



# The Role of Creativity and Self-Directed Learning in Enhancing Students' Problem-Solving Skills (A Systematic Literature Review from 2019 to 2024)

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## ABSTRACT

This study aims to systematically analyze the role of creativity and self-directed learning in enhancing students' problem-solving skills in Informatics learning at Vocational High Schools. This review used a Systematic Literature Review (SLR) approach guided by the PRISMA 2020 Statement. A total of 17 academic articles published between 2019 and 2024 were selected from several databases, including Scopus, ERIC, DOAJ, and Google Scholar. The analysis results indicated that creativity and self-directed learning had a strong and complementary relationship in shaping students' critical and adaptive thinking abilities. Creativity contributed to generating new ideas and innovative solutions, while self-directed learning strengthened responsibility, self-reflection, and the ability to regulate the learning process. These two factors have been proven to contribute positively to the improvement of problem-solving skills, particularly in the contexts of project-based and problem-based learning and digital literacy. These findings affirm that Informatics learning in Vocational High Schools should be guided by pedagogical models that foster creativity and self-direction, and that are oriented toward problem-solving, as part of developing 21st-century competencies.

**Keywords:** *creativity, self-directed learning, SLR*

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## INTRODUCTION

Vocational education currently faces significant challenges in preparing learners capable of adapting to rapid changes in the digital era and the 4.0 Industrial Revolution. Learning no longer focuses solely on the mastery of technical skills, but also on the ability to think creatively, be self-directed, and adapt to emerging technologies [1], [2], [3]. The Informatics subject is an important means of fostering these abilities, as it requires students to think logically and systematically when solving technology-based problems. In this context, the success of Informatics learning at the Vocational High School (*Sekolah Menengah Kejuruan*; SMK) level is not only measured by academic achievement, but also by students' ability to innovate and address real-world problems. Therefore, vocational education needs to integrate cognitive, affective, and digital dimensions within its learning process [4], [5], [6], [7].

Although theoretical and empirical studies on creativity, self-directed learning, and learning outcomes have developed significantly, the literature review indicates that most existing research remains partial and fragmented [8], [9]. Many studies position creativity or self-directed learning as a single variable associated with general academic achievement, without examining their integrated relationship with problem-solving

skills, particularly within the context of Informatics learning in vocational education. In addition, the majority of previous studies have been conducted at the general education or higher education levels, resulting in limited findings that are directly relevant to the specific characteristics of Vocational High Schools (SMK) [10], [11].

Furthermore, studies that examine Informatics learning more focus on technical aspects such as programming mastery, digital literacy, or computational thinking, yet they have not systematically linked the role of internal student factors, such as creativity and self-directed learning, in supporting problem-solving skills as a core competence of the 21st century [12], [13]. However, in the context of vocational education, problem-solving skills are not solely cognitive; they also require self-directed, adaptive, and innovative dispositions aligned with the demands of the digital workplace. This condition indicates a research gap, reflected in the absence of a comprehensive scientific synthesis on how creativity and self-directed learning jointly contribute to problem-solving skills in Informatics learning at Vocational High Schools (SMK).

Based on this gap, the present study was conducted to address the need for a structured, systematic literature review that maps research trends, methodological approaches, and empirical findings on

the relationship among creativity, self-directed learning, and problem-solving skills. Therefore, this Systematic Literature Review (SLR) is directed toward answering the following research questions:

1. How does creativity play a role in enhancing students' problem-solving skills in Informatics learning within vocational education?
2. How does self-directed learning contribute to students' problem-solving skills in the context of Informatics learning?
3. How are creativity and self-directed learning interconnected in shaping the problem-solving skills of Vocational High School (SMK) students in competency-based Informatics learning aligned with 21st-century skills?
4. Which learning models and pedagogical approaches are most dominantly used in research to integrate creativity, self-directed learning, and problem-solving in vocational education?

By formulating these questions, this study not only tries to summarize the findings of previous research but also to construct a more comprehensive conceptual framework of the interactions among variables in Informatics learning. The novelty of this research lies in its integrative approach, which systematically examines creativity and self-directed learning as two key internal factors that complement one another in enhancing the problem-solving skills of Vocational High School (SMK) students, particularly in the Informatics subject. In addition, this study focuses on the context of vocational education and 21st-century competencies, which have been relatively underexplored in-depth in the existing literature.

Accordingly, the findings of this SLR are expected to provide a theoretical contribution in the form of a conceptual mapping of the relationships among variables, as well as a practical contribution by serving as a foundation for the development of Informatics learning strategies that are more creative, self-directed, and oriented toward problem solving in Vocational High Schools.

## RESEARCH METHODS

This study used a Systematic Literature Review (SLR) approach, following the PRISMA 2020 Statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), to analyze the role of creativity and self-directed learning in enhancing students' problem-solving skills in the Informatics subject within vocational education. The review process began with a comprehensive literature search conducted across several reputable academic databases, namely Scopus, Web of Science, ERIC, DOAJ, Google Scholar, and Sinta.

The selection of databases in this study was based on principles of scholarly coverage, publication quality, and relevance to the fields of education, technology, and vocational education. Therefore, this study used a combination of international and national databases to obtain a comprehensive overview of the literature and to minimize publication bias.

Scopus and Web of Science (WoS) were selected because both are highly reputable international databases that index peer-reviewed articles subject to rigorous quality standards. These databases contain a substantial body of recent empirical studies on 21st-century learning, creativity, self-directed learning, and Informatics education and TVET, making them primary references for systematic reviews conducted at a global scale.

ERIC (Education Resources Information Center) was used because it is a specialized education database highly relevant to pedagogy, curriculum, and learning innovation. ERIC enables a more focused exploration of the literature on Informatics learning practices, student competency development, and technology-based vocational education approaches.

DOAJ (Directory of Open Access Journals) was selected to capture high-quality open-access articles that are often not indexed in commercial databases, yet provide significant contributions to studies on education and learning technology, particularly those originating from developing countries.

Google Scholar was used as a complementary database to ensure that no relevant articles were missed, given its broad coverage and ability to include publications across disciplines. This database enhanced search sensitivity, particularly for interdisciplinary topics such as creativity and self-directed learning in Informatics.

Meanwhile, SINTA (Science and Technology Index) was used to accommodate the Indonesian national context. This database is important for capturing local studies relevant to the conditions of vocational education in Indonesia, particularly Vocational High Schools (SMK), which are often not indexed in international databases but possess high contextual value.

By combining these six databases, this study ensured a balance among the quality of academic articles, breadth of coverage, and relevance to the vocational context, thereby producing findings that are more comprehensive and representative. The search was conducted from 1 February to 15 March 2024, with publication years limited to 2019–2024 to ensure relevance to developments in digital learning and 21st-century competencies.

### 1. Literature Search Strategy

The literature search was conducted comprehensively across six academic databases: Scopus, Web of Science (WoS), ERIC, DOAJ, Google Scholar, and SINTA, to ensure balanced coverage of international and national sources. The search strategy used a combination of keywords across TITLE-ABS-KEY (title, abstract, and keywords) to enhance the precision and relevance of the search results.

**Table 1.** Search Queries (TITLE-ABS-KEY) Used in Each Database

Database	Search Query (TITLE-ABS-KEY)
Scopus	TITLE-ABS-KEY ( creativity AND "self-directed learning" AND "problem-solving" AND (informatics OR "informatics education") AND ("vocational education" OR TVET) )
Web of Science	TS = ( creativity AND "self-directed learning" AND "problem-solving" AND informatics AND "vocational education" )
ERIC	(Creativity AND Self-Directed Learning AND Problem-Solving AND Informatics AND Vocational Education)
DOAJ	(creativity AND "self-directed learning" AND "problem-solving" AND informatics)
Google Scholar	allintitle: creativity "self-directed learning" "problem-solving" informatics vocational
SINTA	<i>Kreativitas AND kemandirian belajar AND pemecahan masalah AND informatika AND SMK</i>

2. Inclusion and Exclusion Criteria  
 The search was limited to peer-reviewed articles published between 2019 and 2024 to ensure relevance to developments in digital learning and 21st-century competencies. To ensure the quality and relevance of the literature analyzed, this study applied clear inclusion and exclusion criteria as presented in Table 2.

**Table 2.** Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Type of publication	Peer-reviewed journal articles	Proceedings, books, theses, and non-academic reports
Year of publication	2019–2024	< 2019
Educational context	Vocational education / Vocational High School (SMK) / TVET	General education without a vocational context
Variable focus	Creativity, self-directed learning, and/or problem solving	Does not address the main variables
Field of study	Informatics / Informatics Education	Non-technology-related fields
Language	English and Indonesian	Languages other than English and Indonesian
Document access	Full-text available	Full-text not available

3. Study Selection Process  
 The initial search across all databases yielded 482 articles. Following the cross-database deduplication process, 335 unique articles remained. The first stage of selection was conducted through title and abstract screening, which led to the elimination of 262 articles for lack of relevance to the vocational education context, Informatics, or the research variables.

A total of 73 articles then proceeded to the full-text review stage. At this stage, 49 articles were eliminated because they did not explicitly discuss the relationship between creativity and self-directed learning with problem-solving skills in Informatics learning. The final stage resulted in 24 articles that met all criteria and were analyzed in depth.

examined, and main findings. Data were analyzed thematically to identify patterns, trends, and conceptual relationships among creativity, self-directed learning, and problem-solving skills. The findings were then grouped based on the vocational education context and pedagogical approaches in Informatics learning, thereby enabling the formulation of main themes, the identification of research gaps, and the derivation of theoretical and practical implications for the development of 21st-century learning strategies in Vocational High Schools (SMK).

The complete stages of the article selection process are presented in Figure 1, which illustrates the flow from the initial search to the determination of the final articles analyzed in this study.

4. Data Extraction and Analysis

The selected articles were extracted using a structured extraction sheet that included the following information: author names, year of publication, country of origin, database source, research design, educational context, variables

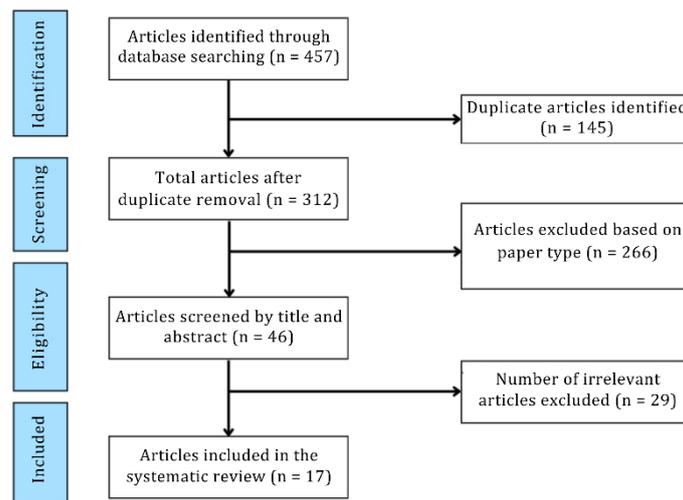


Figure 1. PRISMA Statement Flow Diagram

RESULT AND DISCUSSION

A systematic review of 17 articles meeting the inclusion criteria indicates that recent studies have largely highlighted the relationships among creativity, self-directed learning, and problem-solving skills in the context of Informatics learning and vocational education. This review affirms that these three variables are the central foundation for the development of 21st-century skills oriented toward active, reflective, and technology-based learning. Overall, the review's findings indicate that project-based approaches, interactive digital learning, and problem-based learning are the most frequently used models for fostering critical thinking, creativity, and student self-directed learning in Vocational High Schools (SMK).

Most of the reviewed studies emphasize that creativity plays a crucial role in strengthening divergent thinking abilities and in generating innovative solutions to computational problems. Meanwhile, self-directed learning enables students to regulate their learning processes independently and to take responsibility for their own progress. The combination of these two factors positively enhances problem-solving skills, particularly in the context of Informatics learning, which demands logical, reflective, and adaptive thinking in

response to digital technologies. In addition, the review findings indicate that integrating digital literacy and computational skills strengthens the relationship between self-directed learning and creativity, thereby supporting learning outcomes.

Overall, previous studies emphasize that learning approaches focused on developing creativity and self-directed learning can enhance problem-solving skills through project-based activities, interactive digital media, and contextual Informatics curricula. The application of models such as Project-Based Learning and Problem-Based Learning encourages students to think critically and innovatively, while technology-based learning approaches, such as mobile learning and the flipped classroom, strengthen students' self-directed learning and sense of responsibility. These findings support the importance of transforming Informatics pedagogy in Vocational High Schools toward learning models that are collaborative, creative, and learner-centered.

The following table presents the results of an SLR of 17 selected articles examining the relationships among creativity, self-directed learning, and problem-solving skills in Informatics learning.

Table 1. Systematic Review of Articles Related to Creativity, Self-directed Learning, and Problem-Solving Skills in Informatics Education

No	Author & Year	Focused Topic / Variable	Context or Subject	Findings / Relevance for Informatics / Vocational Education
1	Alperi (2020)	Digital learning materials and self-directed learning	Vocational digital learning	The use of Sigil-based digital learning materials helped foster students' self-directed learning through exploratory and reflective activities.
2	Boronenko & Fedotova (2021)	Digital literacy and creativity	Informatics curriculum	The development of digital literacy was identified as a priority within the Informatics curriculum as a foundation for strengthening creativity and computational thinking.
3	Dagienė et al. (2021)	Informatics curriculum design and problem-solving	K-12 Informatics	An Informatics curriculum integrated with problem-solving activities trained students to think systematically and innovatively.
4	Hariyadi et al.	Self-directed learning	Distance	The <i>Merdeka Belajar</i> approach strengthened

No	Author & Year	Focused Topic / Variable	Context or Subject	Findings / Relevance for Informatics / Vocational Education
	(2023)	and self-management	learning	self-directed learning by providing greater flexibility in time and by increasing responsibility for learning outcomes.
5	Huda et al. (2019)	Mobile learning and self-directed learning	STEM / Vocational	Mobile learning-based instruction enhanced students' motivation and self-directed learning in technology-related fields.
6	Ilmaknun & Ulfah (2023)	Self-directed learning and academic achievement	Science & Technology Education	Self-directed learning has been shown to positively affect students' learning outcomes by increasing intrinsic motivation and individual responsibility.
7	Jabnabillah & Margina (2022)	Motivation and self-directed learning	Online learning	A positive relationship was identified between learning motivation and students' levels of self-directed learning during online learning.
8	Liu et al. (2023)	Creativity and innovation ability	Higher education	Scientific creativity and the ability to innovate were found to have a direct effect on complex problem-solving skills.
9	Maba (2020)	Computer-assisted learning and creativity	Informatics / Music Technology	Computer-assisted learning enhanced creativity through exploratory activities and digital composition.
10	Nasution & Mujib (2022)	Problem-based learning and autonomy	Mathematics Education	The Problem-Based Learning model was effective in enhancing problem-solving skills while simultaneously strengthening students' self-directed learning.
11	Nuritha & Tsurayya (2021)	Video-based learning and self-directed learning	STEM Learning	The use of interactive video-based learning supported by GeoGebra has been shown to enhance self-directed learning and understanding of abstract concepts.
12	Oikonomidis & Sofianopoulou (2023)	Critical thinking and informatics learning	Informatics Education	Informatics textbooks played an important role in fostering critical thinking and problem-solving skills among secondary school students.
13	Pejić & Molcer (2021)	Machine learning and problem-solving	Computer Science	Data mining and machine learning approaches were used to understand patterns of complex problem-solving among Informatics students.
14	Piedade et al. (2020)	Programming and computational thinking	Informatics teacher training	The use of educational robotics was effective in enhancing computational thinking and problem-solving skills among prospective Informatics teachers.
15	Silva et al. (2023)	21 <sup>st</sup> -century skills and digital creativity	High School Education	The development of interactive e-books significantly enhanced students' digital creativity and 21st-century skills.
16	Sulistiyani et al. (2020)	Self-directed learning and problem-solving	Mathematics Education	Self-directed learning was strongly correlated with students' mathematical problem-solving abilities and self-reflection.
17	Vendina & Kirichek (2023)	Problem-solving strategy and logical reasoning	Informatics in Schools	Game-based Informatics learning was effective in developing students' problem-solving and logical reasoning skills.

As shown in Table 1, studies on creativity, self-directed learning, and problem-solving skills in the context of Informatics learning have been widely conducted across various educational levels, including vocational education and Vocational High Schools (SMK). Each reviewed article highlights the important

role of technology-based, project-based, and problem-based learning strategies in strengthening students' higher-order thinking skills. In general, Project-Based Learning (PjBL) and Problem-Based Learning (PBL) are the most frequently applied models, as both emphasize the exploration of creative ideas, independent reflection,

and the contextual application of concepts to solve real-world problems.

### 1. RQ1. The Role of Creativity in Informatics Problem-Solving Skills

The results of the systematic review indicate that creativity plays a significant role in enhancing students' problem-solving skills in Informatics learning within vocational education. Creativity enables students to generate multiple alternative solutions, explore non-linear approaches, and avoid reliance on a single procedure when addressing computational problems [14], [15], [16]. In the context of programming and algorithms, creative students are better able to modify solutions when initial approaches do not produce the expected outputs. This condition indicates that creativity contributes directly to cognitive flexibility and the effectiveness of problem-solving [17], [18], [19], [20]. Therefore, creativity emerges as an essential cognitive element in Informatics learning, requiring higher-order thinking.

Causally, creativity expands the space of cognitive exploration, enabling students to have more options in selecting and refining solutions. These findings are in line with previous studies indicating that creativity is positively correlated with critical thinking and problem-solving abilities in the fields of science and technology [21], [22], [23]. However, several studies also show that creativity does not develop optimally when Informatics learning remains mechanistic and oriented toward the memorization of procedures [24], [25]. This explains why project-based learning models are more effective at fostering creativity than conventional learning approaches. Therefore, creativity needs to be positioned as an outcome of pedagogical design that provides space for exploration and reflection [26], [27].

### 2. RQ2. The Contribution of Self-Directed Learning to Problem-Solving Skills

This review finds that self-directed learning makes a strong contribution to students' problem-solving skills in Informatics learning. Students with a high level of self-directed learning tend to be able to regulate learning goals, select appropriate strategies, and make effective use of digital learning resources [28], [29]. In Informatics activities, such as debugging and algorithm development, self-directed learning helps students persist in dealing with errors and failures. This indicates that problem-solving is influenced not only by cognitive abilities, but also by self-regulation within the learning process [30]. Therefore, self-directed learning emerges as an important internal factor in the success of Informatics learning [31], [32].

This causal relationship occurs because self-directed learning strengthens students' self-regulation, persistence, and metacognitive awareness. These findings are consistent with previous studies indicating that self-directed learning has a significant influence on academic

achievement and problem-solving abilities in the fields of STEM and TVET [33], [34]. However, several studies also reveal that self-directed learning may lead to disparities among students with low digital literacy or who receive minimal pedagogical support. This condition indicates that self-directed learning is facilitated through gradual guidance and constructive feedback. Therefore, the role of teachers remains crucial in guiding students' self-directed learning processes [35], [36].

### 3. RQ3. The Synergy of Creativity and Self-Directed Learning in Shaping Problem-Solving Skills

The synthesis of the literature indicates that creativity and self-directed learning are in a synergistic relationship in shaping students' problem-solving skills in Informatics learning. Creativity functions as a source of ideas and alternative solutions, while self-directed learning ensures that the exploration process continues until solutions can be implemented effectively [37], [38]. In the context of Informatics learning, this synergy is reflected in students' ability to test, revise, and refine algorithms independently [39], [40]. The combination of these two variables generates adaptive and reflective patterns of thinking. Accordingly, problem-solving develops through the interaction between idea exploration and the regulation of the learning process [41], [42].

Logically, creativity without self-directed learning can result in underdeveloped ideas, whereas self-directed learning without creativity tends to yield rigid solutions. These findings are consistent with previous studies emphasizing the importance of integrating divergent thinking and self-regulation to solve complex problems. However, several studies also indicate that this synergy is strongly influenced by the learning context and the availability of technological facilities. This indicates that environmental factors also play a role in determining the effectiveness of the interaction between creativity and self-directed learning. Therefore, the development of problem-solving skills needs to consider internal and external factors simultaneously [43], [44].

### 4. RQ4. Dominant Learning Models in Integrating the Three Variables

This review identifies that Project-Based Learning and Problem-Based Learning are the most dominant learning models used for integrating creativity, self-directed learning, and problem-solving skills. Project-Based Learning encourages students to produce authentic Informatics products, allowing creativity and collaboration to develop naturally [45], [46]. Meanwhile, Problem-Based Learning emphasizes problem analysis, logical reasoning, and data-driven decision making. Both models position students at the center of the learning process and encourage active engagement. Accordingly, project-based and problem-based models have been shown to be well aligned with the

characteristics of vocational Informatics learning [47], [48].

In addition, technology-based learning models such as the flipped classroom and mobile learning also play an important role in strengthening self-directed learning and digital literacy [49], [50], [51]. Digital learning provides flexibility in terms of time and space, allowing students to regulate their learning pace according to their needs [52], [53]. These findings are consistent with previous studies showing that technology-based learning enhances students' autonomy and sense of responsibility. However, the effectiveness of these models is highly dependent on infrastructure readiness and teachers' digital competence. Therefore, the implementation of learning models needs to be adapted to school conditions and student characteristics [54], [55].

### Implications and Synthesis of Findings

Overall, the findings of this review affirm that enhancing problem-solving skills in Informatics learning within vocational education requires a holistic pedagogical approach. Creativity drives innovation and cognitive flexibility, while self-directed learning strengthens students' persistence and self-reflection. The interaction between these two variables gives rise to problem-solving skills that are more adaptive to technological challenges. These findings reinforce previous literature that positions 21st-century competencies as a central foundation of vocational education. Accordingly, Informatics learning needs to be designed to integrate cognitive, affective, and digital aspects in a balanced manner.

From a practical perspective, teachers and curriculum designers are encouraged to adopt learning models that simultaneously foster creativity and self-directed learning. Project-based, problem-based, and technology-based learning should be connected to the context of the digital industry to enhance relevance to the world of work. Although this review provides a comprehensive synthesis, limitations remain, particularly regarding the diversity of contexts and research methods analyzed. Therefore, future research is recommended to empirically examine the relationships among these variables within the context of Indonesian Vocational High Schools (SMK). Accordingly, the findings of this review can serve as a foundation for developing more contextualized and sustainable Informatics learning models.

### CONCLUSION

This study systematically reveals that creativity and self-directed learning play a significant role in enhancing students' problem-solving skills in Informatics learning within vocational education. These two variables function as complementary internal factors in shaping critical, reflective, and adaptive patterns of thinking in response to technological challenges. When creativity is developed through project-based activities and idea exploration, and self-directed learning is strengthened through self-

regulation and digital literacy, problem-solving skills increase substantially.

These findings indicate that the success of Informatics learning is determined not solely by mastery of technical aspects but also by how effectively the learning process cultivates students' autonomy and innovative thinking. Accordingly, vocational education needs to adopt pedagogical approaches that position learners as active participants who are creative, self-directed, and solution-oriented. Conceptually, this review's findings affirm that the synergy between creativity and self-directed learning is an essential prerequisite for developing 21st-century competencies in the era of digital transformation.

The implication is that informatics education in Vocational High Schools (SMK) should be designed as an integrative learning system that integrates technology, self-reflection, and idea creation. This review contributes to academia by enriching the understanding of 21st-century learning dynamics in the vocational domain and by providing a theoretical foundation for developing learning models that foster creativity, self-directed learning, and students' adaptive thinking.

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