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BIBLIOMETRIC ANALYSIS OF TEACHING FACTORY TRENDS IN DEVELOPING ENTREPRENEURIAL SPIRIT IN VOCATIONAL EDUCATION

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Abstract
This study aims to map scientific publication trends related to Teaching Factory and the development of entrepreneurial spirit in the context of vocational education. Bibliometric analysis was conducted using data taken from the Scopus database for the period 2019 to 2024. The data were analyzed using VOSviewer software to identify publication trends, frequently used keywords, collaborations between authors, and the dynamics of research topics over time. The visualization results show that the topics of Teaching Factory and entrepreneurship education are central themes that are closely connected with keywords such as education, development, vocational colleges, and innovation. In addition, research trends show a shift in focus from a conceptual approach to a more applied and innovative approach in vocational education. These findings provide a comprehensive overview of the direction of research development in the field of vocational education and offer a strong foundation for further research, particularly those focused on the integration of industry-based learning and strengthening entrepreneurial competencies.
Keywords: Teaching Factory, Entrepreneurship, Vocational Education, Bibliometric Analysis

Abstrak
Penelitian ini bertujuan untuk memetakan tren publikasi ilmiah yang berkaitan dengan Teaching Factory dan pengembangan jiwa kewirausahaan dalam konteks pendidikan kejuruan. Analisis bibliometrik dilakukan dengan menggunakan data yang diambil dari database Scopus selama periode 2019 hingga 2024. Data dianalisis dengan bantuan perangkat lunak VOSviewer untuk mengidentifikasi tren publikasi, kata kunci yang sering digunakan, kolaborasi antarpenulis,serta dinamika topik penelitian dari waktu ke waktu. Hasil visualisasi menunjukkan bahwa topik Teaching Factory dan entrepreneurship education merupakan tema sentral yang saling terhubung erat dengan kata kunci seperti education, development, vocational colleges, dan innovation. Selain itu, tren penelitian menunjukkan pergeseran fokus dari pendekatan konseptual menuju pendekatan yang lebih aplikatif dan inovatif dalam pendidikan vokasi. Temuan ini memberikan gambaran menyeluruh terhadap arah perkembangan riset dalam bidang pendidikan kejuruan serta menawarkan dasar yang kuat bagi penelitian selanjutnya, khususnya yang berfokus pada integrasi pembelajaran berbasis industri dan penguatan kompetensi kewirausahaan.
Kata kunci: Teaching Factory, Kewirausahaan, Pendidikan Kejuruan, Analisis Bibliometrik

INTRODUCTION

Technological advances in the 5.0 era, industrial development, and digitalization have transformed nearly every aspect of human life. Technology can no longer be controlled or stopped by anyone, as nearly all human activity is now driven by media and communication technology.[1] These changes have had a significant impact on the world of work, where competency and practical skills are key to survival amidst increasingly fierce competition.[2] In this context, education plays a vital role as a foundation for preparing a workforce ready to face future challenges.

One innovative concept that has emerged to address this challenge is the Teaching Factory. The Teaching Factory is more than just a conventional classroom, but rather a simulation of a real-world work environment that combines practical learning with industry demands.[3] This concept aims to provide a holistic learning experience, where students not only understand theory but also engage directly in the production process, similar to the real world of work.[4,5] Thus, the Teaching Factory serves as a bridge connecting education with industry, ensuring graduates possess relevant and employable skills.[6]

The main problem faced by vocational high school (SMK) and university graduates is the gap between their competencies and industry needs.[7] Many companies complain that fresh graduates often lack the skills to apply technical knowledge in the field. Teaching Factory aims to address this issue by creating a learning environment that mimics real-world industrial conditions.

In the Teaching Factory, students are not only taught how to operate machines or understand work procedures, but also trained to collaborate in teams, solve problems, and adapt to the latest technological developments.[8] The primary focus is on encouraging students' active participation in their fields of specialization, while also facilitating the exchange of information and collaboration between individuals with diverse expertise.[9] This approach not only develops hard

[1] R. D. Meidiaputri et al., *Etika Komunikasi Dalam Menggunakan Media Sosial: Suatu Kajian Literatur*, 1, no. 2 (2023).

[2] D. Mavrikios et al., "The Teaching Factory Paradigm: Developments and Outlook," *Procedia Manufacturing* 23 (2018): 1–6.

[3] V. Siatras et al., "Applying the Teaching Factory Paradigm and Augmented Reality Technology for Operator Training," paper presented at Conference on Learning Factories, 2021.

[4] D. Prayogi and M. Fauzan, "Pengembangan Teaching Factory Digital Pada SMK Farmasi Untuk Meningkatkan Kompetensi Wirausaha Siswa," *Jurnal Pendidikan Teknologi Dan Kejuruan* 24, no. 2 (2021): 145–56.

[5] S. Saryono et al., "Penerapan Teaching Factory Dalam Membangun Jiwa Kewirausahaan Siswa SMK," *Jurnal Pendidikan Teknologi Kejuruan* 14, no. 1 (2023): 25–35.

[6] M. Setiyawan, "Kemitraan Industri Dalam Implementasi Teaching Factory Di SMK," *Jurnal Inovasi Pendidikan Vokasi* 9, no. 2 (2023): 120–29.

[7] A. Kurniawan et al., "Pelatihan Kewirausahaan Guru SMK Dalam Rangka Penguatan Teaching Factory," *Jurnal Pendidikan Vokasi* 12, no. 1 (2022): 33–42.

[8] G. Chryssolouris et al., "The Teaching Factory: A Manufacturing Education Paradigm," *Procedia CIRP* 57 (2016): 44–48.

[9] A. Machmuda et al., "Teaching Factory in Vocational High School: Bibliometric Analysis," *Jurnal Pendidikan Ekonomi Undiksha* 14, no. 1 (2022): 63–71, https://doi.org/10.23887/jjpe.v14i1.42385.

skills but also soft skills, such as communication, leadership, and adaptability—all of which are highly sought after in the modern workplace.

Teaching Factory is implemented based on several regulations aimed at ensuring alignment between vocational education and industry needs. Two key regulations underpinning this concept are the Minister of National Education Regulation No. 40 of 2008 concerning Standards for Facilities and Infrastructure for Vocational High Schools/Vocational Vocational High Schools (SMK/MAK), which emphasizes the importance of adequate practical facilities to support production-based learning. The Minister of Industry Regulation No. 3 of 2017 concerning Guidelines for Developing Link and Match Vocational High Schools with Industry encourages collaboration between schools and industry in developing curricula and learning facilities.[10]

The implementation of Teaching Factories in Indonesia has shown positive results.[11] Several vocational schools (SMKs) have successfully established partnerships with major companies, providing students with internship opportunities, certification training, and even employment opportunities after graduation. For example, vocational schools that collaborate with automotive industries like Toyota or Astra International often have Teaching Factory workshops equipped with industry-standard equipment, enabling students to become familiar with the latest technology before entering the workforce.

The implementation of Teaching Factories provides dual benefits, both for students and industry.[12] For students, the benefits include Relevant Practical Experience: Students learn to use the same equipment and technology used in industry, thus reducing the adaptation period when working. Improved Technical and Non-Technical Skills: In addition to technical skills, students are also trained in time management, teamwork, and problem solving. Greater Employment Opportunities: Graduates from schools with good Teaching Factories are often more easily absorbed by partner industries. Meanwhile, for industry, Teaching Factories help in Preparing a Workforce According to Needs Companies can contribute to the development of curricula so that graduates have the required competencies. Reduced Training Costs because students are already accustomed to the work environment since school, companies do not need to spend large costs on basic training. Building Long-Term Relationships with Educational Institutions partnerships between industry and schools can continue to be developed for innovation and joint research.

While Teaching Factories offer numerous benefits, their implementation still faces several challenges. These include limited facilities, such as not all vocational schools (SMKs) having access

[10] S. R. I. Manalu et al., "Tata Kelola Pelaksanaan Teaching Factory," *Jurnal Pendidikan Dan Pembelajaran* 6 (2017): 1–130.

[11] Machmuda et al., "Teaching Factory in Vocational High School: Bibliometric Analysis."

[12] L. Rentzos et al., "A Two-Way Knowledge Interaction in Manufacturing Education: The Teaching Factory," *Procedia CIRP* 32 (2015): 31–35.

to state-of-the-art industrial equipment due to budget constraints. Teacher readiness, such as educators needing to continuously upgrade their competencies to keep pace with technological developments. Synchronizing the curriculum with industry requires intensive communication between schools and industry to ensure the curriculum remains relevant. Addressing these challenges requires a joint commitment from the government, industry, and educational institutions. Increasing the budget for vocational education, industry-based teacher training, and more intensive internship programs could be solutions.

Vocational education plays a strategic role in preparing skilled and work-ready human resources. One model that has proven effective is the Dual System Education (PSG), which combines school learning with hands-on practice in the industrial world. PSG is an integral part of secondary vocational education, offering competency-based vocational programs.[13] Over time, PSG has been further strengthened by the introduction of the Teaching Factory, a learning approach that creates a real-world work environment within schools.

Teaching Factory is not just a conventional practicum, but rather a learning ecosystem involving three main elements: (1) students who act as workers, (2) teachers who act as assessors, facilitators, and program managers, and (3) ordering parties, whether from industry, the community, or the school itself.[14] The collaboration of these three elements creates a learning experience that closely mimics real-world conditions.

The implementation of a Teaching Factory within the Dual System Practice (PSG) is a strategic step to bring the industrial world into schools in a real-world setting.[15] This process begins when a school receives an order or project from an industrial partner, the community, or even an internal request.[16] For example, a mechanical engineering vocational school might receive an order to manufacture spare parts from an automotive company. Once the order is received, teachers and students work together to analyze the technical specifications, required materials, and the project timeline. This analysis phase trains students' critical thinking and planning skills in accordance with industry standards. Afterward, teachers and students demonstrate their readiness to complete the order through a work commitment, enabling students to understand the importance of responsibility for a real-world project.

[13] B. Lizein et al., "Increasing Social Awareness and Responsibility Through Industrial Work Practices in Citizenship Education," *JUPIIS: Jurnal Pendidikan Ilmu-Ilmu Sosial* 15, no. 2 (2023): 260–69.

[14] T. W. I. Permata et al., "The Effect of Teaching Factory Implementation on the Competence and Readiness to Work of Students," *International Journal for Educational and Vocational Studies* 3, no. 3 (2021): 227–35.

[15] L. Rentzos et al., "Integrating Manufacturing Education with Industrial Practice Using Teaching Factory Paradigm," *Procedia CIRP* 17 (2014): 189–94.

[16] Siatras et al., "Applying the Teaching Factory Paradigm and Augmented Reality Technology for Operator Training."

Students execute orders in the Teaching Factory workshop or laboratory under teacher supervision, using industry-standard equipment and following work procedures similar to those in a real factory.[17] Throughout the production process, teachers and industry representatives conduct quality control to ensure the work meets established standards, thus teaching students about precision and quality assurance. Once the product is complete, students submit the order to the customer, along with process documentation and evaluations, thus developing professionalism and client communication skills.

The synergy between PSG and Teaching Factory offers a dual advantage for students and schools. Through PSG, students are directly involved in the industrial world, while Teaching Factory provides them with the opportunity to learn in industrial simulations at school, with facilities that approximate factory standards.[18] This strengthens the relationship between the school and industry while providing students with real-world experience, enabling graduates to become workforce-ready and understand the industry's work culture. Industries also benefit by having a pool of trained candidates, reducing recruitment and training costs for new employees.

The benefits of Teaching Factories are felt by all parties. Students master technical and non-technical skills relevant to industry needs, develop a professional work mindset from an early age, and have a tangible portfolio of Teaching Factory project results, increasing their competitiveness when applying for jobs. For schools, Teaching Factories increase the relevance of the curriculum to job market needs, strengthen the branding of vocational schools, and open up funding opportunities through project collaborations with industry. Meanwhile, for industry, Teaching Factories provide a means to recruit prospective workers who are already familiar with their work culture and are a tangible contribution to the development of vocational education.

Developing an entrepreneurial spirit at the Vocational High School (SMK) level requires a holistic and sustainable approach, not a partial one. In an increasingly competitive and digitalized global context, vocational high school students are required not only to master technical skills but also to possess the mindset, creativity, and courage to create their own jobs. Entrepreneurship education is not enough to simply present business theory; it must also foster entrepreneurial character through real-world experiences, contextual learning, and active involvement in the real economic ecosystem.

Various challenges still hamper the effective implementation of entrepreneurship education in vocational settings. For example, in Malaysia, which also has a fairly advanced TVET (Technical and Vocational Education and Training) system, entrepreneurship education is still considered

[17] D. Mourtzis et al., "Cyber-Physical Systems and Education 4.0: The Teaching Factory 4.0 Concept," *Procedia Manufacturing* 23 (2018): 129–34.

[18] G. Chryssolouris et al., "Manufacturing Systems: Skills & Competencies for the Future," *Procedia CIRP* 7 (2013): 17–24.

unsuccessful in producing independent and competent young entrepreneurs. According to a study by Harun et al. (2023), one of the main obstacles is the limited learning space that addresses soft skills, human behavior, and how to recognize business opportunities. An overly technical curriculum tends to orient students solely toward job skills, rather than developing an entrepreneurial spirit.

This reflects the reality that also occurs in many vocational schools (SMK) in Indonesia. Entrepreneurship programs in vocational schools often focus on short-term targets, such as product sales during market day, without ongoing follow-up or evaluation. However, entrepreneurship is a long-term process that requires instilling values, cultivating a healthy mindset, and thorough business planning. Similarly, Nabi et al. (2017) emphasize the importance of designing entrepreneurship education that measures not only immediate output but also the long-term impact on students' readiness to start and sustain their businesses after graduation.

One strategic approach now being implemented in various vocational schools (SMK) across Indonesia is the integration of Teaching Factories (TEFA) as a production-based learning platform. TEFAs are not only a place for students to practice technical skills but also serve as a real-life laboratory for business learning. Through TEFAs, students are directly exposed to the dynamics of real production, business management, customer service, and product distribution and marketing. Thus, TEFAs provide hands-on experience that can foster an entrepreneurial mindset from an early age.

For example, in several leading vocational schools, such as SMKN 1 Cirebon and SMKN 5 Surabaya, TEFA has been optimized to become a demand-driven production center. Students not only create products for school assignments but also fulfill real orders from the community or partner industries. This provides authentic experience in managing risk, maintaining quality, setting prices, and serving customers professionally. This approach also encourages the involvement of teachers as business mentors, not just instructors, creating a learning ecosystem that closely mirrors real-world practices.

However, TEFA's success does not eliminate challenges. Some schools still face infrastructure challenges, limited market access, and the lack of policies supporting economic activity within the educational environment. Therefore, cross-sector collaboration is needed using a pentahelix approach that combines the roles of academia, industry, government, communities, and the media to strengthen the implementation of entrepreneurship in vocational schools. In this model, industry can act as a production partner and business mentor, the government as a provider of regulations and incentives, the community as a consumer and source of real problems, the media as a channel for promotion and public influence, and academics as designers of adaptive and innovative curricula.

Furthermore, innovative learning approaches such as technopreneurship are also crucial for strengthening the entrepreneurial spirit of vocational school students. In the digital era, technological mastery is a key competitive advantage. Therefore, integrating technological competencies with entrepreneurial skills, for example in programming, digital design, or digital fabrication-based manufacturing, must be part of the curriculum. Project-based learning, which combines product development, market research, branding, and digital marketing, can create a space for students to actualize themselves and create solutions relevant to community needs.

Programs such as student e-commerce development, social media marketing training, and business simulations based on simple ERP software are examples of how technopreneurship can bridge the gap between vocational learning and the realities of future industries. Furthermore, digitalization in education also opens up opportunities for inclusivity, allowing students from remote areas to reach a wider market through online platforms.

To ensure the success of this program, more measurable success indicators need to be developed. These indicators should not only be based on product sales or participation in entrepreneurship events, but also on: the number of students who start businesses after graduation, the sustainability of these businesses for at least one year, the business's contribution to personal or family income, and recognition and cooperation from the business community for students' products. Furthermore, the success of teachers in serving as entrepreneurial mentors also requires special attention, so that intensive training in business management, financial literacy, and digital branding becomes part of the professional development of vocational teachers.

Regulations governing school economic activities, incentives for vocational schools (SMK) that successfully produce young entrepreneurs, and the integration of TEFA into the national youth entrepreneurship program are needed. Central and regional governments can collaborate to provide initial funding, access to business incubation, and creative spaces such as co-working spaces for students and alumni who are starting businesses.

Vocational education plays a strategic role in preparing human resources who are not only technically skilled but also possess an entrepreneurial mentality to create independent jobs. Amidst global economic dynamics, job market uncertainty, and rapid technological developments, vocational education is required to be able to produce graduates who are adaptive, creative, and innovative in responding to the challenges of the Industrial Revolution 4.0 and 5.0. One emerging approach to addressing these challenges is the Teaching Factory (TEFA), a real-life production-based learning model in vocational schools and colleges, which integrates technical skills with real-life business experiences in the teaching and learning process.

With the growing attention to the importance of entrepreneurship in vocational education, research related to Teaching Factories as a means of developing an entrepreneurial spirit has also

experienced a significant increase in the last decade. However, despite the growing literature on entrepreneurship education and Teaching Factories, there is still limited holistic understanding of how this research develops, networks, and impacts educational practice in the field. Therefore, this study aims to conduct a bibliometric analysis of the development of Teaching Factories research and entrepreneurship development in vocational education, as a basis for formulating more effective curriculum development directions, learning models, and industry-academic collaboration strategies.

This study aims to conduct a bibliometric analysis of research developments related to Teaching Factory and the development of an entrepreneurial spirit in vocational education. This study is designed to: (1) map the current research landscape by identifying publication trends, the most productive countries/institutions, and researcher collaboration networks; (2) analyze conceptual evolution through mapping keywords and research theme clusters; (3) uncover research gaps, particularly in the implementation of Teaching Factory as a means of developing entrepreneurship in vocational high schools and vocational colleges; and (4) identify directions for future research development, including integration with educational policies such as Merdeka Belajar Kampus Merdeka and the technopreneurship approach. The results of the analysis are expected to form the basis for developing a curriculum, learning models, and industry-academic collaboration strategies that are more effective in developing an entrepreneurial spirit in vocational students.

RESEARCH METHODS

The bibliometric analysis research method was used to answer the research questions by examining the development of research and its literature (Hakim, 2020). The metadata mapping of the scientific journal Teaching Factory in developing an entrepreneurial spirit was taken from reputable and accredited journals in several international journals and quartile 3 (Q3) and from 2019-2024. The stages in the bibliometric analysis were carried out with the first step of collecting articles related to Teaching Factory in developing an entrepreneurial spirit using Publish or Perish (PoP). Then, the data was processed and analyzed using Microsoft Excel to obtain tables and graphs. Next, to visualize the article data in the form of a network and VOS Viewer was used. VOS Viewer software was used to analyze the development map of Teaching Factory publications in developing an entrepreneurial spirit. The output of data processing was in the form of network visualization, overlay visualization, and density visualization. The network visualization map was used to see the relationship and cluster of research themes related to keywords. Ovelay Visualization was used to identify the year in which the related research theme was conducted. Meanwhile, density

visualization was used to analyze research themes that were already saturated and still rarely studied.

RESULTS AND DISCUSSION

This section reviews trends in publications, citations, cross-country research collaborations, and research focuses related to Teaching Factories and entrepreneurial development in the context of vocational education. The development of publications reflects the increasing scientific interest in this topic from 2019 to 2024, indicating that Teaching Factories are increasingly viewed as a strategic approach to bridging education and industry. Meanwhile, the trend in citations reflects the influence and contribution of these studies to the development of scientific literature and serve as important references for other researchers in the field of vocational education and entrepreneurship. The increase in citations indicates broader recognition within the academic community of the urgency of strengthening entrepreneurial competencies through the Teaching Factories approach. Furthermore, cross-country research collaborations illustrate the extent to which researchers are collaborating globally in developing studies on industry-based vocational learning innovations and entrepreneurship. This collaboration is expected to foster greater research quality and impact through the involvement of diverse perspectives and expertise. Finally, the research focus trends highlight key areas in the exploration of Teaching Factory and entrepreneurship, such as industry curriculum integration, student entrepreneurial competencies, pedagogical innovation, and digital transformation in vocational learning, which are evolving dynamically from 2019 to 2024.

Publish or Perish Data Collection Results

Results Collection of articles based on the Google Scholar database by utilizing the PoP software from 2019-2024 in Table 1, the publication of articles about Teaching Factory in developing an entrepreneurial spirit contained 200 articles, 3882 citations, 388.20 citations per year, 19.41 citations per article, 1.00 authors per article, with 30 H indexes and 50 G indexes, 30 individual indexes 3.00 annual H indexes, and 10 hA indexes.

Development of Scientific Publications

Judging from the results of the development of scientific publications regarding Teaching Factory in developing an entrepreneurial spirit from 2015-2020, a total of 200 publications were obtained on Google Scholar in the following table.

Year	Number of Publications	Percentage
2019	21	10.5%
2020	25	12.5%
2021	26	13%
2022	31	15.5%
2023	46	23%
2024	51	25.5%
Total	200	100%

Based on Table 2 above, there were 21 (10.5%) publications in 2019, 25 (12.5%) publications in 2020, 26 (13%) in 2021, 31 (15.5%) in 2022, 46 (23%) in 2023, and 51 (25.5%) in 2024. From year to year, this research has increased, proving that it is still a topic of interest to be developed.

Map of Scientific Publication Development

1. **Network Visualization**

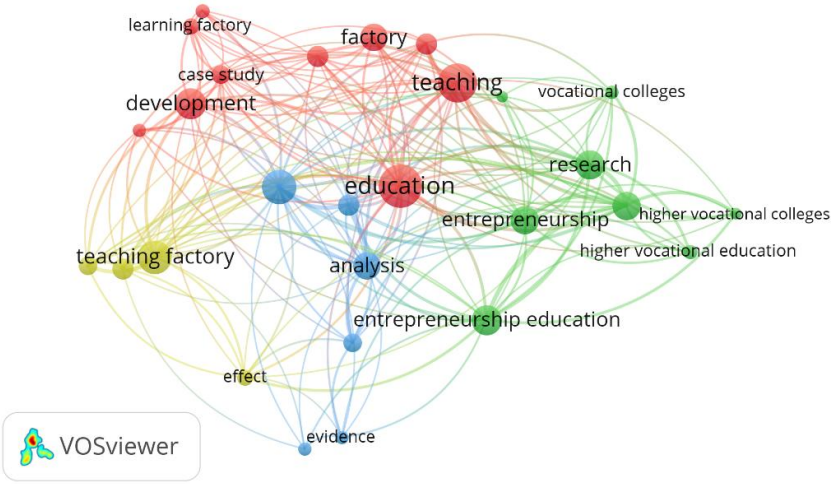

Figure 1. Network Visualization

The network visualization shows the relationships between keywords that frequently appear in the analyzed literature. The network visualization results (Figure 1) show that the dominant keywords with high connectivity include education, teaching, teaching factory, entrepreneurship, and research. These words form the central nodes in the network, which are closely connected to each other.

Several identifiable thematic clusters are the Education and Industry Cluster, consisting of words such as education, teaching, factory, and industry, which signify the close relationship

between the educational environment and industrial practices in the teaching factory concept. The Entrepreneurship and Innovation Cluster, with keywords such as entrepreneurship, innovation, vocational colleges, and research, forms a separate cluster, indicating a strong focus on developing entrepreneurship in vocational education. The Methodological and Evaluative Cluster, with keywords such as analysis, systematic review, and evidence, indicates the use of analysis-based studies and literature reviews as research approaches.

This indicates that research in this field is not only focused on the implementation of teaching factories, but is also increasingly developing towards innovative development and entrepreneurship based on vocational education.

2. Overlay Visualization

The overlay visualization shows the temporal evolution of each keyword based on its year of emergence. Blue indicates keywords that were more dominant at the beginning of the analysis period (around 2018–2019), while yellow indicates keywords that appeared more frequently in more recent years (2021–2022).

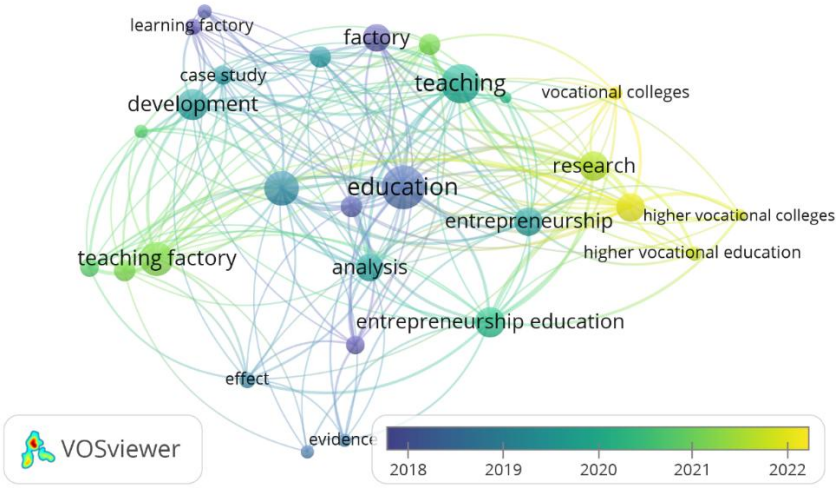

Figure 2. Overlay Visualization

The overlay results show that initial topics such as learning factories, systematic reviews, and case studies were explored more extensively in the initial phase, serving as a conceptual and evaluative basis for implementing new learning models. However, in recent years, there has been a shift in interest toward keywords such as entrepreneurship, innovation, vocational colleges, and higher vocational education, reflecting increased attention to the implementation aspects and tangible impact of industry-based learning on developing vocational students' entrepreneurial competencies. The current research focus is shifting from theoretical studies to applied and transformative approaches in vocational education.

3. Density Visualization

The density visualization illustrates the intensity of keyword occurrence and connectivity. Yellow indicates the most dense and frequent areas in the literature, while blue indicates areas with lower intensity.

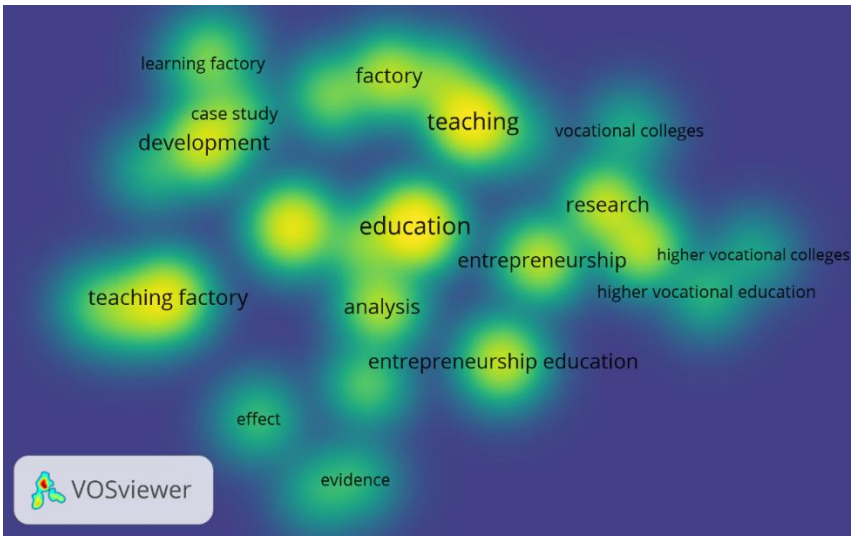

Figure 3. DensityVisualization

Keywords such as education, teaching, teaching factory, entrepreneurship, and research are in high-density areas, indicating that these concepts are at the heart of emerging research in this field. Conversely, keywords such as systematic review, evidence, and effect are in low-density areas, indicating that evaluative and evidence-based aspects are still underexplored.

CONCLUSION

Based on the results of a bibliometric analysis of the literature discussing teaching factories and the development of an entrepreneurial spirit in vocational education, it was found that the two topics are closely interrelated and have experienced dynamic development in recent years. The teaching factory concept is not only positioned as a production-based learning model, but also as a strategy to instill an entrepreneurial spirit among vocational education students. Keywords such as education, teaching, entrepreneurship, and research appear consistently and dominantly in the network map, indicating the high level of researcher attention to strengthening the synergy between education and the industrial world. Overlay visualizations show that current research trends are shifting towards innovation, entrepreneurship, and links with higher-level vocational education, such as vocational colleges and higher vocational education. Meanwhile, density visualizations confirm that the primary focus of the literature remains concentrated on the teaching factory concept

and entrepreneurship development, with room for exploration in evidence-based evaluative approaches and systematic impact measurement.

SUGGESTION and RECOMMENDATIONS

Based on these findings, it is recommended that further research place greater emphasis on evaluating the quantitative and qualitative impact of teaching factory implementation on strengthening students' entrepreneurial competencies. Future research should also expand the approach by integrating digital technologies, such as augmented reality or interactive simulation systems, to enhance industry-based learning experiences. Furthermore, the development of the teaching factory model should be tailored to specific local needs and relevant industrial sectors to ensure the sustainability and competitiveness of vocational education graduates. It is also crucial for researchers and practitioners to collaborate across institutions and countries to develop innovative frameworks that support the transformation of vocational education toward a stronger entrepreneurial orientation that is more adaptive to changing times.

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