationship between Entrepreneurial Thinking in Science Education

Bibliometric analysis was conducted using VOSViewer with a database obtained from scopus.com after collection, filtering and tidying. The database from scopus.com is stored as a Research Information System and analyzed using VOSViewer. Based on analysis using Title and Abstract Field, 53 terms were obtained that were most relevant to the keywords: "entrepreneurial AND thinking AND science AND education". Following are the results of bibliometric analysis in the form of Network Visualization on the 53 selected terms.

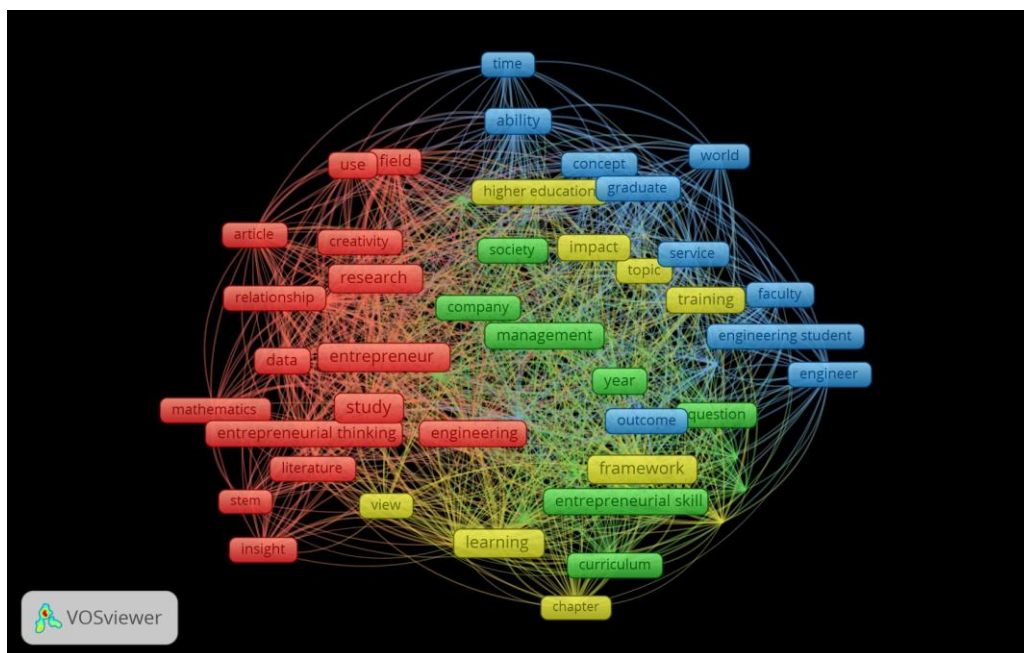


Figure 3. Network Visualization based on Title and Abstract

Figure 3 shows the results of bibliometric analysis in the form of Network Visualization, which is based on the title and abstract fields. The analysis results obtained four clusters marked with four

different colours for each item: red, yellow, blue, and green. The description of these clusters is shown in Table 3.

Table 3. Clusters of bibliometric results based on Title and Abstract

Cluster	Colour	Item	Number
1	Red	Analysis, article, creativity, data, engineering, entrepreneur, entrepreneurial thinking, filed, insight, literature, mathematic, relationship, research, stem, study, use	16
2	Green	Business, company, curriculum, design thinking, entrepreneurial educator, entrepreneurial skill, example, management, person, question, society, teacher, year	13
3	Blue	Ability, concept, engineer, engineering student, entrepreneurial mindset, faculty, graduate, importance, industry, outcome, service, time, world	13
4	yellow	Case study, chapter, entrepreneurial education, focus, framework, higher education, impact, learning, topic, training, view	11

Network visualisation shows the connection between Entrepreneurial thinking and other items, such as STEM, engineering, mathematics, design thinking, and learning. This analysis indicates that ET is one of the variables to pay attention to in science research. In this way, research opportunities regarding ET can be expanded to other aspects of science education, such as learning strategies, learning media, learning models, practicum activities, and laboratory or non-laboratory projects. The overlay visualisation results on VOSViewer also show that research on ET is still a topic that has yet to be researched; this is indicated by the colour of the ET item, which is light green towards yellow. This colour indicates that ET research only started to be carried out in 2019. Apart from that, the Density visualisation shows that ET has a dark colour level, which shows that this research still needs to be carried out. The following Figure 4 shows the overlay and density visualisation of the results of the VOSViewer analysis.

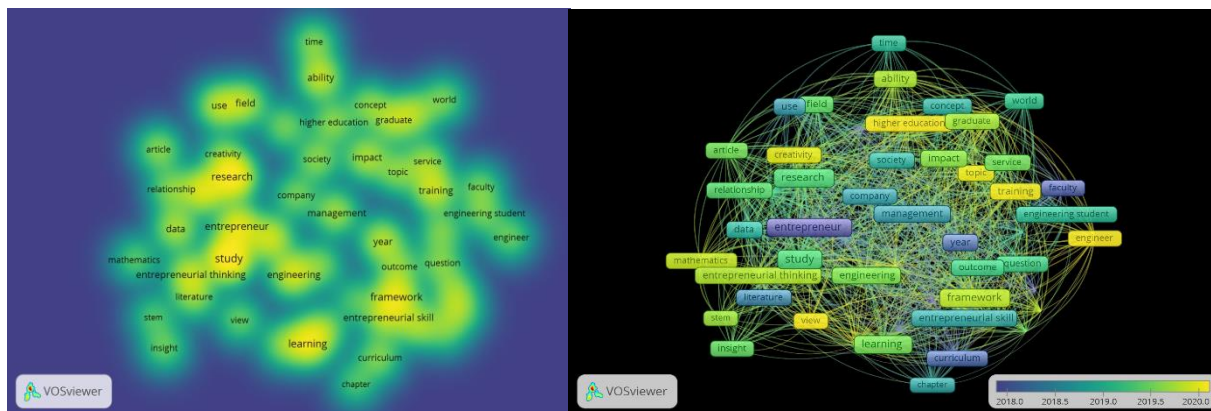


Figure 4. Overlay and Density Visualization based on Title and Abstract

In Figure 4, the relationship between ET and the field of science education is shown from the network visualization relationship. ET is included in cluster 1 with a total of 46 links or connections; these connections include STEM, engineering, and mathematics, which have the same cluster (red cluster). The relationship between ET, STEM, and engineering can be found in several studies, including the use of STEM and bio-inspired design in developing an entrepreneurial mindset (Bosman & Shirey, 2023), developing learning modules by integrating ET and STEM (Siew & Ahmad, 2022), the effect of STEM-Arduino-based problem-solving activities on the development of entrepreneurial skills (Sari et al., 2022), development of ET test tools for students in STEM learning (Ahmad & Siew, 2021), developing entrepreneurial character through learning Ethno-STEM integrated natural products

(Sudarmin et al., 2019), and physics innovation and entrepreneurship (PIE) in physics lectures in the first year (Jones et al., 2019).

The relationship between ET and items in other clusters was also found in several articles, including the relationship between learning items (yellow cluster) and design thinking items (green cluster). This connection can be seen from several studies, including the development of learning with a combination of technology and entrepreneurial education through design thinking (Lynch et al., 2021), the development of teacher professionalism in teaching STEM-oriented learning and ET pedagogy (Xu et al., 2019), building engineering learning to improve entrepreneurial behaviour (Ten Caten et al., 2019), developing a science learning curriculum with the integration of entrepreneurial education (Taajamaa et al., 2019), increasing entrepreneurial mindset through digital classes assisted by jigsaw-puzzle models (Tabrizi, 2017), and developing entrepreneurial mindset through applied science courses (Cañon et al., 2014; Päätaalo, 2015).

Overlay and density visualization in Figure 5 provide an overview of new opportunities for further research. In Figure 5, there are items whose research trend only started in 2019, with density still in the green and dark yellow areas, such as ET, mathematics, view, creativity, ability, higher education, topic, training, and engineering. These items can be used as variables that are developed in further research by paying attention to the relationship between the variables and each other. Research opportunities ET variables and science education can be developed by paying attention to the following considerations. (1) To facilitate and practice entrepreneurial thinking, the learning process being developed needs to present activities that are oriented towards hands-on and minds-on activities in designing a product that is an innovative way to solve problems. (2) Problem-solving needs to begin with the exploration and investigation of needs and problems in society so that there is relevance between the product being developed and the problems being faced. (3) The teaching process carried out must strengthen the three core components of ET, namely curiosity, connection, and value creation.

CONCLUSION

The bibliometric analysis using VOSViewer with the keywords entrepreneurial AND thinking AND science AND education with document database sources from scopus.com concludes as follows. Research on entrepreneurship linked to science is starting to develop and experience a significant increase, especially in the 2020-2021 range. The research focus includes developing the integration of entrepreneurship in science and engineering, as well as developing skills related to entrepreneurship, such as developing entrepreneurial behaviour, entrepreneurial character, and ET. ET in science education began to be researched in 2018 in connection with STEM, learning processes, and design thinking. In general, this research is carried out at the university level, targeting science and engineering students. Further research opportunities related to entrepreneurial thinking in science education can be expanded to various aspects of science education, such as learning strategies, learning media, and project activities both in the classroom and outside the classroom while still paying attention to the three core keys in ET, namely curiosity, connection, and value creation.

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