Acta Pedagogia Asiana

Review
Volume 5(2), 2026 346−364
https://doi.org/10.53623/apga.v5i2.1141

Constructivist Teaching Strategies in Secondary Science Education: A Systematic Review of Student-Centered and Active Learning Approaches

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SUBMITTED: 7 April 2026; REVISED: 26 May 2026; ACCEPTED: 29 May 2026

ABSTRACT: Constructivist teaching strategies have gained increasing attention in science education because they emphasize student-centered, inquiry-oriented, and active learning experiences. This study presents a systematic review of empirical research on constructivist instructional approaches in secondary science education published between 2019 and 2025. Following the PRISMA 2020 framework, a structured literature search was conducted using Scopus, ERIC, and Google Scholar. Eighty-eight records were initially identified, and after duplicate removal, screening, and eligibility assessment, 43 studies were included in the final qualitative synthesis. The reviewed literature examined several constructivist approaches, including Problem-Based Learning, Inquiry-Based Learning, cooperative learning, guided inquiry laboratory activities, project-based learning, and integrated constructivist instructional models. A thematic synthesis approach was employed to analyze cognitive, affective, and skill-based learning outcomes across the studies. Unlike earlier reviews that mainly focused on single instructional approaches, this review comparatively synthesized multiple constructivist strategies within a unified analytical framework. The findings revealed that constructivist instructional approaches were consistently associated with improvements in academic achievement, conceptual understanding, engagement, critical thinking, science process skills, creativity, collaboration, and motivation. Problem-Based Learning and Inquiry-Based Learning emerged as the most frequently implemented and strongly supported strategies. However, the review also identified important implementation challenges related to instructional scaffolding, teacher preparedness, classroom management, resource limitations, and contextual variation. Some studies further suggested that constructivist approaches did not always produce immediate learning gains when instructional support was insufficient. Overall, the findings indicate that constructivist teaching strategies offer strong potential for improving secondary science education when they are carefully designed and effectively facilitated in classrooms.

KEYWORDS: Problem-based learning; guided inquiry; cooperative learning; science process skills; STEM pedagogy

1. Introduction

Science education has increasingly shifted from traditional teacher-centered instruction toward more student-centered and constructivist approaches that emphasize active participation, inquiry, collaboration, and problem-solving [1]. Constructivist pedagogy is grounded in the idea that learners actively construct knowledge through interaction with experiences, prior understanding, and social engagement rather than passively receiving information from teachers [2]. The theoretical foundations of constructivist pedagogy are commonly associated with the works of Piaget, who emphasized cognitive knowledge construction through active experience, and Vygotsky, who highlighted the importance of social interaction and collaborative learning in cognitive development. These perspectives collectively support instructional environments where learners actively engage in inquiry, discussion, reflection, and problem-solving activities to construct scientific understanding. In secondary science classrooms, these approaches have gained significant attention because they promote deeper conceptual understanding, critical thinking, and meaningful engagement in scientific learning processes [3].

Recent literature consistently highlights the educational value of constructivist and active learning approaches in science education. Systematic reviews and meta-analyses have reported that student-centered instructional strategies improve academic achievement and conceptual understanding [4]. Other studies have also emphasized increased motivation and higher-order thinking skills among science learners exposed to inquiry-oriented instruction [5]. Research on active learning and learner-centered pedagogy further suggests that constructivist environments encourage students to participate more actively in scientific inquiry and collaborative learning experiences [6]. Inquiry-oriented STEM instruction has likewise been associated with the development of creativity, inquiry skills, and problem-solving abilities considered essential for twenty-first century learning [7]. Additional evidence indicates that instructional design and active engagement strategies significantly contribute to effective science learning environments in secondary STEM education [8]. Contemporary reviews further suggest that science achievement and scientific literacy are strengthened when students participate in guided and student-centered learning activities [9]. Recent studies also continue to highlight the importance of carefully designed STEM instructional practices in supporting deeper conceptual understanding and learner engagement [10].

Among the most widely implemented constructivist strategies in science education are Problem-Based Learning (PBL), Inquiry-Based Learning (IBL), cooperative learning, guided inquiry laboratory activities, and integrated active learning models. Problem-Based Learning has been extensively associated with improvements in academic achievement and metacognitive development [11]. Several studies further reported that PBL strengthens students' critical thinking and problem-solving abilities because learners are required to solve authentic and complex scientific problems [12]. Meta-analytical findings also support the effectiveness of PBL in improving conceptual understanding and science achievement in secondary science education [13]. Inquiry-Based Learning, meanwhile, encourages students to formulate questions, investigate evidence, and construct explanations, thereby strengthening conceptual understanding and inquiry competence [14]. Other studies also found that inquiry-oriented learning environments positively influence intrinsic motivation and science process skills [15]. Additional reviews suggest that inquiry-based instruction becomes more effective when teachers receive adequate preparation and support for facilitating scientific inquiry [16].

Cooperative and collaborative learning approaches also contribute significantly to meaningful science learning by promoting peer interaction, communication, and shared knowledge construction [17]. Research further indicates that collaborative science learning environments support engagement and participation among secondary learners [18]. Teacher guidance also appears to play an important role in maintaining productive collaborative learning experiences and improving conceptual discussion quality [19]. More recent action research findings additionally suggest that collaborative science instruction may positively influence classroom engagement and achievement outcomes when implemented effectively [20].

Despite the growing evidence supporting constructivist approaches, findings across studies remain fragmented. Many previous reviews focused primarily on a single instructional strategy such as PBL or IBL without examining how multiple constructivists approaches collectively influence learning outcomes in secondary science education [21]. Other studies emphasized positive academic outcomes while giving comparatively less attention to implementation challenges, contextual limitations, or contradictory findings associated with student-centered learning [22]. Some evidence also suggests that constructivist approaches may not always produce immediate improvements in achievement or student interest when instructional support is insufficient or poorly structured [23]. These variations highlight the need for a broader synthesis that critically examines both the strengths and limitations of constructivist teaching strategies across different educational contexts.

Another important gap involves the limited integration of cognitive, affective, and skill-based outcomes within a single review framework. Existing literature often examines academic achievement, motivation, engagement, or science process skills separately, making it difficult to understand the multidimensional impact of constructivist pedagogy in science classrooms [24]. Other studies have focused on scientific creativity and inquiry-oriented learning outcomes without comparatively synthesizing broader learning domains [25]. Recent meta-analytical evidence further suggests that problem-based, project-based, and inquiry-based instructional approaches influence multiple dimensions of student learning, including motivation, engagement, and collaborative competence [26]. However, the increasing number of empirical and review studies published between 2019 and 2025 has not yet been synthesized comprehensively within a unified review focused specifically on secondary science education.

To address these gaps, the present study conducts a systematic review of recent empirical research on constructivist teaching strategies in secondary science education published between 2019 and 2025. Unlike earlier reviews that concentrated on individual instructional approaches, this review comparatively synthesizes Problem-Based Learning, Inquiry-Based Learning, cooperative learning, guided inquiry laboratory activities, project-based learning, and integrated constructivist models within a single analytical framework. The review examines cognitive, affective, and skill-based learning outcomes while also identifying implementation challenges and contextual limitations reported across studies. By integrating recent evidence from multiple constructivist approaches, this study aims to provide a more comprehensive and critical understanding of student-centered science instruction and its implications for future research and classroom practice.

2. Methodology

2.1. Research design.

This study employed a systematic literature review (SLR) design to examine recent empirical research on constructivist teaching strategies in secondary science education. The review focused on student-centered and active learning approaches commonly associated with constructivist pedagogy, including Problem-Based Learning (PBL), Inquiry-Based Learning (IBL), cooperative learning, guided inquiry laboratory activities, project-based learning, and integrated constructivist instructional models. The review followed the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure transparency, consistency, and replicability throughout the study selection and synthesis process. To enhance methodological transparency and reduce the risk of selective reporting, a review protocol was developed prior to the conduct of the study. Although the review protocol was not formally registered in databases such as PROSPERO due to the educational nature of the review topic, the protocol predefined the research questions, eligibility criteria, search strategy, data extraction procedures, and thematic synthesis framework used throughout the review process. This systematic review aimed to identify the constructivist teaching strategies most frequently implemented in secondary science education between 2019 and 2025, examine the cognitive, affective, and skill-based learning outcomes associated with these instructional approaches, and analyze the implementation challenges and limitations reported across the reviewed studies.

2.2 Search strategy.

A structured literature search was conducted using three major academic databases: Scopus, ERIC, and Google Scholar. These databases were selected because of their extensive coverage of peer-reviewed educational and STEM-related research. Scopus was used to access internationally indexed journals, ERIC was selected for its specialization in educational research, and Google Scholar was utilized to identify additional relevant peer-reviewed studies not indexed in the other databases. To maintain search manageability and relevance, Google Scholar screening focused primarily on the most relevant peer-reviewed studies appearing within the initial search result pages based on keyword relevance and alignment with the inclusion criteria. The search was limited to journal articles published between January 2019 and December 2025 to ensure that the review reflected recent developments in constructivist science education research. The selected timeframe also allowed the inclusion of contemporary instructional practices and post-pandemic educational developments related to active learning and student-centered pedagogy. The search process used Boolean combinations of keywords associated with constructivist instruction and science education. The search terms included (“constructivist teaching” OR “constructivist approach” OR “student-centered learning” OR “active learning”) AND (“problem-based learning” OR “inquiry-based learning” OR “cooperative learning” OR “guided inquiry”) AND (“secondary science education” OR “high school science” OR “STEM education”). The search process was conducted between January and March 2026. Database searches were performed using title, abstract, and keyword fields whenever database filtering options were available. In Google Scholar, screening was limited to the first 200 results ranked by relevance to maintain search manageability while ensuring inclusion of highly relevant peer-reviewed studies. Additional manual screening of reference lists from selected review articles was also conducted to identify potentially relevant studies not captured during the initial database search. The database search initially identified 88 records. After duplicate removal, 76 records remained for title and abstract screening. During the screening stage, 7 studies were excluded because they did not align with the objectives and eligibility criteria of the review. The remaining 69 studies underwent full-text assessment for eligibility. Following detailed evaluation, 19 studies were excluded due to insufficient outcome reporting and lack of empirical data. Consequently, 43 studies met all inclusion criteria and were included in the final qualitative synthesis. Figure 1 presents the PRISMA flow diagram summarizing the study selection process.

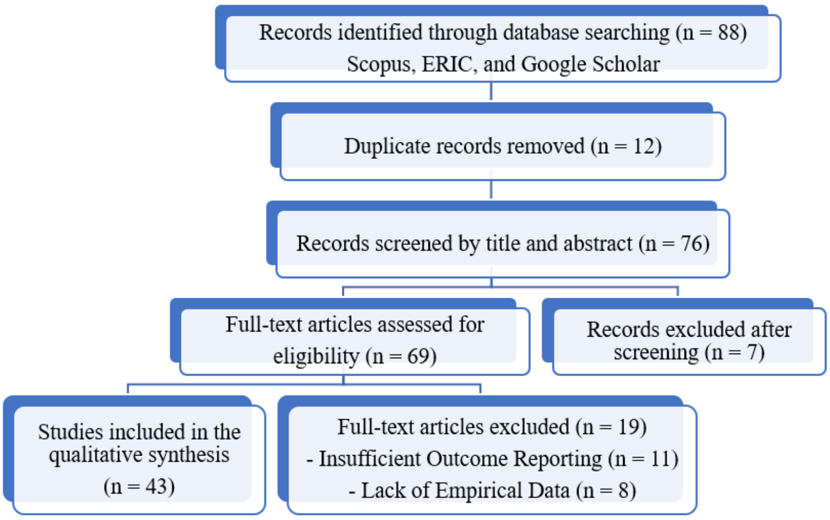

Figure 1. PRISMA 2020 flow diagram of the study selection process.

2.3. Eligibility criteria.

Clear inclusion and exclusion criteria were established prior to the screening process to ensure consistency and relevance in study selection. Studies were included if they were peer-reviewed journal articles published in English between 2019 and 2025 and focused on constructivist or student-centered instructional strategies in secondary science education. Eligible studies were also required to report empirical findings related to academic achievement, conceptual understanding, engagement, motivation, critical thinking, science process skills, or other relevant learning outcomes. Studies were excluded if they focused exclusively on elementary or tertiary education, involved non-science subject areas, lacked empirical evidence, or emphasized technology integration without clear pedagogical grounding. Conference proceedings, editorials, books, and conceptual papers without data were also excluded from the review. The screening and eligibility assessment processes were conducted systematically to ensure consistency in study selection. Any uncertainties identified during title–abstract screening and full-text evaluation were resolved through careful re-examination of the inclusion and exclusion criteria to maintain methodological consistency throughout the review process. To improve consistency during the screening and eligibility assessment process, studies were reviewed through repeated evaluation of titles, abstracts, and full texts based on the predefined inclusion and exclusion criteria. Ambiguous cases were carefully reassessed to minimize selection bias and maintain methodological consistency throughout the review process. The eligibility criteria helped ensure that the review remained focused on empirical evidence related to constructivist teaching approaches in secondary science education.

2.4. Data extraction.

Relevant information from the included studies was systematically extracted using a structured data extraction template to ensure consistency and comparability across studies. The extracted information included authors and year of publication, country or educational context, research design, participant characteristics, instructional strategy implemented, reported learning outcomes, major findings, and identified limitations. This process facilitated thematic comparison across different constructivist approaches and educational contexts.

2.5 Quality appraisal.

To strengthen the methodological rigor of the review, each included study was evaluated using several quality indicators commonly applied in educational research reviews. These indicators included clarity of research objectives, appropriateness of research design, adequacy of sample description, transparency of intervention procedures, validity and reliability of instruments, appropriateness of data analysis methods, and reporting of study limitations. To strengthen methodological rigor and consistency in evidence evaluation, the included studies were appraised using adapted quality assessment indicators derived from the Critical Appraisal Skills Programme (CASP) and Joanna Briggs Institute (JBI) educational research appraisal frameworks. The appraisal criteria included clarity of research objectives, appropriateness of research design, adequacy of sampling procedures, transparency of intervention implementation, validity and reliability of instruments, appropriateness of data analysis procedures, and completeness of reporting. Each study was evaluated descriptively according to these indicators to support balanced interpretation of methodological strengths and limitations across the reviewed literature. Studies demonstrating clear methodological procedures and transparent reporting were interpreted with greater confidence during synthesis, whereas studies with limited methodological detail were interpreted more cautiously. This appraisal process contributed to balanced interpretation of the reviewed evidence.

2.6. Data analysis.

A thematic synthesis approach was employed to analyze the findings across the included studies. The studies were first grouped according to the primary constructivist instructional strategy examined, namely Problem-Based Learning, Inquiry-Based Learning, cooperative learning, guided inquiry laboratory activities, project-based learning, and integrated constructivist models. The reported outcomes were subsequently categorized into three major domains: cognitive outcomes, affective outcomes, and skill-based outcomes. Cognitive outcomes included academic achievement and conceptual understanding, affective outcomes included motivation and engagement, while skill-based outcomes included critical thinking, creativity, collaboration, and science process skills. Organizing the findings into these domains enabled clearer identification of recurring patterns, similarities, and differences across constructivist teaching strategies and educational settings. Because the included literature involved diverse research designs, educational settings, and outcome measures, the findings were synthesized narratively through thematic analysis rather than quantitative pooling of effect sizes. This approach allowed broader comparison of recurring patterns and implementation themes across heterogeneous studies. A quantitative meta-analysis was not conducted because the included studies differed substantially in intervention duration, participant characteristics, instructional approaches, outcome variables, and methodological designs. These variations limited statistical comparability across studies and supported the appropriateness of qualitative thematic synthesis.

3. Results

3.1. Overview of included studies.

A total of 43 studies met all eligibility criteria and were included in the final qualitative synthesis following the PRISMA 2020 screening process. The included studies were published between 2019 and 2025 and examined various constructivist teaching strategies implemented in secondary science education contexts. The reviewed literature consisted of systematic reviews, meta-analyses, experimental studies, action research, and mixed-methods investigations that explored the effectiveness of student-centered and active learning approaches in science classrooms. The studies collectively investigated several constructivist instructional strategies, including Problem-Based Learning (PBL), Inquiry-Based Learning (IBL), cooperative or collaborative learning, guided inquiry laboratory activities, project-based learning, and integrated constructivist instructional models. Across the reviewed studies, the most frequently examined outcomes included academic achievement, conceptual understanding, student engagement, critical thinking, science process skills, intrinsic motivation, creativity, and collaboration. The included studies varied across educational contexts, research designs, and instructional implementations. Most studies were conducted in secondary STEM or science classrooms and examined the effects of constructivist instructional strategies on cognitive, affective, and skill-based learning outcomes. Table 1A summarizes the representative characteristics of selected included studies.

3.1.1 Distribution of Studies by Research Design

The methodological distribution of the included studies is presented in Table 1. Experimental and quasi-experimental designs represented the largest proportion of the reviewed literature, followed by systematic reviews and meta-analyses. This finding indicated that recent constructivist science education research was strongly supported by both empirical classroom interventions and evidence synthesis studies. As shown in Table 1, experimental and quasi-experimental studies accounted for the highest proportion of the reviewed literature (34.9%), suggesting that many researchers continued to evaluate constructivist teaching approaches through classroom-based interventions. Meanwhile, systematic reviews and meta-analyses collectively represented 41.9% of the included studies, reflecting the growing effort to synthesize evidence on student-centered science instruction.

Table 1. Distribution of included studies by research design.

Research Design	Frequency (n)	Percentage (%)
Systematic Reviews	11	25.6
Meta-Analyses	7	16.3
Experimental / Quasi-Experimental	15	34.9
Action Research	4	9.3
Mixed-Methods / Descriptive	6	13.9
Total	**43**	**100**

3.1.2. Distribution by Constructivist Teaching Strategy

The reviewed studies investigated multiple constructivist instructional approaches in secondary science education. Table 2 summarizes the distribution of studies according to the primary instructional strategy examined. Problem-Based Learning emerged as the most frequently investigated constructivist strategy, representing 30.2% of the included studies. Inquiry-Based Learning closely followed at 27.9%, highlighting the continued emphasis on inquiry-oriented science instruction in contemporary science education research. Cooperative learning and guided inquiry laboratory approaches were also commonly explored because of their role in promoting engagement, communication, and science process skills.

Table 2. Distribution of studies by constructivist teaching strategy.

Instructional Strategy	Frequency (n)	Percentage (%)
Problem-Based Learning (PBL)	13	30.2
Inquiry-Based Learning (IBL)	12	27.9
Cooperative / Collaborative Learning	6	14.0
Guided Inquiry Laboratory Activities	4	9.3
Integrated Constructivist Models	4	9.3
Project-Based Learning	4	9.3
Total	**43**	**100**

3.2. Effects of Problem-Based Learning (PBL).

Thirteen studies examined the implementation of Problem-Based Learning in secondary science education. Across these studies, PBL was consistently associated with positive cognitive and skill-based outcomes. Most studies reported improvements in academic achievement, conceptual understanding, critical thinking, metacognitive development, and problem-solving ability. As summarized in Table 3, 11 out of 13 studies (84.6%) reported significant improvements in academic achievement, while 10 studies (76.9%) identified enhanced problem-solving and critical thinking skills. In addition, 8 studies (61.5%) reported increased student engagement and motivation during science learning activities. Meta-analytical evidence also suggested that PBL produced moderate to strong positive effects compared with traditional lecture-based instruction. Despite these positive findings, several studies emphasized that PBL effectiveness depended heavily on instructional scaffolding, teacher facilitation, and classroom structure. Insufficient guidance and poorly designed problem scenarios were reported to reduce conceptual clarity and increase student difficulty during inquiry processes.

Table 3. Reported outcomes of Problem-Based Learning studies.

Learning Outcome	Frequency (n)	Percentage (%)
Academic Achievement	11	84.6
Critical Thinking / Problem-Solving	10	76.9
Student Engagement	8	61.5
Conceptual Understanding	7	53.8
Motivation / Metacognition	6	46.2

3.3. Effects of Inquiry-Based Learning (IBL).

Twelve studies focused on Inquiry-Based Learning approaches in science education. The reviewed studies consistently reported that inquiry-oriented instruction improved conceptual understanding, science process skills, scientific reasoning, and intrinsic motivation. As presented in Table 4, 10 studies (83.3%) reported improvements in conceptual understanding, while 9 studies (75.0%) identified increased science process skills and inquiry competencies. Furthermore, 8 studies (66.7%) reported improvements in intrinsic motivation and engagement, suggesting that inquiry activities helped students become more actively involved in scientific learning. Several studies also highlighted that inquiry-based instruction promoted creativity and independent thinking because students were encouraged to formulate questions, analyze evidence, and construct explanations. However, some studies cautioned that overly open-ended inquiry tasks could overwhelm students when instructional support was insufficient.

Table 4. Reported outcomes of Inquiry-Based Learning studies

Learning Outcome	Frequency (n)	Percentage (%)
Conceptual Understanding	10	83.3
Science Process Skills	9	75.0
Engagement / Motivation	8	66.7
Critical Thinking	7	58.3
Creativity	4	33.3

3.4. Effects of cooperative and collaborative learning.

Six studies investigated cooperative and collaborative learning approaches in secondary science classrooms. The findings demonstrated that structured peer interaction positively influenced engagement, participation, communication, and collaborative problem-solving. As presented in Table 5, all six studies (100.0%) reported increased student engagement, while four studies (66.7%) identified improvements in academic achievement and conceptual discussion quality. Collaborative learning environments also appeared to support confidence and classroom participation among learners. Nevertheless, some studies reported implementation challenges related to unequal participation, classroom management difficulties, and teacher preparedness in facilitating collaborative learning environments effectively.

Table 5. Reported outcomes of cooperative and collaborative learning studies.

Learning Outcome	Frequency (n)	Percentage (%)
Student Engagement	6	100.0
Academic Achievement	4	66.7
Collaborative Skills	4	66.7
Conceptual Discussion Quality	3	50.0
Motivation	3	50.0

3.5. Integrated constructivist and project-based approaches.

Integrated constructivist models and project-based instructional approaches were also associated with multidimensional learning benefits. These studies commonly combined inquiry, collaboration, problem-solving, and active learning within broader STEM-oriented learning environments. Most integrated constructivist studies reported improvements in academic achievement, creativity, motivation, and higher-order thinking skills. Project-based approaches were particularly associated with long-term engagement and authentic application of scientific knowledge. However, the reviewed studies also emphasized that integrated approaches require extensive planning, teacher preparation, and sufficient classroom resources to achieve optimal effectiveness.

3.6. Overall distribution of learning outcomes.

The overall learning outcomes reported across the 43 reviewed studies are summarized in Table 6. Cognitive outcomes such as academic achievement and conceptual understanding were the most frequently reported findings, followed by engagement, critical thinking, and science process skills. The findings indicate that constructivist teaching strategies most consistently support cognitive learning outcomes, particularly academic achievement and conceptual understanding. Nevertheless, affective and skill-based outcomes such as engagement, motivation, collaboration, and creativity were also frequently reported, demonstrating the multidimensional impact of student-centered science instruction.

Table 6. Overall distribution of learning outcomes across reviewed studies.

Learning Outcome	Frequency (n)	Percentage (%)
Academic Achievement	39	90.7
Conceptual Understanding	35	81.4
Student Engagement	31	72.1
Critical Thinking / Problem-Solving	27	62.8
Science Process Skills	24	55.8
Motivation	22	51.2
Creativity	14	32.6

3.6.1. Comparative synthesis of constructivist teaching strategies.

Table 7 presents a comparative synthesis of the major constructivist instructional strategies identified across the reviewed studies. The table summarizes the dominant learning outcomes, major instructional strengths, and commonly reported implementation challenges associated with each approach. Problem-Based Learning and Inquiry-Based Learning demonstrated the strongest associations with cognitive learning outcomes, particularly academic achievement, conceptual understanding, and critical thinking. Meanwhile, cooperative and collaborative learning approaches were more strongly associated with engagement, participation, and communication-related outcomes. Across all instructional strategies, the findings suggest that structured facilitation, instructional scaffolding, and contextual adaptation remain critical factors influencing successful implementation.

Table 7. Comparative synthesis of constructivist teaching strategies.

Instructional Strategy	Dominant Learning Outcomes	Major Strengths	Common Challenges
Problem-Based Learning (PBL)	Academic achievement, critical thinking, problem-solving	Promotes authentic learning and metacognitive development	Requires strong instructional scaffolding and carefully structured problems
Inquiry-Based Learning (IBL)	Conceptual understanding, science process skills, motivation	Encourages investigation, autonomy, and scientific reasoning	Open inquiry may cause cognitive overload when support is insufficient
Cooperative / Collaborative Learning	Engagement, communication, collaboration	Enhances peer interaction and classroom participation	Unequal participation and classroom management difficulties
Guided Inquiry Laboratory Activities	Science process skills, conceptual learning	Supports hands-on investigation and inquiry skills	Requires laboratory resources and teacher facilitation
Project-Based Learning	Creativity, engagement, application of knowledge	Encourages authentic and interdisciplinary learning	Demands extensive planning and time allocation
Integrated Constructivist Models	Multidimensional learning outcomes	Combines inquiry, collaboration, and active learning	Requires high instructional preparedness and resource availability

3.7. Cross-strategy patterns and emerging themes.

Across all reviewed studies, several recurring patterns emerged. First, constructivist approaches consistently promoted active participation and deeper engagement in science learning. Second, instructional guidance and scaffolding appeared to play a crucial role in determining the effectiveness of student-centered learning environments. Third, blended or integrated constructivist models demonstrated broader multidimensional outcomes because they combined inquiry, collaboration, and authentic problem-solving activities. At the same time, several studies identified contextual and implementation-related limitations. These included insufficient teacher preparation, time constraints, lack of classroom resources, cognitive overload during open inquiry activities, and inconsistent student participation during collaborative tasks. Additionally, a small number of studies reported that constructivist approaches did not always produce immediate improvements in achievement or interest when compared with more structured instructional methods. Overall, the reviewed evidence strongly supports the effectiveness of constructivist teaching strategies in secondary science education while also highlighting the importance of structured facilitation, contextual adaptation, and teacher preparedness in successful implementation.

4. Discussion

4.1. Interpretation of the main findings.

This systematic review synthesized 43 studies published between 2019 and 2025 that examined constructivist teaching strategies in secondary science education. Overall, the findings demonstrate that student-centered and active learning approaches positively influence multiple dimensions of science learning, particularly academic achievement, conceptual understanding, engagement, critical thinking, and science process skills. Across the reviewed studies, Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL) emerged as the most frequently implemented and most consistently supported instructional approaches, suggesting that contemporary science education increasingly emphasizes inquiry, collaboration, and authentic problem-solving experiences [27]. Additional reviews further support the effectiveness of inquiry-oriented and learner-centered science instruction in improving science learning outcomes [28]. Meta-analytical findings likewise indicate that active and constructivist instructional strategies consistently support science achievement and conceptual understanding among secondary learners [29].

The findings indicate that cognitive outcomes remain the most frequently reported benefits of constructivist instruction. Academic achievement was reported in 90.7% of the reviewed studies, while conceptual understanding appeared in 81.4% of the studies. Earlier research suggests that learners develop deeper understanding when they actively engage with scientific concepts through exploration, investigation, and collaborative reasoning rather than passive memorization [30]. Other studies also emphasize that active learning environments improve inquiry competence and student participation in science classrooms [31]. Recent reviews further associate constructivist STEM instruction with improved scientific reasoning and inquiry skill development [32]. In constructivist classrooms, students are encouraged to connect prior knowledge with new experiences, which may explain the consistent improvements observed in conceptual learning and scientific reasoning [33]. Additional evidence also highlights the importance of carefully designed STEM instructional strategies in supporting deeper science learning outcomes [34].

Problem-Based Learning demonstrated particularly strong effects on academic achievement and critical thinking. Most PBL studies reported improvements in students' ability to analyze problems, justify solutions, and apply scientific concepts in authentic contexts [35]. Other meta-analytical evidence further supports the effectiveness of PBL in improving metacognitive development and higher-order thinking skills among science learners [36]. Additional reviews likewise indicate that problem-solving-oriented science instruction strengthens conceptual understanding and science achievement [37]. These findings are consistent with constructivist learning theory, which emphasizes active knowledge construction through meaningful problem-solving experiences [38]. Furthermore, several studies suggested that PBL environments support metacognitive development because learners are required to monitor their reasoning, evaluate evidence, and reflect on their decisions throughout the learning process [39]. However, the effectiveness of PBL appeared strongly dependent on instructional scaffolding and teacher facilitation. Studies reported that insufficient guidance may cause students to focus more on task completion than conceptual understanding, particularly when problems are overly complex or poorly structured [40]. Additional findings also indicate that beginning science teachers often experience difficulties implementing inquiry and problem-based approaches effectively during classroom instruction [41].

Inquiry-Based Learning also produced consistent positive outcomes, especially in conceptual understanding, science process skills, and intrinsic motivation [42]. Inquiry-oriented instruction allows students to experience science as an investigative process rather than simply a collection of facts, thereby encouraging curiosity, experimentation, and independent reasoning. Several reviewed studies reported that inquiry activities improve students' ability to formulate questions, interpret evidence, and communicate scientific explanations [43]. Moreover, inquiry-based environments were associated with increased engagement and creativity because students were given greater autonomy in exploring scientific problems. Nevertheless, the findings also suggest that inquiry-based learning may become less effective when learners are provided with minimal support. Some studies noted that overly open-ended inquiry tasks can overwhelm students and reduce instructional efficiency, particularly among learners with limited prior knowledge or weak self-regulation skills. These findings support the view that constructivist instruction becomes most effective when inquiry and student autonomy are balanced with appropriate scaffolding, structured facilitation, and contextual instructional support.

Cooperative and collaborative learning approaches also demonstrated strong effects on engagement and classroom participation. Collaborative environments appear to support meaningful discussion, peer explanation, communication, and shared problem-solving, which contribute to deeper understanding of scientific concepts. However, the reviewed studies also identified several implementation challenges, including unequal participation among group members, classroom management difficulties, and the need for effective teacher facilitation to maintain productive collaboration. These findings suggest that cooperative learning becomes most effective when collaborative tasks are carefully structured and actively monitored by teachers.

4.2. Beyond academic achievement: multidimensional learning outcomes.

One important contribution of this review is its synthesis of cognitive, affective, and skill-based outcomes within a single analytical framework. Previous reviews frequently focused on a single outcome domain, particularly academic achievement. In contrast, the present review demonstrates that constructivist approaches influence learning in multidimensional ways. Although academic achievement remained the most commonly reported outcome, affective outcomes such as engagement and intrinsic motivation were also frequently identified across the reviewed studies. Increased engagement across multiple studies suggests that constructivist instruction may help create more meaningful and participatory science learning environments. Motivation appeared particularly strong in inquiry-based and project-based learning contexts where students were encouraged to investigate authentic scientific questions, collaborate with peers, and apply scientific concepts to real-world situations. Skill-based outcomes also emerged consistently across studies. Science process skills, critical thinking, creativity, and collaboration were commonly associated with inquiry-oriented and problem-solving instructional approaches. These findings are important because modern science education increasingly emphasizes competencies such as reasoning, communication, creativity, collaboration, and scientific inquiry rather than rote memorization alone. Constructivist learning environments appear particularly effective in supporting these broader educational goals because students actively participate in knowledge construction and authentic scientific practices.

4.3. Critical reflections and contradictory evidence.

Although the overall findings strongly support constructivist teaching strategies, the reviewed evidence also highlights several limitations and contradictory findings that should be acknowledged. The present review therefore considered not only positive outcomes but also studies reporting weaker or inconsistent instructional effects. Some evidence suggests that constructivist approaches do not always produce immediate improvements in achievement or student interest, particularly when instructional activities lack sufficient structure, scaffolding, or alignment with assessment practices.

The review also revealed that instructional guidance remains a critical factor in successful implementation. Poorly scaffolded inquiry activities may increase cognitive overload, confusion, or disengagement among learners, especially among students with limited prior knowledge or weak self-regulation skills. Consequently, constructivist approaches appear most effective when balanced with structured facilitation, explicit instruction, and carefully designed learning supports rather than unrestricted open-ended inquiry.

Teacher preparedness also emerged as a recurring implementation concern. Several studies reported that science teachers often experience difficulties in facilitating inquiry discussions, managing collaborative learning environments, and designing authentic problem-solving activities. Limited professional training, insufficient classroom resources, and time constraints were frequently identified as barriers to effective implementation. These findings suggest that the success of constructivist instruction depends not only on instructional design itself but also on institutional support, teacher competence, and contextual readiness.

4.4 Comparison with previous reviews.

The findings of the present review are generally consistent with earlier systematic reviews and meta-analyses reporting positive effects of active learning and constructivist instructional approaches in science education. However, unlike many earlier reviews that focused primarily on a single instructional strategy such as PBL or IBL, the present study comparatively synthesized multiple constructivist approaches within one analytical framework. This broader synthesis allowed clearer identification of recurring instructional patterns and multidimensional learning outcomes across different educational contexts. Another distinguishing contribution of this review involves its emphasis on multidimensional learning outcomes and implementation challenges. While earlier reviews frequently concentrated on academic achievement alone, the present review integrated cognitive, affective, and skill-based outcomes while also considering contradictory evidence and contextual limitations. This approach provides a more balanced understanding of both the strengths and limitations of constructivist pedagogy in secondary science education. Furthermore, by focusing specifically on studies published between 2019 and 2025, this review provides an updated synthesis of recent post-pandemic educational practices and contemporary developments in student-centered science instruction. The increasing emphasis on inquiry, collaboration, creativity, and STEM integration observed across the reviewed studies reflects broader educational shifts toward twenty-first century competencies and active learning environments.

4.5. Implications for science education practice and research.

The findings of this review have several implications for science education practice. First, constructivist teaching strategies appear most effective when accompanied by structured instructional guidance and carefully designed learning activities. Teachers play an essential role in facilitating discussion, scaffolding inquiry processes, clarifying misconceptions, and maintaining productive collaborative learning environments. Consequently, teacher professional development programs should focus not only on introducing constructivist theories but also on developing practical classroom facilitation skills.

Second, the findings suggest that science assessment practices may need to align more closely with constructivist instructional goals. Traditional assessments emphasizing factual recall may not adequately capture the development of inquiry skills, problem-solving abilities, creativity, and collaboration. Alternative assessments such as performance tasks, reflective activities, inquiry projects, and collaborative investigations may therefore provide more appropriate measures of student learning within constructivist classrooms.

Finally, future research should continue examining contextual factors that influence the effectiveness of constructivist instruction, including classroom resources, teacher expertise, student readiness, and curriculum alignment. More longitudinal studies are also needed to investigate the long-term effects of constructivist approaches on scientific reasoning, motivation, creativity, and STEM-related career outcomes. Future systematic reviews may additionally benefit from employing multi-reviewer screening procedures, inter-rater reliability analysis, and quantitative meta-analytic comparisons across specific instructional approaches to strengthen methodological rigor and evidence comparability.

4.6. Limitations of the review.

Several limitations of the present review should be acknowledged. First, the review included only English-language peer-reviewed journal articles published between 2019 and 2025, which may have excluded relevant studies published in other languages or formats. Second, the included studies demonstrated substantial methodological and contextual variation, limiting direct comparability across findings. Third, although the review employed structured quality appraisal procedures, the synthesis remained primarily qualitative and did not include statistical meta-analysis of effect sizes. Finally, database indexing limitations and the selective screening approach used in Google Scholar may have resulted in the omission of some relevant studies despite systematic search procedures.

5. Conclusion

This systematic review synthesized 43 studies published between 2019 and 2025 that examined constructivist teaching strategies in secondary science education. The findings indicate that student-centered instructional approaches, particularly Problem-Based Learning, Inquiry-Based Learning, cooperative learning, guided inquiry laboratory activities, and integrated constructivist models, generally contribute positively to science learning outcomes. Across the reviewed literature, constructivist approaches were consistently associated with improvements in academic achievement, conceptual understanding, engagement, critical thinking, science process skills, and motivation. The review further suggests that constructivist pedagogy supports multidimensional learning by encouraging students to actively participate in scientific inquiry, collaborative discussion, and authentic problem-solving experiences. Rather than functioning as passive recipients of information, learners in constructivist environments appear to develop deeper conceptual understanding and broader scientific competencies through active knowledge construction and social interaction. These findings reinforce the growing emphasis on inquiry, collaboration, and higher-order thinking within contemporary science education. However, the review also demonstrates that the effectiveness of constructivist instruction is strongly influenced by instructional design, teacher facilitation, and contextual implementation factors. Several studies reported challenges related to insufficient scaffolding, limited teacher preparedness, cognitive overload during open inquiry activities, unequal participation in collaborative tasks, and resource limitations. In addition, some evidence suggested that constructivist approaches may not always produce immediate improvements in achievement or interest when implementation lacks sufficient structure and support. These findings highlight the importance of balanced instructional guidance and careful contextual adaptation in student-centered science instruction. One important contribution of this review is its comparative synthesis of multiple constructivist approaches within a single analytical framework. Unlike previous reviews that focused primarily on individual strategies such as Problem-Based Learning or Inquiry-Based Learning, the present study integrated cognitive, affective, and skill-based outcomes across diverse instructional models. This broader perspective provides a more comprehensive understanding of both the strengths and limitations of constructivist pedagogy in secondary science education. Overall, the reviewed evidence suggests that constructivist teaching strategies remain promising approaches for improving science learning when implemented thoughtfully and supported by effective instructional facilitation. Future research may further examine long-term learning outcomes, contextual variations across educational settings, and the comparative effectiveness of blended constructivist models to strengthen evidence-based science instruction and educational practice.

Acknowledgments

The authors sincerely express their gratitude to Almighty God for His guidance, wisdom, strength, and countless blessings throughout the completion of this study. The authors also extend their heartfelt appreciation to Prof. Mauricio S. Adlaon for his valuable supervision, academic guidance, and insightful recommendations during the conduct of this research. Furthermore, the authors acknowledge the researchers and scholars whose published works contributed significantly to the development and completion of this systematic review.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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