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Problem-solving skills and self-efficacy in biology education: A systematic review

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The study aims to analyze how both constructs have been investigated in empirical research, the reported relationships between them, the educational levels at which they are studied, and the methodological approaches and instruments employed. A systematic literature review (SLR) combined with bibliometric analysis was used as the method to provide a comprehensive overview of research trends, thematic clusters, and conceptual structures. Articles published between 2015 and 2025 in the Scopus database were screened and selected following PRISMA guidelines, resulting in seven studies that met the inclusion criteria. The bibliometric analysis identified five main thematic clusters, indicating the interaction between cognitive, affective, social, and pedagogical dimensions. The review shows that problem-solving skills are predominantly treated as indicators of cognitive achievement, while self-efficacy is positioned as a separate affective factor. Only two studies explicitly examined the relationship between these variables, reporting positive and mutually reinforcing interactions, whereas most studies analyzed them independently. Quantitative approaches with experimental or quasi-experimental designs dominated, with cognitive aspects assessed through performance tests and self-efficacy measured via Likert-scale questionnaires. Overall, the findings highlight the limited integration of cognitive–affective constructs in biology education research and emphasize the need for conceptual and methodological models that capture the dynamic interplay between self-efficacy and problem-solving performance. These insights provide implications for designing holistic and developmentally appropriate learning interventions in biology education.

INTRODUCTION

Biology education is a learning process that requires comprehension of abstract concepts and the interconnections among complex life systems (Nehm, 2019). It involves intricate and abstract content that necessitates students' ability to interpret information and integrate multiple interrelated concepts (Momsen et al., 2022). Furthermore, biology is closely linked to real-world phenomena, including health, environmental, and sustainability issues (Walker & Nouri, 2025). This positioning renders biology education not merely a knowledge transmission process but also a medium for cultivating scientific thinking. Students are expected to identify problems, analyze causal relationships, and apply biological knowledge contextually. Consequently, the characteristics of biology learning demand instructional approaches that actively promote deep cognitive engagement (Tobler et al., 2025).

Aligned with the demands of 21st-century education, biology instruction increasingly emphasizes the development of higher-order thinking competencies, including critical thinking, scientific reasoning, and problem-solving skills (Giamellaro et al., 2025). Problem-solving skills are particularly crucial, as students are confronted with complex issues that often lack a single correct solution (Pinar et al., 2025). In this context, biology education extends beyond mere memorization of concepts, requiring students to formulate problems, generate alternative solutions, and evaluate decisions based on scientific evidence. Problem-solving also facilitates the connection between biological concepts and real-world situations encountered by students (Nigussie et al., 2025). Therefore, problem-solving can be regarded as an essential skill in biology education, relevant both to academic requirements and everyday life. This recognition underscores the need for in-depth studies on the development and characteristics of problem-solving skills within the domain of biology education.

Problem-solving skills constitute a core component of higher-order cognitive abilities that are essential in biology education, as they enable students to understand, analyze, and interpret diverse life phenomena scientifically through systematic and evidence-based thinking processes (Sun et al., 2022). Within the context of science education, problem-solving is not merely viewed as the capacity to arrive at a final answer, but rather as a sequence of scientific reasoning processes encompassing problem identification, hypothesis formulation, data collection and analysis, and drawing logically sound and empirically justifiable conclusions (Pinar et al., 2025). Biology learning, which often involves abstract concepts and complex phenomena, requires students to integrate conceptual knowledge with analytical reasoning, rendering problem-solving skills crucial for the construction of meaningful scientific understanding (Koć-Januchta et al., 2022). Problem-based learning approaches have been shown to be effective in fostering deep cognitive engagement, as they train students to connect biological concepts with real-world contexts through sustained scientific reasoning.

The problem-solving process in science education is conceptualized as a series of structured and interrelated cognitive activities that demand sustained engagement of students' higher-order thinking skills (Stuppan et al., 2025). The initial stage of problem-solving begins with the ability to identify and comprehend the problem, which involves recognizing problematic situations and formulating the problem clearly and specifically through the activation of relevant prior knowledge to construct an accurate mental representation of the issue at hand (Rott et al., 2021; Rubenstein et al., 2020). Insufficient problem understanding can directly compromise the effectiveness of subsequent problem-solving stages, making this initial phase critical in determining the overall quality of the problem-solving process (Musengimana et al., 2025). In the context of biology education, problem comprehension often requires the analysis of complex, multidimensional life phenomena, such as interactions between biological systems and non-linear cause-and-effect relationships, demanding students' capacity to simultaneously interpret concepts, empirical data, and causal relationships (Eberbach et al., 2021; Gilissen et al., 2021). The strategy planning stage involves the ability to select approaches and procedures appropriate to the characteristics of the problem, formulate hypotheses, and design systematic steps that are scientifically justifiable (Nigussie et al., 2025; Teig, 2024). During the implementation phase, students execute the planned strategies through experiments, data analysis, and logical reasoning, which requires precision, consistency, and the ability to adjust strategies when encountering obstacles or unexpected results (Eymur & Çetin, 2024). The final stage of problem-solving evaluation and reflection serves to assess the accuracy and relevance of solutions based on scientific principles, while also reflecting on the effectiveness of the processes and strategies employed. Through reflection, students develop metacognitive skills to monitor and regulate their own thinking processes, thereby supporting the development of deeper and more sustainable scientific understanding in biology education (Willison et al., 2024). Thus, the stages of problem-solving from problem comprehension, strategy planning, and implementation to evaluation constitute a comprehensive cycle of scientific reasoning that collectively fosters the development of students' higher-order thinking skills (Pinar et al., 2025).

Self-efficacy is conceptualized as a cognitive construct that influences affective states, representing an individual's belief in their capacity to organize and execute the actions required to achieve specific learning goals (Schunk, 2020). In the context of biology education, self-efficacy plays a crucial role, given the subject's demands for understanding complex concepts and exercising high-level analytical and investigative thinking (Jansen et al., 2015). Beliefs in one's own abilities shape how students perceive learning tasks whether as challenges to be mastered or obstacles to be avoided (Lee & List, 2021). Students with high self-efficacy typically exhibit more positive and adaptive learning orientations and demonstrate greater readiness to confront academic difficulties, trusting that their efforts will yield meaningful progress. Conversely, low self-efficacy is often associated with a tendency to avoid challenging tasks and reduced perseverance in completing cognitively demanding activities (Schweder et al., 2025). Accordingly, self-efficacy is regarded as a determinant of the quality of student engagement in biology learning, encompassing both conceptual tasks and practical inquiry-based activities.

Numerous studies indicate that self-efficacy is strongly associated with student engagement, perseverance, and academic performance in science education. Students with high self-efficacy tend to participate more actively in class discussions, practical activities, and inquiry-based learning and are less likely to give up when encountering initial failures (Woreta et al., 2025). Students with high self-efficacy similarly demonstrate increased engagement in classroom discussions, laboratory activities, and inquiry-based learning, and they persist despite early setback (Valenzuela-Peñuñuri et al., 2024; Y. Wang et al., 2024). The positive relationship between self-efficacy and academic performance has been confirmed through multiple indicators, ranging from test results to the quality of completing complex tasks that require conceptual understanding and scientific reasoning.

Although the role of self-efficacy in learning has been widely examined, most studies still treat it as a construct relatively separate from problem-solving skills. Research on self-efficacy generally focuses on its influence on motivation, academic achievement, or attitudes toward the subject, whereas studies on problem solving emphasize cognitive aspects such as thinking strategies and logical reasoning. This separation between affective and cognitive dimensions limits a comprehensive understanding of how self-belief and cognitive abilities interact in the process of scientific problem solving (Reuter et al., 2025). Problem-solving in biology education requires not only cognitive skills but also psychological resilience and confidence in facing conceptual and investigative challenges (Rasyidina et al., 2023). Therefore, integrating self-efficacy with problem-solving skills remains a relatively unexplored research area that is essential to investigate to gain a more holistic understanding of the dynamics of biology learning.

Theoretically, cognition and affect are regarded as two interacting dimensions that cannot be separated in the learning process. Cognition involves how individuals process and organize information, whereas affect encompasses beliefs, motivation, and emotions accompanying students' mental activities (Ortega et al., 2013). Contemporary learning theories emphasize that the effectiveness of thinking is not solely dependent on intellectual capacity but is also strongly influenced by affective conditions that support students' mental engagement throughout the learning process (Reuter et al., 2025). Affect functions as a driving force that directs the intensity and quality of cognitive engagement, so that without adequate affective support, students' cognitive potential often fails to be fully realized. In the context of science education, the interaction between cognitive and affective dimensions becomes increasingly important due to the demands of complex scientific thinking, indicating that effective learning requires consideration of both dimensions simultaneously and in an integrated manner.

Most studies in biology education tend to examine problem-solving skills and self-efficacy as separate constructs (Hsu et al., 2024; Nehm, 2019). Research on problem solving typically emphasizes cognitive aspects such as thinking strategies, analytical abilities, and conceptual mastery. In contrast, studies focusing on self-efficacy generally concentrate on learning motivation, attitudes toward learning, and overall academic performance, so that affect is often treated as a supporting variable rather than as an integrated component of the cognitive process (Valenzuela-Peñuñuri et al., 2024). This fragmentation pattern indicates that few studies have investigated how cognitive constructs influence affect, even though this interaction is crucial in science learning. Self-efficacy, as a cognitive construct, represents a key factor influencing students' affective states, since beliefs in one's own abilities determine motivation, learning orientation, and mental engagement during the learning process

(Schunk, 2020). Therefore, neglecting the role of cognition in shaping affect may limit understanding of how students respond to learning challenges and optimize their thinking potential.

Therefore, this study aims to analyze how problem-solving skills and self-efficacy have been investigated in biology education research (RQ1). In addition, the study seeks to examine how the relationship between problem-solving skills and self-efficacy has been reported (RQ2). Furthermore, the research maps the educational levels studied (RQ3) and reviews the methodological trends and instruments used to measure problem-solving skills and self-efficacy (RQ4). Consequently, this study not only provides a descriptive overview of the development of research in the field but also identifies conceptual and empirical gaps that remain underexplored. Thus, the objectives of this research are analytical and reflective regarding the direction and quality of research in biology education. Theoretically, this study contributes through an integrative synthesis of cognitive and affective dimensions by positioning problem-solving skills and self-efficacy as interacting constructs within the learning process. This synthesis underscores that the effectiveness of problem-solving in biology is determined not only by higher-order thinking abilities but also by self-belief and affective conditions that support students' cognitive engagement. Practically, the findings offer implications for the development of more holistic biology instruction, integrating the enhancement of scientific thinking skills and self-efficacy simultaneously within instructional strategies and assessment practices.

METHODS

This study employed a Systematic Literature Review (SLR) approach combined with bibliometric analysis to provide a comprehensive overview of research trends, patterns of relationships between variables, educational contexts and levels, as well as methodological characteristics of studies examining problem-solving skills and self-efficacy in biology education. The SLR procedure followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines as proposed by Moher et al. (2009), serving as a systematic framework for the identification, screening, eligibility assessment, and inclusion of articles, thereby ensuring transparency and replicability of the review process. Data sources were drawn from the Scopus database, covering articles published between 2015 and 2025, to capture the most relevant and recent developments in biology education research. Article searches were conducted using a combination of keywords representing the main variables and context of the study, namely "problem-solving skills", "self-efficacy", "biology learning", "biology education", and "science education". Bibliographic data obtained were subsequently analyzed using the bibliometrics VOS-viewer software to map keyword co-occurrences, research topic trends, and emerging focus areas within the literature. Identified articles were then screened in a stepwise manner following PRISMA procedures, including title, abstract, and full-text review, until a set of articles aligned with the study objectives and research questions was obtained. The inclusion and exclusion criteria used in the article selection process are detailed in Table 1.

Table 1.
Criteria of Inclusion and Exclusion

Criteria Type	Inclusion	Exclusion
Publication Period	Articles published between 2015 and 2025	Articles published prior to 2015
Language	Articles written in English or Indonesian	Articles not written in English or Indonesian
Type of Literature	Empirical research articles (quantitative, qualitative, or mixed-methods studies)	Literature reviews, conference proceedings, conceptual articles, and editorials
Source Type	Peer-reviewed journal articles	Books, book chapters, and non-journal reports
Accessibility	Full-text articles accessible for review	Articles not available in full-text form
Research Variables	Articles examining problem-solving skills and/or self-efficacy	Articles that do not investigate problem-solving skills or self-efficacy

Criteria Type	Inclusion	Exclusion
Field of Study	Biology education or science education within a learning context relevant to biology	Studies conducted outside the context of biology education or science education

The predefined inclusion and exclusion criteria were subsequently applied during the article selection stages following the PRISMA methodology to determine which articles were eligible for in-depth analysis. The article selection process is presented visually in Figure 1

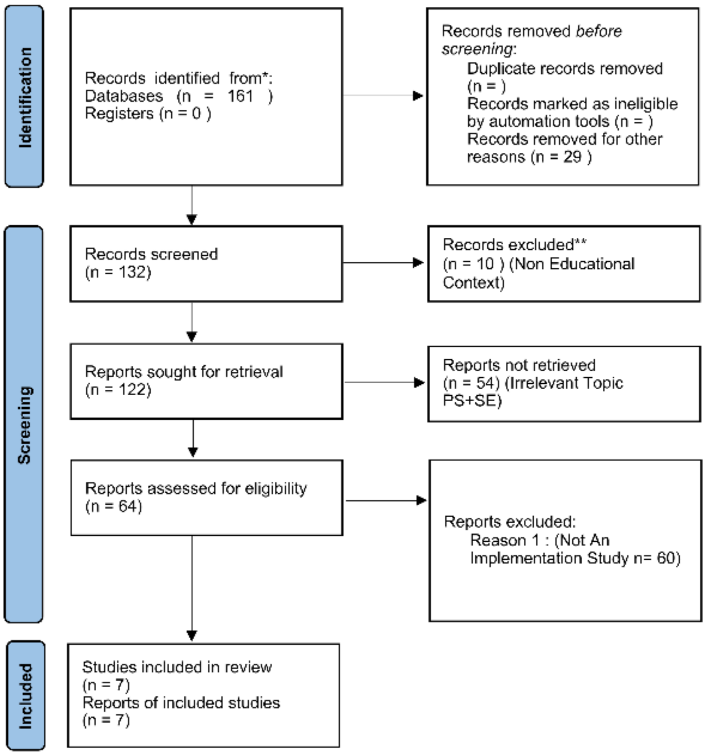

Figure 1. Flowchart of The PRISMA Methodology for Systematic Literature Review (SLR)

The initial stage began with the identification of articles through the Scopus database using the predetermined combination of keywords. This search process yielded a set of articles relevant to the topic of problem-solving skills and self-efficacy in biology education. All bibliographic data obtained were then exported and examined to identify duplicate records, which were removed prior to the screening stage. During the screening stage, the remaining articles were reviewed based on titles and abstracts, applying the inclusion and exclusion criteria. At this stage, non-empirical articles, such as literature reviews, conference proceedings, conceptual articles, and editorials, were excluded from the selection. In addition, articles that were not relevant to the context of biology or science education were also eliminated. The next stage involved an eligibility assessment through full-text reading. During this stage, the selection focused on the alignment of the research variables, namely problem-solving skills and/or self-efficacy, as well as their relevance to the context of biology education. Articles that did not address these variables or for which full-text access was unavailable were excluded from the analysis.

Based on the entire selection process, a total of seven articles met all inclusion criteria and were deemed eligible for further analysis. These selected articles originate from reputable international journals and represent empirical research in the fields of biology and science education. The subsequent stage of the study involved an in-depth analysis of the seven included articles. The analysis was conducted descriptively and thematically, grouping the articles according to patterns of the relationship between problem-solving skills and self-efficacy, educational context and levels, research methods and instruments employed, and the instructional models implemented. The novelty of this systematic literature review lies in its integrative analytical framework, which simultaneously examines the relationship between problem-solving skills and self-efficacy within the specific context of biology education—an approach that has rarely been synthesized in previous reviews. By connecting research variables, educational settings, instructional models, and assessment instruments within a unified thematic structure, this review provides a more comprehensive and context-specific synthesis. The results of this analysis were then synthesized to address the research objectives and questions established in this systematic literature review.

RESULTS AND DISCUSSION

Bibliometric Analysis

This study first presents the results of a bibliometric analysis to provide an initial overview of the research landscape at a macro level. The bibliometric analysis in this section focuses on mapping the conceptual structure of studies examining problem-solving skills and self-efficacy in biology education. This approach is grounded in the perspective of science mapping, which views scientific publications as representations of knowledge development, allowing keyword co-occurrence patterns to be used to identify thematic clusters and emerging research directions within the field (Schunk, 2020). The visualization of relationships among keywords is presented as a network visualization, displayed in Figure 2.

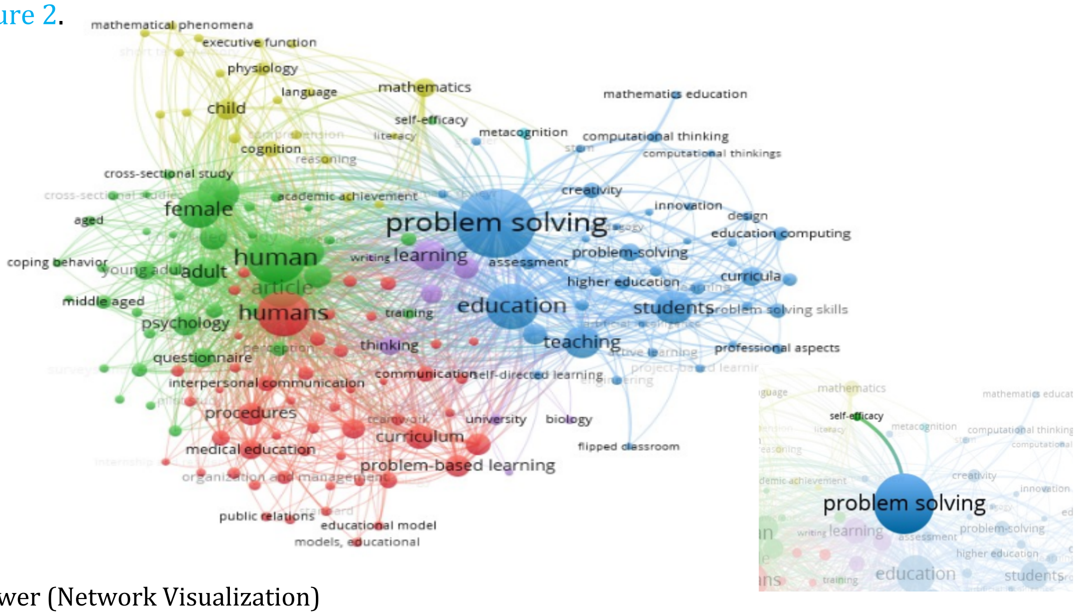

Figure 2. Vos-Viewer (Network Visualization)

Based on Figure 2. the network visualization reveals five main clusters. The blue cluster consists of problem solving, education, students, teaching, and learning, indicating that the primary focus of research is on the learning context. The green cluster represents psychological aspects and human behavior, relating to affective factors in the learning process. The red cluster includes curriculum, problem-based learning, medical education, procedures, and professional aspects, reflecting the connection between problem solving and curriculum development as well as problem-based learning. The yellow cluster encompasses mathematics, metacognition, computational thinking, and mathematical phenomena, highlighting the relationship between problem solving and higher-order thinking skills. Meanwhile, the purple cluster contains communication, teamwork, self-directed learning, and assessment, which are associated with 21st-century skills. These clustering patterns emphasize that problem-solving research does not exist as an isolated construct but is integrated with cognitive, affective, social, and pedagogical dimensions within the learning context.

Next, to examine the dynamics of research topic development over time, the bibliometric analysis was further presented using an overlay visualization. This visualization allows for the identification of temporal trends, indicating topics that were studied earlier as well as those that are relatively new and have emerged in recent years. The results of the overlay visualization are presented in Figure 3.

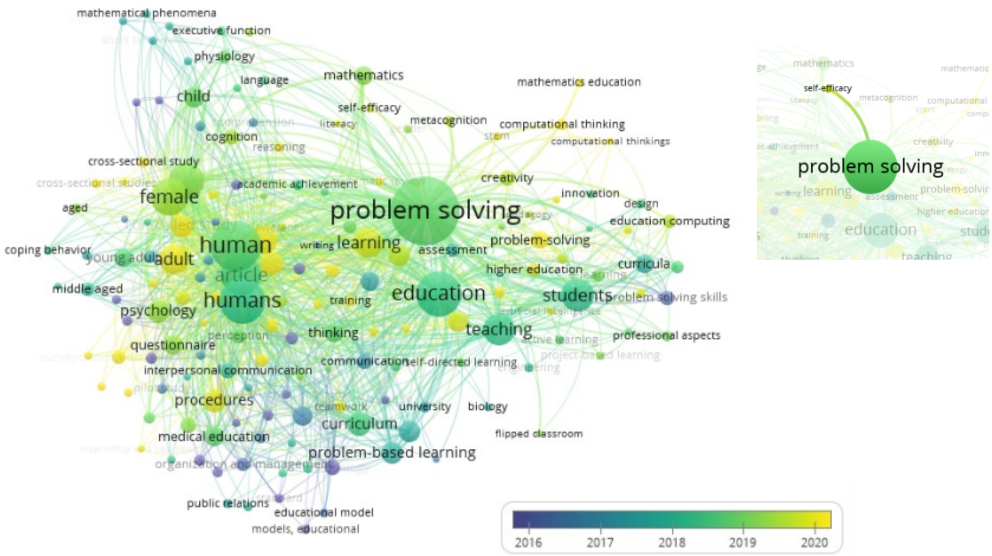

Figure 3. Vos-Viewer (Overlay Visualization)

The overlay visualization results illustrate the temporal development of research publications based on colour gradients. The keyword problem-solving appears in green, indicating that research and publications on this topic were predominantly conducted around 2019. In contrast, the keyword self-efficacy appears in green transitioning to yellow, suggesting that studies on this topic emerged and developed between 2019 and 2020. These findings indicate that although problem solving and self-efficacy developed within a relatively similar timeframe, they tend to be studied in parallel and have not yet been extensively positioned as explicitly interconnected constructs within biology education.

In addition to examining relationships and temporal trends, the intensity of research focus was analyzed using density visualization. This visualization aims to identify the topics that appear most frequently and exhibit the highest research intensity within the literature. The results of the density visualization are presented in Figure 4

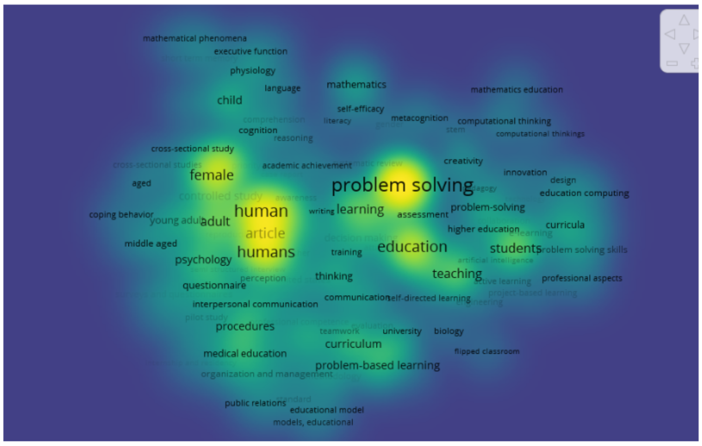

Figure 4. Vos-Viewer (Density Visualization)

Based on Figure 4., colors represent the intensity of topic occurrence within the literature, with topics that are more frequently addressed shown in red and less frequently discussed topics indicated in blue. The visualization results show that the three most frequently studied topics are problem solving, human, and female. In contrast, topics such as biology, self-efficacy, and STEM appear in bluer shades, indicating that these topics remain relatively underexplored. These findings suggest the presence of research gaps, particularly concerning the development of self-efficacy and problem-solving skills in biology and STEM education.

Overall, the bibliometric analysis indicates that problem-solving skills and self-efficacy have emerged as developing topics within the science education literature. However, their integration within the context of biology education remains relatively limited. Conceptual mapping, temporal trends, and topic density analyses reveal a research gap concerning studies that simultaneously connect cognitive and affective dimensions. Therefore, to gain a deeper understanding of how these two constructs have been investigated in empirical research, the subsequent analysis focuses on a thematic synthesis of the included articles, considering variable characteristics, educational context, research methods, and instructional models employed.

Characteristics and Research Patterns of Problem-Solving Skills and Self-Efficacy

Research on biology education over the past decade has shown a strong emphasis on the development of problem-solving skills as an indicator of students' cognitive achievements. In contrast, affective aspects such as self-efficacy have not always received equivalent attention, despite their crucial role in influencing how students respond to cognitive challenges (Losa & Merino, 2024). This imbalance is reflected in how the two variables are positioned in research, both in terms of their variable status and patterns of investigation. Consequently, understanding of the relationship between cognitive and affective dimensions in biology education remains partially developed. The placement patterns of problem-solving skills and self-efficacy in biology education research, as identified in the included studies, are summarized in Table 2.

Table 2

Roles of Problem-Solving Skills and Self-Efficacy Variables in Biology Learning Research

Authors	Year	City, Country	Problem-Solving Skills	Self-Efficacy
Winarto et al	2025	Java, Indonesia	Dependent variable	Not examined
Li & Yu	2025	Shanghai, China	Dependent variable	Not examined
Liu et al	2023	Nanjing, Jiangsu, China	Dependent variable	Dependent variable
Çavuş et al	2025	Muş, Turkey	Dependent variable	Dependent variable
Nugroho et al	2025	Surakarta, Indonesia	Dependent variable	Not examined
Baiduri & Usmiyatun	2025	Malang, Indonesia	Not examined	Primary variable
Aytekin & Topcu	2024	Kocaeli, Turkey	Dependent variable	Not examined

Based on Table 2, problem-solving skills in biology education research are generally positioned as a dependent variable, serving as an indicator of cognitive learning outcomes. This pattern is dominant in most studies, such as Winarto et al. (2025), Li and Yu (2025), Nugroho et al. (2025), and Aytekin and Topcu (2024), which treat problem solving as an outcome measured following specific instructional interventions. These findings suggest that problem-solving skills are more frequently regarded as a learning output rather than as a core construct shaping the learning process itself. Moreover, the connection of problem solving with HOTS frameworks or as an independent conceptual variable remains relatively limited. This pattern indicates that research focus tends to be evaluative rather than exploratory regarding the mechanisms underlying the development of problem-solving skills.

In contrast, the position of self-efficacy in biology education research appears more marginal and inconsistent. Most studies do not explicitly examine self-efficacy, and only a few investigations position it as a primary or outcome variable, as in Baiduri and Usmiyatun (2025). Research that simultaneously examines problem solving and self-efficacy remains very limited, with only two studies treating both as dependent variables concurrently. This situation indicates that the affective dimension has not been systematically integrated into studies of problem-solving skills. Consequently, the relationship between students' self-beliefs and cognitive performance in biology education remains underdeveloped (Hu et al., 2022). These findings underscore a research gap in developing biology instructional models that integrate cognitive and affective aspects simultaneously. The results highlight the limited integration between problem-solving skills and self-efficacy. Therefore, the subsequent discussion focuses on how the relationship between these two variables has been analyzed in the literature.

The relationship between problem-solving skills and self-efficacy is often assumed to be interrelated, yet it is not always empirically tested. Theoretically, self-efficacy is understood as an individual's belief in their capability to accomplish tasks, which has the potential to influence cognitive performance, including problem-solving. However, how this assumption is operationalized in empirical research demonstrates considerable variation. The patterns of the relationship between these two variables, as reported in the included studies, are summarized in Table 3.

Table 3
Reported Relationship Patterns between Problem-Solving Skills and Self-Efficacy in Biology Learning Studies

Relationship Pattern	Number of Studies
Correlational relationship	2
Direct effect	0
Mediating role	0
Not analyzed	5

Based on Table 3, only two of the seven studies explicitly analyzed the relationship between problem-solving skills and self-efficacy. The study by Liu et al. (2023) reported a direct positive relationship, indicating that students with higher self-efficacy tend to exhibit better problem-solving skills. Similar findings were reported by Çavuş et al. (2025), showing a positive and mutually reinforcing relationship between the two variables within the learning context. This pattern suggests that self-efficacy functions as an affective factor contributing to students' cognitive performance. Nevertheless, both studies were limited to direct relationship analyses without exploring more complex underlying mechanisms.

In contrast, the majority of the remaining studies did not empirically examine the relationship between problem-solving skills and self-efficacy. Five studies did not test inter-variable relationships because they focused solely on one construct or did not include either self-efficacy or problem-solving in their analytical models. No studies were found that investigated direct causal relationships, nor the role of self-efficacy as a mediating or moderating variable in the development of problem-solving skills. This situation indicates that the cognitive affective relationship in biology education is still treated separately in research designs. The tendency to separate cognitive and affective aspects in science education research has also been highlighted in various theoretical studies and systematic reviews, which emphasize the need to integrate self-efficacy into the analysis of students' cognitive performance (Schunk, 2020). The limited empirical analysis of the relationship between problem-solving skills and self-efficacy underscores the importance of examining the educational levels and learning contexts in which these constructs are most frequently studied.

The examination of problem-solving skills and self-efficacy in biology education cannot be separated from the context of students' cognitive development at different educational levels. Differences in learning characteristics between elementary, secondary, and higher education students have implications for the focus and research approaches employed. Therefore, mapping educational levels is essential to understand at which levels these two variables are most frequently studied and how research attention is distributed. The distribution of studies by educational level is presented proportionally in Figure 5.

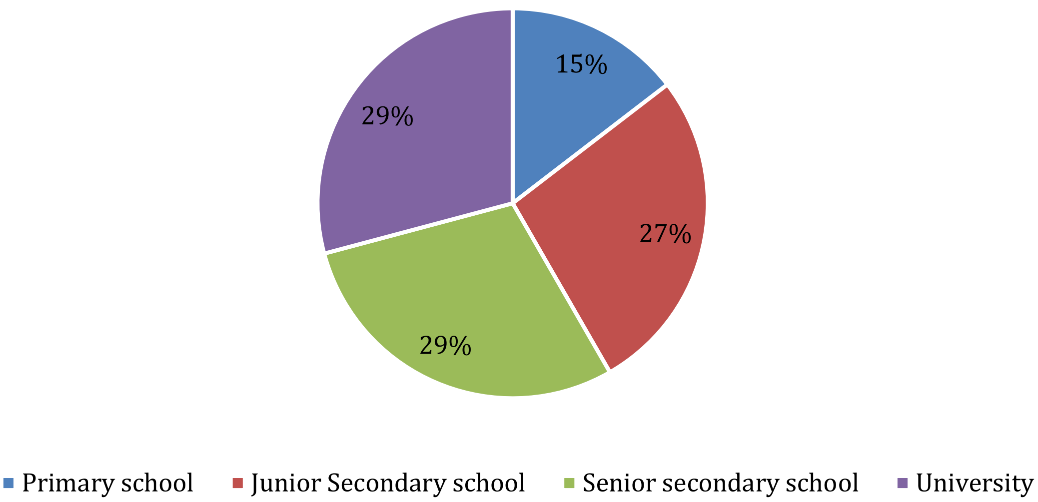

Figure 5. Distribution of Studies Based on Educational Level

Based on Figure 5, studies on problem-solving skills and self-efficacy in biology education are relatively evenly distributed across lower secondary, upper secondary, and higher education levels, each accounting for 28.6% of the research. This pattern indicates that secondary and tertiary education serve as the primary contexts for investigation, in line with the increasing complexity of students' cognitive and academic demands. Notably, studies that integrate problem-solving skills and self-efficacy simultaneously are more frequently conducted at the upper secondary and higher education levels, suggesting that students at these stages are considered capable of reflecting on both their self-beliefs and cognitive performance more comprehensively. This aligns with Zimmerman (2002), who stated that metacognitive reflection and self-regulation abilities, including the evaluation of self-efficacy and cognitive performance, develop more fully in upper secondary and higher education. In contrast, at the lower secondary level, studies tend to position problem-solving skills solely as cognitive outcomes, without explicitly linking them to affective aspects. These findings underscore the importance of strengthening integrated investigations of problem solving and self-efficacy at secondary education levels, particularly lower and upper secondary, as a crucial transitional phase for developing higher-order thinking skills and academic readiness. In line with the dominance of studies at secondary and higher education levels, it is essential to further examine how research methods and measurement instruments are employed in studying problem-solving skills and self-efficacy.

The choice of research methods and measurement instruments reflects how researchers conceptualize problem-solving skills and self-efficacy as constructs that can be empirically observed and assessed. In biology education studies, the methodological approach not only determines the type of data generated but also constrains or expands the possibilities for analyzing the relationship between cognitive and affective aspects. Therefore, a review of the research methods and measurement instruments employed is essential to understand the depth and focus of analyses in the included studies. A summary of the research methods and measurement instruments used in the seven included articles is presented in Tables 4 and 5.

Table 4
Research Methods Employed in Studies on Problem-Solving Skills and Self-Efficacy

Method	Number of Studies
Experimental / Quasi-experimental	6
Correlational survey	1

Tabel 5
Instruments Used in Studies on Problem Solving and Self-Efficacy

Variable	Common Instruments
Problem Solving	Essay tests, problem-based questions, problem-solving rubrics
Self-Efficacy	Likert-scale questionnaires

Based on Table 4 dan Table 5, the majority of studies employed quantitative approaches with experimental or quasi-experimental designs, reflecting a strong orientation toward testing the effectiveness of instructional interventions on problem-solving skills and, in some cases, self-efficacy. Problem-solving skills were typically measured through essay tests, problem-based questions, or performance assessment rubrics, emphasizing both the cognitive process and learning outcomes of students. In contrast, self-efficacy was almost exclusively assessed using Likert-scale questionnaires, thus reflecting students' subjective perceptions and beliefs. This difference in instrument characteristics indicates a clear methodological separation between the measurement of cognitive and affective aspects. Such a separation potentially limits the depth of relational analyses between problem solving and self-efficacy, especially when both variables are not measured simultaneously within designs that allow testing of causal or structural relationships.

Overall, this review indicates that biology education research over the past decade has been dominated by approaches that treat problem-solving skills as indicators of cognitive achievement and self-efficacy as a standalone affective aspect. The positioning of variables, the limited empirical analysis of their relationships, the prevalence of evaluative experimental designs, and the differences in measurement instruments suggest that cognitive-affective integration has not yet become mainstream in biology education research designs. Although self-efficacy is theoretically understood as a mechanism influencing how students manage cognitive challenges, empirical evidence examining causal relationships, or the mediating or moderating roles between the two constructs, remains very limited and context-specific. This finding underscores the need for a paradigm shift in research from merely measuring learning outcomes toward the development of conceptual and methodological frameworks capable of capturing the dynamic interplay between self-efficacy and students' cognitive performance more comprehensively and progressively within biology education. A study conducted by (X.-M. Wang et al., 2024) using structural equation modeling (SEM), the study demonstrated that self-efficacy not only exhibits a positive correlation with problem-solving ability but also operates through higher-order cognitive mechanisms, such as metacognition and critical thinking, that mediate its relationship with problem-solving skills. Furthermore, findings reported by Li et al., (2024) reveal that the relationship among self-efficacy, motivation, and academic achievement is reciprocal in nature, indicating that self-efficacy is not only shaped by cognitive attainment but also actively contributes to it. This reciprocal pattern is theoretically aligned with Social Cognitive Theory, particularly its principle of reciprocal determinism, which posits dynamic interactions among personal beliefs, learning strategies, and academic outcomes. These findings reinforce the argument that cognitive–affective integration in science education research should not be treated as a supplementary perspective, but rather as a methodological imperative for capturing the mechanistic relationship between students' self-beliefs and their cognitive performance more comprehensively and progressively.

CONCLUSION

This systematic review demonstrates that, although problem-solving skills and self-efficacy are essential components of biology education, they are frequently studied in isolation. Most prior research emphasizes either cognitive processes, such as analytical reasoning and strategic thinking, or affective factors, including motivation and learning confidence, without examining the dynamic interplay between the two. The findings underscore that self-efficacy, conceptualized as a cognitive construct influencing affective outcomes, plays a critical role in shaping students' engagement, persistence, and performance in complex biology tasks. Despite its theoretical significance, empirical evidence on the causal relationship or mediating role of self-efficacy in problem-solving remains limited. Moreover, most studies have focused on secondary and tertiary education, highlighting a gap in research within early-stage biology learning contexts. This review emphasizes the need for developing an integrative instructional framework that simultaneously fosters both cognitive and affective competencies. Future research should empirically examine the effectiveness of such a framework to determine how self-efficacy can enhance problem-solving performance across diverse biology learning contexts, thereby supporting a holistic understanding of students' learning dynamics.

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