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Bibliometric analysis of STEM-based creative thinking skills in vocational education

Fathimah Hajar Al Adawiyyah[1], Tiara Sekar Harnum[2], Sintha Wahjusaputri[3], and Abdul Rahman A Ghani[4]

[1,2,3,4] Sekolah Pascasarjana, Universitas Muhammadiyah Prof. Dr. Hamka, Pancoran, Jakarta Selatan
Corresponding Author. e-mail: 2509017001@uhamka.ac.id

Abstract
STEM-based learning has been widely discussed to support the development of creative thinking skills in vocational education. However, related research remains fragmented and insufficiently synthesized. This study aims to map research trends, pedagogical approaches, and methodological characteristics of STEM-based creative thinking skills in vocational education. A qualitative bibliometric analysis was conducted using performance analysis and qualitative synthesis of publications from 2016 to 2025. Through a multi-stage screening process, 1,360 initial records were refined into eight core articles that met the inclusion criteria, as most studies discussed STEM education, creative thinking, or vocational education separately rather than integratively. The findings indicate that this research field remains emergent, with fluctuating publication trends and geographical concentration primarily in Indonesia. Project-Based Learning (PjBL) was identified as the dominant pedagogical approach, while assessment practices gradually shifted toward performance- and product-based evaluation. This review contributes by providing an integrated synthesis of pedagogical trends, assessment practices, and research gaps related to teacher readiness, methodological diversification, and long-term skill sustainability in vocational education.
Keywords: *Creative Thinking, STEM, vocational education, bibliometric analysis, research trends*

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INTRODUCTION

Creative thinking is one of the key competencies needed to face the challenges of the 21st century (Aini et al., 2020; S. E. Putri et al., 2024). In vocational education, these skills are particularly critical because students are expected not only to master technical competencies but also to generate innovative solutions to complex and dynamic workplace problems (Ripki et al., 2019). The current industrial environment increasingly demands graduates who are capable of adaptation, problem solving, and interdisciplinary thinking. Consequently, fostering creative thinking skills in Vocational High Schools has become a foundational goal for preparing competent and adaptive graduates (Susilo et al., 2025). Conceptually, creative thinking is

characterized by fluency, flexibility, originality, and elaboration, all of which support learners in generating and refining solutions to practical problems in vocational contexts (Dalyanto et al., 2021; Munandar, 2014).

Vocational education in Indonesia serves as a bridge between the education system and industry (Pusriawan & Soenarto, 2019; Rahmadani et al., 2023). According to World Economic Forum (2025), 57% of employers identify creative thinking as a core workforce skill, while 69% emphasize analytical thinking and 51% highlight technological literacy. These findings indicate that technical mastery alone is insufficient without the cognitive agility to solve nonroutine problems. The 4C skills framework, which includes creativity, has been empirically shown to contribute significantly to vocational students' employability (Thornhill-Miller et al., 2023). This demand reinforces the need for learning approaches that foster creative thinking as part of vocational literacy (Adawiyyah et al., 2025; Fathoni, 2020).

The Science, Technology, Engineering, and Mathematics (STEM) approach has been widely documented as an effective project-based strategy to enhance students' creative thinking (Indranuddin et al., 2024; Sirajudin et al., 2021). STEM emphasizes interdisciplinary integration and contextual problem solving, encouraging students to design, evaluate, and refine solutions through experimentation and reflection (Roehrig et al., 2021). In vocational education, STEM-based learning helps connect theoretical concepts with industrial practices while supporting the development of creative thinking in applied settings.

Although numerous studies have examined creative thinking, STEM education, and vocational education separately, research that integrates these three domains remains limited and fragmented. A bibliometric analysis by Andriyono et al. (2024), which examined 524 Scopus-indexed documents, confirms that research on creativity and creative thinking in vocational education has grown significantly since 2014 and spans diverse fields including engineering (35%), social sciences (20%), and computer science (13%). However, their study did not specifically examine the intersection of creative thinking with the STEM approach, nor did it map how STEM-based learning contributes to creative thinking in vocational education.

Moreover, existing studies on STEM-based creative thinking in vocational education tend to focus on isolated classroom implementations without providing a coherent synthesis of research trends, pedagogical approaches, and methodological patterns. As a result, three specific gaps remain unclear: (1) how research in this niche area has developed over time, (2) which instructional approaches and assessment methods are most used, and (3) what underexplored themes require further investigation.

This study addresses these gaps by conducting a qualitative bibliometric synthesis of available literature on STEM-based creative thinking skills in vocational education published between 2016 and 2025. Specifically, this research identifies publication trends, geographical distribution of existing studies, dominant instructional models, assessment instruments, and research methods used in the literature. Unlike large-scale global bibliometric studies, this review provides an in-depth thematic mapping of a focused corpus, offering a foundational roadmap for future curriculum and instructional research in vocational education.

METHODS

Methods

This research uses a qualitative approach with bibliometric analysis to examine the development of research on STEM-based creative thinking in vocational education from 2016 to 2025. This period was selected to capture research trends related to the three focal topics, particularly STEM education, which has experienced significant growth over the past two decades. The analytical framework was guided by the bibliometric model proposed by Donthu et al., (2021) and the technical guidelines developed. These models were adopted because it provides a clear structure for analyzing descriptive patterns, such as annual publication trends and the distribution of researcher countries. In addition, this approach allows for in-depth narrative analysis when the available dataset is too limited to support complex visual mapping techniques.

Following Donthu et al. (2021), bibliometric analysis comprises performance analysis and science mapping. Science mapping techniques (co-authorship and keyword co-occurrence) were not applied because our dataset did not meet the minimum threshold requirements, at least five keyword occurrences or eight documents per author for stable visualization (Eck & Waltman, 2022). Therefore, this study focused on performance analysis and qualitative synthesis for smaller corpora.

Data Search and Selection

The first stage involved defining the research objectives and scope based on three core concepts: creative thinking skills, STEM education, and vocational education. These concepts were used as the basis for developing a systematic literature search strategy across reputable scientific databases. The second stage consisted of data collection and literature screening, conducted through keyword searches within titles, abstracts, and keywords. The selection process was carried out in stages by assessing the relevance of titles, abstracts, and research focus, following the principle of transparent filtering (Snyder, 2019). The article selection process was guided by the inclusion and exclusion criteria presented in Table 1.

Table 1. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Topic	STEM, creative thinking, and vocational education	Only one or two concepts
Year	2016–2025	Outside the selected period
Type	Journal articles and conference proceedings	Books, theses, dissertations
Context	Vocational education	General education
Accessibility	Full text accessible	Inaccessible full text

The selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Figure 1 presents the PRISMA flow diagram of the study selection process.

Although the initial search identified 1,360 publications, most studies discussed STEM education, creative thinking, or vocational education separately rather than integratively. Therefore, only eight articles fully met the inclusion criteria and were considered relevant for the final analysis.

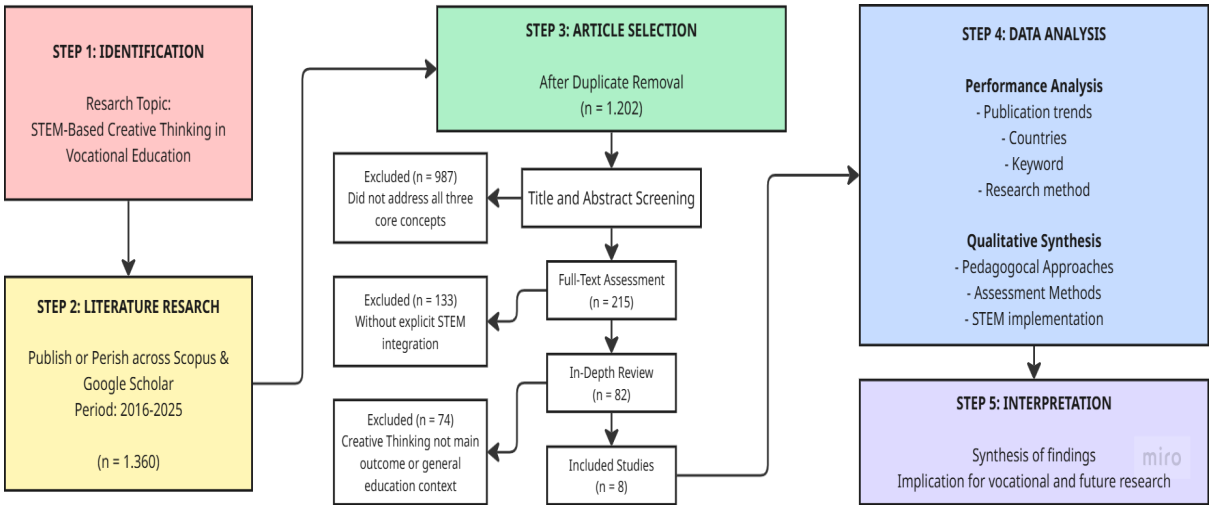

Figure 1. Research Procedure Flowchart

Data Analysis

Data analysis was conducted through two primary components. The first component is performance analysis, which is a descriptive bibliometric analysis that mapped the distribution of publications by year, country, journal, keywords, and research method characteristics. The second component was qualitative synthesis, which involved an in-depth review of the selected articles to identify pedagogical trends, approaches to assessing creative thinking skills, contexts of STEM implementation in vocational education, and emerging research gaps within the literature. This combined approach aligns with contemporary bibliometric review practices that integrate metadata analysis with narrative content synthesis (Donthu et al., 2021; Marzi et al., 2025).

RESULTS AND DISCUSSION

Results

The literature search in this study was conducted using Publish or Perish across reputable scientific databases, including Google Scholar and ScienceDirect, covering the period from 2016 to 2025. An initial dataset of 1,360 publications was retrieved through a combination of the keywords *"creative thinking," "STEM education,"* and *"vocational education"* searched within titles, abstracts, and keywords.

Of the 1,360 initial publications, 1,145 were excluded because they did not address creative thinking. This initial dataset then underwent a first-stage screening focusing on publications that explicitly addressed the concept of creative thinking in their titles or abstracts. At this stage, 215 publications were identified as relevant. These 215 publications consisted of: (a) 133 that discussed creative thinking without STEM integration, (b) 74 that discussed STEM but without explicit integration with creative thinking, and (c) 8 that fully addressed all three concepts.

The screening process continued with a second stage that emphasized studies integrating the STEM approach within learning contexts. From the 215 publications, 133 were excluded for lacking STEM integration, resulting in 82 articles that met the established criteria.

In the third stage, a more in-depth selection was conducted by examining the relevance of each publication's content to the vocational education context. This examination involved careful reading of the abstracts and research focus, resulting in 74 articles being excluded, leaving only eight articles that were fully aligned with the topic of STEM-based creative thinking skills in vocational education.

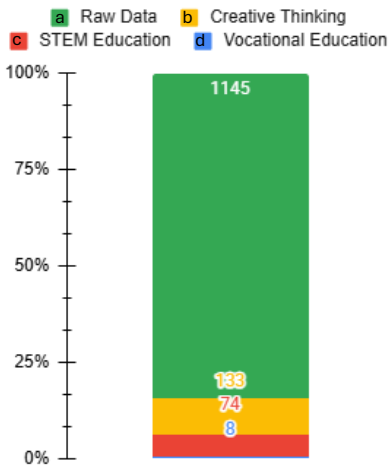

Figure 2. Distribution of Data Across Each Stage of the Literature Screening Process

Distribution of Publications by Year

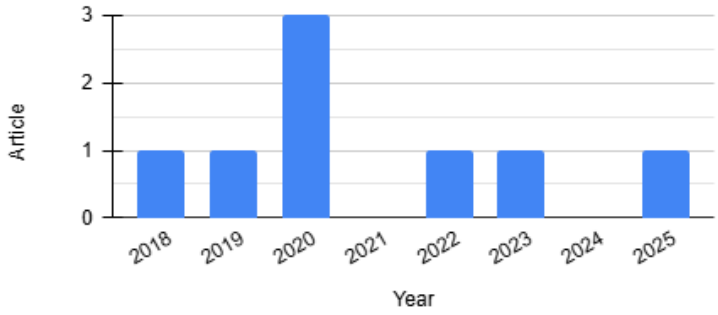

Figure 3. Number of Publication Each Year

As presented in Figure 3, publications on STEM-based creative thinking skills in vocational education were unevenly distributed across the observation period. One article was published in 2018 and 2019, followed by an increase to three articles in 2020. No publications were identified in 2021. Subsequently, one article was published in each of 2022, 2023, and 2025, while no publications appeared in 2024. This distribution indicates a fluctuating publication pattern rather than a consistent upward trend, suggesting that research on STEM-based creative thinking skills in vocational education remains limited and has not yet developed into a consistently established research field. The absence of a sustained increase in publications suggests that STEM-based creative thinking in vocational education remains a niche area of research and has not yet developed into a consistently established field of inquiry.

Distribution of Publications by Country/Institution

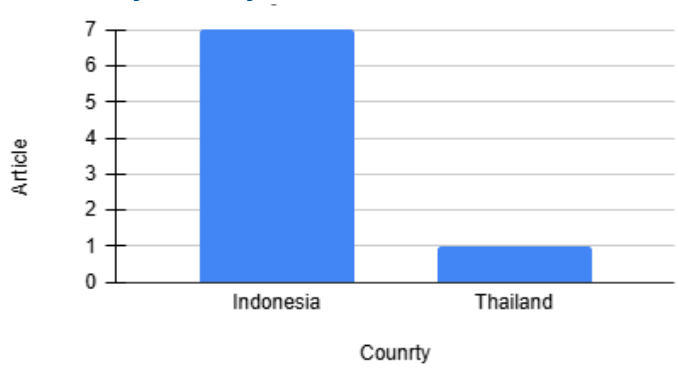

Figure 4. Number of Publication Each Country

As shown in Figure 4, the affiliation analysis indicates that the majority of publications originated from Indonesia, followed by Thailand. This geographical composition suggests that research on STEM-based creative thinking skills in vocational education remains concentrated in developing countries that are actively strengthening their vocational education systems. Most reviewed studies were conducted in vocational institutions offering engineering, pharmacy, or physics programs, indicating that STEM-based learning interventions are closely associated with the availability of laboratory and workshop facilities. Overall, this distribution suggests that the development of STEM-based creative thinking research is strongly influenced by national educational priorities and institutional readiness. This pattern also suggests that research on STEM-based creative thinking in vocational education has not yet achieved broad international representation.

Distribution of Publications by Journal Sources

Among the eight final articles, publications were distributed across various journals focusing on vocational education, applied sciences, STEM education, and vocational pedagogy. The range of journals publishing these studies is relatively broad, encompassing outlets oriented

toward educational policy as well as journals specifically dedicated to science subject didactics. No single core journal was found to dominate publications on STEM education, creative thinking skills, and vocational education, indicating that this field of research is still in its developmental stages and is necessarily interdisciplinary in scope.

This distribution of this research across various journals indicates that research on STEM-based creative thinking skills in vocational education has not yet been included in an established or consolidated academic field. Instead, it reflects the diverse theoretical foundations and methodological approaches used by researchers in this field. The lack of a dominant journal also indicated that manuscripts addressing this topic may be published in various academic publication platforms, as long as they remain within the broader domain of education and technology.

Keyword Analysis

The keyword analysis indicates that the most frequently appearing terms in several research include *"creative thinking," "STEM education," "vocational education," "project-based learning (PjBL)," "innovation,"* and *"skills/competence."* The frequency of these keywords forms a strong relational pattern, in which project-based learning (PjBL) frequently serves as a conceptual bridge between the concept of STEM and the dependent variable of creative thinking. This pattern indicates that existing research primarily focuses on integrating STEM principles with project-based learning strategies to develop creative thinking as a core learning outcome.

The presence of the terms skills and competence further indicates the pragmatic orientation of these studies, emphasizing the development of work-relevant capabilities rather than purely theoretical constructs. This keyword pattern underscores that creative thinking is widely conceptualized as a critical outcome of STEM-based vocational education, particularly within learning environments that prioritize hands-on projects and contextual problem-solving.

Table 2. Description of Selected Articles

No.	Article Title	Year	Country	Journal	Author	Method	Sample	Main Focus and Findings
1	The Outcomes of STEM Education-Based Learning Using an Engineering Design Process with Training Packages for IIoT in Vocational Thailand	2025	Thailand	International Journal of Learning, Teaching and Educational Research	Seetao et al.	Quantitative/ Quasi-Experimental	Vocational students in Thailand	EDP-based STEM integrated with IIoT significantly improves technical creative thinking and design innovation.
2	Integration of STEM Project-Based Learning into 21st Century Learning and Innovation Skills (4Cs) in Vocational Education Using SEM Model Analysis	2023	Indonesia	Hacettepe Üniversitesi Eğitim Fakültesi Dergisi	Yusuf et al.	Quantitative using SEM-PLS	Vocational students majoring in software engineering	STEM-PBL has a significant effect on creative thinking as a component of 21st-century skills (4Cs).
3	Project-Based Learning Using an Ethno-STEM Approach: Improving Creative Thinking Skills of Pharmacy Students at a Medical Vocational High School	2022	Indonesia	International Conference on Science, Education and Technology	Rinto et al.	Qantitative/ Quasi-experimental	Pharmacy vocational students	Ethno-STEM significantly improves creative thinking dimensions, particularly flexibility and originality.
4	STEM: Innovation in Vocational Learning	2020	Indonesia	Jurnal Pendidikan Teknologi dan Kejuruan	Fathoni	Qualitative/ Literature review	Relevant references on implementing the STEM approach in vocational education.	Examines innovative STEM approaches that enhance creative thinking, integrate PBL and PjBL, and support career confidence.
5	Project-Based Learning Based on STEM (Science Technology Engineering and Mathematics) to Develop Skills of Vocational Students	2020	Indonesia	International Conference On Vocational Education And Training	Widiyanti et al.	Qualitative descriptive	Vocational high school	Implementation of STEM-based PjBL to develop vocational students' creative and problem-solving skills. Findings: STEM-PjBL enhances creativity, HOTS, and work-related skills through authentic project activities.
6	Enhancing Physics Students' Creative Thinking Skills Using a STEM-Implemented Challenge-Based Learning Model in Vocational Schools	2020	Indonesia	Journal of Physics: Conference Series	Putri et al.	Quantitative/ Experimental	Vocational physics students	STEM-based CBL improves creative thinking, particularly fluency and elaboration.
7	Integrating STEM (Science Technology Engineering and Mathematics) Education on Advancing Vocational Student's Creative Thinking Skills	2019	Indonesia	Atlantis Press	Marsono et al.	Qualitative/ Literature review	Big Data about vocational students implementing STEM to develop creative thinking	STEM-based learning effectively enhances vocational students' creative thinking skills through project-based, problem-solving, and interdisciplinary learning approaches.
8	Developing a Thinking Skill System for Modeling Creative and Critical Thinking of Vocational High School Students	2018	Indonesia	IOP Conf. Series: Journal of Physics: Conf. Series	Dewanto et al.	Research and Development (R&D)	Vocational high school students	Develops a creative and critical thinking skills system model to enhance vocational students' thinking abilities.

Research Method Characteristics in Previous Studies

Based on the eight selected articles, the following methodological patterns were observed. Four articles used quantitative or quasi-experimental designs with pretest-posttest instruments. These articles implemented STEM-based instructional models including Project-Based Learning (Widiyanti et al., 2020; Yusuf et al., 2023), Challenge Based Learning (Putri et al., 2020), and Engineering Design Process (Seetao et al., 2025). Two articles were literature reviews (Fathoni, 2020; Marsono et al., 2019). One article used qualitative descriptive design (Widiyanti et al., 2020). One article used Research and Development method (Dewanto et al., 2018). No mixed-methods studies were identified in the eight selected articles.

The most common data collection method was the pretest-posttest design using Torrance-based creative thinking instruments, appearing in four articles (N. Putri et al., 2020; Rinto et al., 2022; Seetao et al., 2025; Widiyanti et al., 2020).

Discussion

This study aimed to map research trends, pedagogical approaches, and methodological characteristics of STEM-based creative thinking skills in vocational education. Based on the systematic screening of 1,360 records yielding eight core articles, the findings indicate that this topic represents an emerging area of research.

Research Development Based on Year of Publication

The bibliometric analysis of the eight selected articles shows that research on STEM-based creative thinking in vocational education has developed within a fluctuating temporal pattern from 2018 to 2025. Scholarly attention began to emerge in 2018, culminated in 2020 with three publications, but was not sustained as no publications were found in 2021, and only single studies appeared intermittently in subsequent years.

This finding differs from Agussuryani et al. (2022), who reported that research on STEM and HOTS in vocational schools peaked in 2020 with 56% of publications on Google Scholar and 40% on Scopus. The lower publication volume in the present study (only eight articles over eight years) suggests that the specific intersection of creative thinking, STEM, and vocational education is still a niche area within the broader STEM-HOTS research landscape.

Based solely on the eight articles that explicitly integrated all three concepts, this research field remains emergent and has yet to achieve sustained growth. Without a steady accumulation of studies, it is difficult to develop evidence-based pedagogical models or standardized assessment instruments specifically for STEM-based creative thinking in vocational education (Bowen et al., 2025; Sukkeewan et al., 2024). Future research needs to prioritize replication studies and collaborative efforts to establish a more sustained research trajectory

Dynamics of Research Development and Geographical Context

The majority of studies (7 out of 8) originated from Indonesia, with one study from Thailand in 2025. This geographical concentration may be related to national vocational education reforms in Indonesia, including Presidential Instruction No. 9/2016 and the Making Indonesia 4.0 roadmap Ministry of Industry of the Republic of Indonesia (2018), which emphasized creativity and higher-order thinking skills as key learning outcomes. However, based solely on the eight articles, the present study cannot establish a causal link between these policies and the research output. The emergence of one study from Thailand in 2025 suggests a possible expansion beyond the Indonesian context, but more evidence is needed to confirm this trend.

The limited representation of studies from developed countries does not necessarily indicate a lack of emphasis on creativity within STEM education. As Roehrig et al. (2021) noted, established STEM systems often embed creative thinking within engineering and design processes rather than examining it as a separate empirical variable.

Dominance of Project-Based Learning within the STEM Learning Ecosystem

The analysis of learning approaches indicates that Project-Based Learning (PjBL) is the most dominant and frequently used learning model in STEM-based vocational education. This pattern may be explained by the fact that since 2018, vocational education paradigms have increasingly shifted toward product-based learning models, such as Teaching Factory approaches, which simulate authentic industrial environments. In this context, PjBL serves as a suitable pedagogical fit for STEM, as it encourages students to transform theoretical knowledge into functional tools or practical solutions rather than merely memorizing scientific formulas (Fathoni et al., 2020).

This pattern is empirically supported by Yusuf et al. (2023), who applied Structural Equation Modeling (SEM) analyisis and demonstrated that the integration of PjBL and STEM had a significant direct effect on vocational students' creative thinking, with a path coefficient value of 0.344. These results were supported by Widiyanti et al. (2020), who confirmed that the syntax of PjBL facilitates students in moving beyond basic technical competencies toward the engineering design processes that require originality. In addition, Marsono et al., (2019) reported that STEM-based learning enhances creative thinking when integrated with contextual, problem-based, and interdisciplinary approaches, which strongly aligns with the pedagogical characteristics of Project-Based Learning in vocational education. Through PjBL, students are engaged in complex, design-oriented problem solving that requires them to generate original products rather than merely replicate existing solutions.

In addition to PjBL, other learning models also contribute to the diversification of pedagogical strategies within STEM-based vocational learning. Putri et al. (2020) implemented Challenge-Based Learning and found it to be effective in improving the fluency and flexibility dimensions of creative thinking. Meanwhile, Seetao et al. (2025) introduced an Engineering Design Process (EDP)-baesd approach through the development of Industrial Internet of Things (IIoT) training packages, demonstrating that within vocational contexts, creative thinking can be cultivated through systematic technical problem solving. Overall, these results indicate that although PjBL remains the dominant model, alternative STEM approaches also have a complementary role to develop creative thinking in vocational education.

Dimensions and Instruments for Assessing Students' Creative Thinking Skills

The synthesis of articles indicates that there is significant variation in the methods used to measure creative thinking skills in vocational education contexts, from cognitive to technical domains. The most common approach found is psychometric assessment using standardized test instruments. Studies by Putri et al. (2020) and Rinto et al. (2022), for instance, adopted Torrance-based indicators to quantitatively measure improvements in students' fluency, flexibility, originality, and elaboration before and after learning activities. The dominance of standardized instruments such as the Torrance Tests of Creative Thinking was particularly visible during the early phase of STEM-related research between 2018 and 2020. This preference was largely practical, as researchers at that time required globally validated instruments to rapidly demonstrate that newly implemented STEM approaches had measurable positive effects.

However, as understanding of the characteristics of vocational education developed, assessment trends have started to change. Beyond cognitive dimensions, performance-based assessment has emerged as a defining feature of vocational education research. Studies conducted by Fathoni et al. (2020) and Putri et al. (2020) placed greater emphasize on the quality of students' prototypes and technical innovations produced by students, such as the functional performance of Internet of Things (IoT) systems, as actual evidence of creative thinking skills. This transition indicates that in vocational school contexts, the understanding of creative thinking is no limited to abstract ideas produced during exams but also includes how innovative and useful the products created in the workshop are. Consequently, product-based assessment is considered more relevant for measuring students' work readiness than conventional paper-

based examinations.

Furthermore, Dewanto et al. (2018) introduced methodological innovation by developing an intelligent assessment system based on a Naïve Bayes algorithm that is capable of automatically modelling students' creative and critical thinking skills. This innovation reflects an early attempt to move from manual assessment to technology-enhanced assessment.

Flexibility of STEM Implementation Across Vocational Specializations

Although STEM is commonly associated with engineering-related fields, this review identifies considerable flexibility in its implementation across various vocational high school specializations. This result indicates that the STEM approach is adaptable and can be adjusted to the unique characteristics of different vocational programs. This expansion began to be noticeable in publication trends above 2020, when researchers began to realize that STEM is not just subject content, but an interdisciplinary mindset that can be applied across diverse learning contexts (Roehrig et al., 2021). This suggests that the boundaries between departments are becoming less rigid, allowing an engineering approach to be applied even in non-technical fields.

In technology-related programs, Yusuf et al. (2023) in Software Engineering and Seetao et al. (2025) in Industrial Automation and Electronics demonstrated that STEM implementation requires students to apply creative thinking to design efficient systems and solve complex technical problems. Similarly, Rinto et al. (2022) successfully integrated an Ethno-STEM approach in vocational pharmacy education, while Dewanto et al., (2018) showed that STEM-related creative thinking can be implemented across vocational specializations by modeling students' thinking skills and applying constructivist, problem-oriented learning tasks aligned with each vocational context.

This research indicates that creative thinking in vocational education is not limited to mechanical or technical engineering contexts but can also be developed in health-related fields through innovations based on local wisdom. By modifying traditional product processing methods, students were able to better understand learning material while being encouraged to transform traditional practices into health-related innovations with new economic value. Overall, the reviewed studies suggest that STEM-based creative thinking skills can be implemented across a wide spectrum of vocational disciplines.

Research Gaps and Directions for Future Studies

Despite the positive findings identified in this research, several important research gaps remain and require further investigation. The first gap relates to the focus of existing studies, which dominate emphasize student learning outcomes while ignoring the key agents in the classroom, which are the teachers. The successful implementation of STEM-based learning in vocational education depends heavily on teachers' pedagogical readiness and their understanding of interdisciplinary integration. Without sufficient conceptual and instructional competence, teachers are likely to deliver material in fragmented subject-based formats rather than as a coherent, project-oriented learning experiences. This gap aligns with the critique about the disconnect between idealized educational policies and the realities of classroom practice (Burgess & Lowe, 2022; Rahman et al., 2025).

The second gap relates to research methodology. While the dominance of quantitative and experimental designs has been effective in demonstrating the measurable impact of STEM-based interventions, these approaches often fail to capture the depth of the creative thinking develops and what barriers students encounter during problem solving. Therefore, greater methodological diversification is needed through qualitative or mixed-methods studies that can more deeply explore students' subjective experiences and cognitive processes during creative problem solving (Behnamnia et al., 2025; Rahayu et al., 2025).

Lastly, the majority of research found was short-term or cross-sectional designs, typically conducted within a single semester. This limitation raises critical questions regarding the sustainability and long-term relevance of creative thinking skills developed during vocational

education. There remains limited evidence on whether these skills endure over time and result in concrete benefits once graduates enter the workforce. Longitudinal research is therefore urgently needed to examine the long-term impact of STEM-based creative thinking interventions on employability, adaptability, and professional performance in real industrial contexts (Romanova, 2022).

CONCLUSION

This study provides a qualitative bibliometric synthesis of research on STEM-based creative thinking skills in vocational education published between 2016 and 2025. Through a multi-stage screening process, 1,360 initial records were refined into eight core articles that explicitly discussed the integration of STEM approaches and creative thinking within vocational education contexts. The findings indicate that this field of research remains emergent, limited in scale, and characterized by fluctuating publication patterns rather than sustained growth.

The reviewed studies show that Project-Based Learning (PjBL) is the most dominant instructional approach used to support creative thinking development in STEM-based vocational learning, complemented by Challenge-Based Learning and Engineering Design Process approaches. The findings also suggest that STEM-based creative thinking interventions can be implemented across various vocational specializations, including engineering and health-related fields. In addition, assessment practices have gradually shifted from standardized psychometric instruments toward more contextual performance- and product-based evaluations aligned with vocational learning characteristics.

Despite these developments, several research gaps remain. Existing studies still predominantly focus on short-term student learning outcomes, while issues related to teachers' pedagogical readiness, long-term sustainability of creative thinking skills, and broader methodological diversification remain limited. Overall, this review indicates that research on STEM-based creative thinking in vocational education is still developing and requires broader empirical and methodological exploration in future studies.

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