

Student-Centered Learning in Scientific Writing Training to Enhance the Academic Literacy of Senior High School Students: A Systematic Literature Review

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ABSTRAK

The increasing demand for twenty-first-century competencies has highlighted the importance of scientific writing and academic literacy as essential skills for senior high school students. However, conventional teacher-centered instruction often provides limited opportunities for students to actively construct knowledge and develop scientific communication skills. This study aimed to synthesize recent empirical evidence on how Student-Centered Learning (SCL) contributes to scientific writing training in enhancing students' academic literacy and to identify the most effective pedagogical strategies reported in the literature. A Systematic Literature Review (SLR) was employed following a structured review procedure. Relevant empirical studies published between 2021 and 2025 were retrieved from reputable national and international journals. The selected studies were analyzed using qualitative content analysis through identification, categorization, comparison, and thematic synthesis of the findings. The review revealed that Student-Centered Learning consistently improves scientific writing competence by promoting inquiry, collaboration, critical reflection, and evidence-based argumentation. Furthermore, SCL enhances broader dimensions of academic literacy, including academic reading and writing, critical thinking, scientific reasoning, communication skills, and learner autonomy. Among the pedagogical strategies identified, Inquiry-Based Learning, Project-Based Learning, collaborative writing with peer feedback, and technology-enhanced learning demonstrated the strongest and most consistent positive outcomes. These findings suggest that Student-Centered Learning provides an integrated pedagogical framework that transforms scientific writing into an active process of knowledge construction while strengthening academic literacy. Consequently, this review offers valuable theoretical insights and practical recommendations for educators, curriculum developers, and policymakers seeking to design learner-centered scientific writing programs that effectively prepare students for higher education and lifelong learning.

INTRODUCTION

The rapid advancement of science, technology, and digital communication has transformed the competencies required of students in the twenty-first century. Contemporary education no longer emphasizes the acquisition of factual knowledge alone but increasingly prioritizes higher-

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order thinking skills, problem-solving abilities, collaboration, communication, creativity, and academic literacy. Among these competencies, academic literacy has become one of the most fundamental capacities because it enables students to critically access, evaluate, synthesize, and communicate scientific information in accordance with academic conventions. As students prepare for higher education and increasingly knowledge-based societies, the ability to produce scientific writing has become an essential indicator of educational quality rather than merely an additional academic skill.

Scientific writing represents one of the highest forms of academic literacy because it requires students to integrate reading comprehension, information literacy, critical reasoning, argument construction, evidence-based analysis, and academic communication into a coherent scholarly product. However, many senior high school students continue to experience difficulties in developing scientific writing competence. These challenges include limited understanding of scientific writing structures, insufficient ability to organize ideas logically, inadequate utilization of scholarly references, weak academic language proficiency, and limited opportunities to engage in authentic writing practices. Consequently, scientific writing instruction should not merely emphasize the final written product but should also facilitate students' cognitive, metacognitive, and collaborative learning processes throughout knowledge construction.

Recent educational reforms have increasingly shifted from teacher-centered instruction toward Student-Centered Learning (SCL), which positions students as active participants in constructing knowledge rather than passive recipients of information. Within this paradigm, teachers function primarily as facilitators who design meaningful learning environments that encourage inquiry, collaboration, reflection, and independent learning. Such pedagogical transformation aligns closely with the objectives of scientific writing instruction because scientific writing inherently requires students to formulate questions, analyze evidence, evaluate information, construct logical arguments, and communicate findings systematically.

Growing empirical evidence demonstrates that Student-Centered Learning significantly contributes to the development of higher-order thinking skills required for academic writing. Active learning environments encourage students to participate in discussions, collaborative investigations, analytical reasoning, and problem-solving activities that collectively strengthen scientific literacy, communication skills, and critical thinking (Irwandi et al., 2025). Similarly, investigation-oriented learning strategies provide students with opportunities to engage collaboratively in knowledge construction, thereby improving both critical thinking and collaborative competencies that are indispensable for producing high-quality scientific papers (Listiana et al., 2023). These findings indicate that Student-Centered Learning extends beyond instructional methodology; it represents a comprehensive educational philosophy that promotes intellectual independence and academic engagement.

Academic literacy is likewise strengthened when students are actively involved in meaningful learning experiences rather than relying solely on traditional lecture-based instruction. Contextual learning approaches have been shown to improve scientific literacy because students actively discover, analyze, and communicate knowledge within authentic contexts, resulting in deeper conceptual understanding and more meaningful learning experiences (Sari et al., 2022). Likewise, strengthening school literacy programs through continuous integration into classroom instruction has been found to enhance students' scientific literacy, critical thinking, and ability to interpret and communicate scientific information effectively (Susilowati et al., 2024). These findings reinforce the notion that literacy development should be embedded across learning activities instead of being treated as an isolated instructional objective.

The effectiveness of Student-Centered Learning becomes even more apparent when integrated with inquiry-based pedagogy. Inquiry learning encourages students to investigate authentic problems, explore diverse sources of information, formulate arguments, and construct evidence-based conclusions independently. Such learning experiences have been found to improve students' writing abilities because learners actively develop ideas, organize arguments systematically, and refine their academic communication through investigative processes (Putri & Novita, 2024). Rather than memorizing writing conventions, students gradually internalize scientific reasoning by engaging directly with authentic academic tasks.

Similarly, project-oriented instructional approaches provide meaningful opportunities for students to integrate knowledge with real-world applications. Project-Based Learning enables learners to participate actively in planning, implementing, and evaluating academic projects, thereby strengthening scientific literacy, independent learning, communication, and problem-solving abilities (Rediani, 2024). The integration of project-based learning with digital technology further enhances these outcomes by facilitating experimentation, collaborative inquiry, and technology-supported knowledge construction. Such digital project-based learning environments have been demonstrated to improve scientific literacy, conceptual understanding, and critical thinking while simultaneously preparing students for twenty-first-century learning demands (Saputri et al., 2025).

Another important aspect of Student-Centered Learning involves collaborative academic writing. Inquiry-based collaborative writing encourages students to exchange ideas, conduct peer review, evaluate arguments, and revise their work based on constructive feedback. This collaborative process substantially improves academic writing quality while simultaneously strengthening students' critical thinking and analytical reasoning (Shofiah et al., 2024). Rather than perceiving writing as an individual task, collaborative writing transforms scientific writing into an interactive process of collective knowledge construction.

The development of scientific writing competence also requires appropriate instructional resources. Well-designed instructional materials that incorporate twenty-first-century competencies—including critical thinking, creativity, collaboration, and communication—have been shown to improve students' scientific writing abilities by creating more active and problem-oriented learning environments (Aisah & Sukiman, 2022). Furthermore, systematically organized scientific writing textbooks provide structured guidance on idea development, academic referencing, manuscript organization, and scholarly writing conventions, thereby enhancing students' writing competence through progressive instructional support (Ihsan et al., 2025). These instructional resources become increasingly effective when implemented within Student-Centered Learning environments that emphasize active participation, continuous reflection, and authentic learning experiences.

Collectively, these findings demonstrate that academic literacy and scientific writing competence cannot be developed through passive instructional approaches. Instead, they require learning environments that actively engage students in inquiry, collaboration, reflection, problem-solving, and authentic communication. Consequently, Student-Centered Learning offers a promising pedagogical framework for integrating scientific writing training with academic literacy development among senior high school students. Nevertheless, despite the growing body of literature supporting active learning approaches, the existing evidence remains fragmented across different educational contexts, instructional models, and literacy outcomes. A more comprehensive synthesis is therefore required to understand how Student-Centered Learning contributes

specifically to scientific writing training and academic literacy development at the senior high school level.

The successful implementation of scientific writing instruction depends not only on active pedagogical approaches but also on learning designs that systematically cultivate students' academic literacy. Academic literacy extends beyond the ability to read and write; it encompasses the capacity to interpret scholarly information, evaluate evidence critically, construct logical arguments, synthesize multiple sources, and communicate ideas using appropriate academic conventions. Consequently, scientific writing training should be designed as a continuous learning process in which students actively construct knowledge through inquiry, reflection, collaboration, and authentic academic practice rather than merely completing writing assignments.

One important pedagogical approach supporting this objective is disciplinary literacy, which emphasizes students' understanding of how knowledge is constructed, communicated, and validated within academic disciplines. Scientific writing develops more effectively when instruction integrates disciplinary literacy because students learn not only the formal structure of scientific papers but also the reasoning processes underlying evidence-based argumentation and scholarly communication (Zulfah & Senam, 2022). This perspective shifts writing instruction from teaching technical writing skills toward cultivating scientific reasoning and intellectual inquiry, thereby enabling students to understand why scientific writing follows particular academic conventions.

The quality of students' scientific writing is likewise influenced by several interconnected factors, including mastery of scientific paper structure, idea development, effective use of scholarly references, and adherence to academic language conventions. These competencies cannot be acquired instantly but require continuous practice accompanied by constructive feedback throughout the learning process (Wulandari et al., 2022). Accordingly, scientific writing instruction should emphasize iterative learning cycles in which students repeatedly draft, revise, evaluate, and improve their academic work while receiving guidance from teachers and peers. Such an approach aligns closely with Student-Centered Learning because students become active participants responsible for improving the quality of their own learning.

Another essential dimension concerns the integration of twenty-first-century competencies into scientific writing instruction. Educational institutions increasingly recognize that effective academic writing requires not only linguistic proficiency but also critical thinking, creativity, collaboration, and communication skills. Instructional materials developed around these four competencies (4C skills) have demonstrated positive impacts on students' scientific writing performance because they encourage learners to solve authentic problems, communicate ideas effectively, collaborate with classmates, and generate innovative academic solutions (Aisah & Sukiman, 2022). These competencies represent essential components of Student-Centered Learning, where learning activities encourage students to become independent thinkers rather than passive recipients of information.

Similarly, authentic scientific writing programs that combine technology integration, case-based learning, collaborative activities, research presentations, and structured mentoring have proven effective in strengthening students' reading abilities, writing competence, literacy motivation, reflective thinking, and academic engagement (Maula & Harahap, 2024). These findings suggest that scientific writing training should not be viewed merely as a language-learning activity but as a multidisciplinary academic process integrating research, communication, collaboration, and reflective learning. Such comprehensive instructional designs create meaningful learning experiences that simultaneously improve students' academic literacy and research competence.

Beyond instructional materials and literacy-oriented approaches, problem-oriented learning models also contribute substantially to scientific writing development. Learning activities centered on contextual problems encourage students to analyze complex situations, evaluate evidence, formulate logical arguments, and develop scientifically supported solutions. Consequently, students become more capable of producing coherent and academically rigorous scientific writing because they continuously practice evidence-based reasoning throughout the learning process (Yuliarti & Mulyono, 2024). These findings reinforce the importance of designing scientific writing instruction around authentic problems rather than isolated writing exercises.

Likewise, Project-Based Learning provides students with opportunities to transform theoretical knowledge into authentic academic products through sustained inquiry and collaborative investigation. Students participating in project-based learning are actively involved in planning, implementing, monitoring, and evaluating learning projects, resulting in improved reading competence, academic writing, critical thinking, communication, and scientific literacy (Mokalu et al., 2024). Rather than treating writing as the final stage of instruction, Project-Based Learning positions writing as an integral component of knowledge construction, allowing students to document, analyze, and communicate their learning outcomes systematically.

The integration of digital technology further strengthens these educational processes. Contemporary digital project-based learning environments facilitate collaborative investigation, information retrieval, experimentation, and technology-supported communication, thereby enhancing students' scientific literacy, conceptual understanding, and higher-order thinking skills (Saputri et al., 2025). Given the rapid digitalization of education, scientific writing instruction increasingly requires technological support that enables students to access scholarly information efficiently, collaborate remotely, revise academic manuscripts collaboratively, and communicate research findings using various digital platforms.

Collaborative learning also plays a significant role in improving academic writing quality. Inquiry-based collaborative writing enables students to exchange perspectives, provide peer feedback, evaluate arguments critically, and revise manuscripts through iterative discussions. Such collaborative interactions substantially strengthen critical thinking, academic reasoning, and scientific writing competence because students learn not only from instructors but also from peer evaluation and collective reflection (Shofiah et al., 2024). These findings further illustrate that scientific writing is fundamentally a social and intellectual process in which knowledge is refined through dialogue and collaboration.

The growing body of empirical evidence demonstrates that Student-Centered Learning contributes positively to scientific writing competence through various instructional approaches, including inquiry-based learning, project-based learning, contextual learning, collaborative writing, disciplinary literacy, authentic literacy programs, and technology-supported instruction. Collectively, these approaches promote active participation, independent inquiry, collaborative problem-solving, critical reflection, and academic communication, all of which constitute essential dimensions of academic literacy among senior high school students. Nevertheless, although these studies consistently report positive educational outcomes, most investigate individual instructional models, specific classroom interventions, or isolated literacy components. Comprehensive syntheses examining how Student-Centered Learning systematically enhances scientific writing training and academic literacy remain relatively limited, particularly within the context of secondary education.

This limitation becomes increasingly important because senior high school represents a critical educational stage during which students begin developing research competence and

preparing for higher education. Strengthening scientific writing and academic literacy during this period has significant implications for students' readiness to participate in academic communities, conduct independent inquiry, and engage in evidence-based communication throughout their educational trajectories. Therefore, a systematic synthesis of existing empirical evidence is necessary to establish a comprehensive understanding of how Student-Centered Learning can be effectively implemented in scientific writing training to improve the academic literacy of senior high school students.

The increasing integration of Student-Centered Learning (SCL) into contemporary education has attracted considerable scholarly attention over the past decade. Numerous empirical studies have consistently demonstrated that learning environments emphasizing active participation, inquiry, collaboration, and reflection contribute significantly to students' academic achievement and higher-order thinking skills. However, despite the growing body of evidence supporting Student-Centered Learning, relatively few studies have comprehensively synthesized its contribution to scientific writing training and academic literacy development among senior high school students. Consequently, understanding the current state of knowledge requires careful examination of previous research while simultaneously identifying unresolved issues that remain underexplored.

One of the most comprehensive studies was conducted by Kerimbayev et al. (2023), who performed a systematic literature review examining the implementation of Student-Centered Learning supported by modern technologies in distance education. Their review concluded that Student-Centered Learning consistently improves student engagement, independent learning, collaboration, critical thinking, and overall learning achievement across various educational settings. More importantly, the study highlighted a fundamental transformation in teachers' professional roles, shifting from knowledge transmitters toward facilitators who guide learners in constructing knowledge independently. Although this study provides strong theoretical support for Student-Centered Learning, its discussion primarily focuses on digital learning environments and general educational outcomes rather than specifically addressing scientific writing instruction or academic literacy among secondary school students.

Similarly, Lee and De La Paz (2021) synthesized previous studies concerning science writing interventions designed for students with learning disabilities and English learners. Their systematic review demonstrated that student-centered writing instruction substantially improves scientific writing quality, conceptual understanding, organizational skills, and critical thinking. The authors further emphasized that writing activities involving exploration, discussion, revision, and reflective learning produce significantly better outcomes than traditional teacher-centered instruction. Nevertheless, the review concentrates primarily on intervention strategies within science education and special educational contexts without providing a comprehensive synthesis concerning the broader development of academic literacy through Student-Centered Learning at the senior high school level.

Further evidence supporting learner-centered scientific writing was presented by Kong et al. (2024), who investigated instructional approaches designed to overcome barriers in scientific writing. Their findings indicated that peer exchange, collaborative discussion, reflective writing, and structured goal-setting effectively reduce writing anxiety while simultaneously improving writing quality, motivation, and critical thinking. The study demonstrated that students become more confident academic writers when they actively participate in collaborative learning communities. Although these findings strongly reinforce Student-Centered Learning principles, the investigation was conducted primarily within higher education contexts, thereby limiting its

applicability to senior secondary education where students possess different developmental characteristics and academic needs.

Comparable conclusions were reported by Kim and Kim (2024), who examined the implementation of Writing-to-Learn strategies in secondary science classrooms. Their research revealed that continuous writing activities significantly improve students' conceptual understanding, reasoning abilities, communication skills, and academic literacy. Students participating in active writing tasks demonstrated higher levels of conceptual comprehension than those experiencing conventional instruction because writing functioned as a cognitive tool for knowledge construction rather than merely an assessment activity. These findings further confirm the close relationship between active learning and academic literacy development. However, the study focuses primarily on science learning outcomes rather than examining scientific writing training as a structured educational program.

Within the Indonesian educational context, Maula and Harahap (2024) investigated the implementation of an Authentic Literacy Program through scientific writing activities at MTsN 2 Cirebon. Their study found that integrating collaborative learning, technology, case-based instruction, mentoring, and research presentation significantly enhanced students' reading competence, writing skills, reflective thinking, literacy motivation, and scientific communication. This research provides valuable empirical evidence supporting scientific writing as an effective vehicle for academic literacy development. Nevertheless, the investigation remains context-specific and does not synthesize broader empirical evidence regarding Student-Centered Learning across diverse educational settings.

Collectively, these previous studies consistently demonstrate that Student-Centered Learning positively influences scientific writing, academic communication, critical thinking, collaboration, and literacy development. Likewise, empirical findings from Indonesian researchers indicate that inquiry-based learning (Putri & Novita, 2024), contextual learning (Sari et al., 2022), disciplinary literacy instruction (Zulfah & Senam, 2022), project-based learning (Rediani, 2024; Mokalu et al., 2024), collaborative inquiry writing (Shofiah et al., 2024), authentic literacy programs (Maula & Harahap, 2024), scientific writing instructional materials (Aisah & Sukiman, 2022; Ihsan et al., 2025), literacy movement integration (Susilowati et al., 2024), digital project-based learning (Saputri et al., 2025), problem-oriented learning (Yuliarti & Mulyono, 2024), investigation-based learning (Listiana et al., 2023), and active scientific literacy instruction (Irwandi et al., 2025) all contribute to strengthening various dimensions of students' academic competence. Despite these positive findings, most existing studies examine these instructional approaches independently rather than integrating them into a unified conceptual framework explaining how Student-Centered Learning systematically enhances scientific writing training and academic literacy.

This situation reveals several important research gaps. First, previous investigations predominantly employ experimental, quasi-experimental, classroom action research, or case study methodologies, whereas systematic literature reviews synthesizing recent empirical findings remain limited. Second, many studies investigate either Student-Centered Learning, scientific writing, or academic literacy separately without explicitly analyzing the interrelationships among these three constructs. Third, previous research largely focuses on higher education or specific classroom interventions, leaving relatively limited evidence concerning comprehensive scientific writing training for senior high school students. Fourth, despite increasing educational attention toward twenty-first-century competencies, there remains insufficient synthesis regarding how various student-centered instructional models collectively contribute to developing academic literacy through scientific writing instruction.

Addressing these research gaps constitutes the principal novelty of the present study. Unlike previous investigations focusing on single instructional models or isolated educational interventions, this study systematically synthesizes empirical evidence concerning Student-Centered Learning in scientific writing training specifically aimed at enhancing the academic literacy of senior high school students. By integrating findings from recent national and international publications, this review develops a comprehensive conceptual understanding of the pedagogical mechanisms through which Student-Centered Learning strengthens scientific writing competence, critical thinking, collaborative learning, scientific communication, and academic literacy. Furthermore, the study identifies emerging research trends, recurring instructional patterns, existing methodological limitations, and future research directions that have not been comprehensively discussed in previous reviews.

Based on the identified research gaps, this systematic literature review addresses the following research question: How does Student-Centered Learning contribute to scientific writing training in enhancing the academic literacy of senior high school students, and what pedagogical strategies have been demonstrated to be most effective according to recent empirical evidence?

Accordingly, the objective of this study is to systematically review and synthesize recent empirical literature concerning the implementation of Student-Centered Learning in scientific writing training for senior high school students. Specifically, this review seeks to identify effective instructional approaches, examine their contributions to academic literacy development, analyze recurring pedagogical patterns, and formulate evidence-based recommendations for future educational practice and research.

The significance of this study is both theoretical and practical. Theoretically, this review enriches the growing body of literature concerning Student-Centered Learning, scientific writing instruction, and academic literacy by integrating fragmented empirical findings into a coherent conceptual framework. It also extends current understanding regarding the relationship between active learning environments and academic writing competence within secondary education. Practically, the findings provide valuable guidance for teachers, curriculum developers, school administrators, and educational policymakers in designing scientific writing programs that effectively promote students' academic literacy through learner-centered pedagogical approaches. Ultimately, this systematic literature review is expected to contribute to improving the quality of scientific writing instruction while supporting the development of academically literate graduates who are well prepared to participate successfully in higher education and lifelong scholarly learning.

METHODS

1. Research Approach

This study employed a Systematic Literature Review (SLR) approach to synthesize and critically analyze previous empirical studies concerning the implementation of Student-Centered Learning (SCL) in scientific writing training to enhance the academic literacy of senior high school students. A systematic literature review was considered appropriate because it enables researchers to identify, evaluate, and integrate research findings using transparent, systematic, and replicable procedures. According to Page et al. (2021), systematic reviews provide rigorous evidence by applying explicit criteria during the identification, selection, evaluation, and synthesis of relevant studies. Likewise, Snyder (2019) emphasized that systematic literature reviews contribute to theory development by summarizing current knowledge, identifying research trends, and revealing existing research gaps. Therefore, the SLR approach was expected to provide a comprehensive

understanding of the relationship between Student-Centered Learning, scientific writing instruction, and academic literacy.

2. Research Design

This study adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework as the research design. The PRISMA guidelines were used to ensure that the literature review process was conducted systematically, transparently, and consistently. The review process consisted of four sequential stages: identification, screening, eligibility assessment, and inclusion of relevant studies. Following the recommendations of Page et al. (2021), each stage was documented to enhance the transparency and reproducibility of the review process. The selected studies focused on Student-Centered Learning, scientific writing instruction, academic literacy, and related instructional approaches published between **2021 and 2025**.

3. Data Sources and Data Collection

The literature was collected from several reputable academic databases, including Scopus, Web of Science, ERIC, ScienceDirect, SpringerLink, Taylor & Francis Online, Google Scholar, and the Directory of Open Access Journals (DOAJ). These databases were selected because they provide high-quality peer-reviewed publications in education and social sciences. To obtain relevant literature, combinations of keywords such as *Student-Centered Learning*, *Scientific Writing*, *Scientific Writing Training*, *Academic Literacy*, *Writing Instruction*, *Academic Writing*, *Active Learning*, and *Senior High School Students* were employed using Boolean operators (AND and OR). Xiao and Watson (2019) explained that systematic searching across multiple academic databases improves the comprehensiveness of literature retrieval while minimizing publication bias. Consequently, searching multiple databases increased the likelihood of identifying studies that were directly relevant to the objectives of this review.

4. Inclusion and Exclusion Criteria

To ensure the relevance and quality of the selected literature, predefined inclusion and exclusion criteria were established before the review process. The inclusion criteria comprised: (1) articles published between 2021 and 2025; (2) peer-reviewed journal articles; (3) publications written in English or Indonesian; (4) studies discussing Student-Centered Learning, scientific writing, academic literacy, or related pedagogical approaches; and (5) empirical studies conducted in secondary or higher education settings. Conversely, conference abstracts, editorials, book reviews, opinion papers, duplicate publications, and studies lacking sufficient methodological information were excluded from the review. The application of explicit selection criteria reduced potential bias and ensured that only studies relevant to the research objectives were included in the final analysis (Page et al., 2021).

5. Data Extraction and Analysis

Following the selection process, the included studies were organized using a literature matrix consisting of the authors, publication year, research objectives, research methods, participants, instructional approaches, principal findings, and educational implications. This procedure facilitated systematic comparison across studies and enabled the identification of recurring themes and research patterns. The collected data were subsequently analyzed using **thematic content analysis**, whereby similar findings were categorized into major themes, including Student-Centered Learning implementation, scientific writing instruction, academic literacy development, inquiry-based learning, project-based learning, collaborative learning, and critical thinking. Braun and Clarke (2021) argued that thematic analysis provides a flexible yet rigorous approach for identifying meaningful patterns across qualitative datasets. Accordingly, thematic analysis enabled

the researcher to synthesize diverse empirical findings into a coherent conceptual framework explaining how Student-Centered Learning contributes to scientific writing training and academic literacy enhancement.

6. Trustworthiness of the Review

To ensure the credibility and trustworthiness of the review, only peer-reviewed journal articles published in reputable academic databases were included. Furthermore, each selected article was carefully examined in terms of its research objectives, methodological rigor, data collection procedures, findings, and relevance to the present study. Throughout the review process, the researcher consistently followed the PRISMA 2020 reporting guidelines to maintain transparency, consistency, and replicability. According to Page et al. (2021), adherence to standardized systematic review procedures enhances the validity and reliability of evidence synthesis while reducing the possibility of researcher bias. Therefore, the methodological procedures adopted in this study were expected to produce a comprehensive, reliable, and evidence-based synthesis regarding the implementation of Student-Centered Learning in scientific writing training to enhance the academic literacy of senior high school students.

RESULTS

1. The Contributions of Student-Centered Learning to Scientific Writing Training in Enhancing Academic Literacy

a. Student-Centered Learning and Scientific Writing Development

The synthesis of the selected studies consistently demonstrated that Student-Centered Learning (SCL) plays a significant role in improving students' scientific writing competence. Across the reviewed literature, SCL shifted the learning process from teacher-directed instruction to active student engagement, enabling learners to construct knowledge through inquiry, collaboration, discussion, reflection, and authentic writing experiences. Rather than merely learning the structure of scientific papers, students were encouraged to explore scientific problems, analyze evidence, formulate arguments, and communicate ideas systematically.

One of the most frequently reported findings was the importance of active learning during scientific writing instruction. Kerimbayev et al. (2023) revealed that learner-centered learning environments supported by technology increased students' engagement, independent learning, collaboration, and critical thinking, all of which contributed to more meaningful learning experiences. Similarly, Westbrook et al. (2022) concluded that learner-centered pedagogy consistently enhanced students' participation, motivation, and academic achievement across various educational settings. These findings indicate that active participation is a fundamental element in developing scientific writing competence because students learn by constructing knowledge rather than passively receiving information.

The reviewed studies also showed that Student-Centered Learning significantly improved scientific writing competence. Inquiry-Based Learning encouraged students to investigate problems, organize ideas logically, and present evidence-based conclusions. Putri and Novita (2024) reported that inquiry-oriented instruction positively influenced students' writing achievement by promoting independent investigation and reflective thinking. Likewise, Lin et al. (2023) found that inquiry-based writing instruction strengthened students' ability to organize scientific ideas, integrate evidence, and produce coherent academic texts.

Several studies further emphasized that structured scientific writing programs contributed substantially to students' writing quality. Maula and Harahap (2024) demonstrated that the Authentic Literacy Program improved students' academic writing skills through collaborative learning, research presentations, and technology integration. Likewise, Ihsan et al. (2025) reported

that systematic scientific writing textbooks enhanced students' understanding of scientific writing conventions, citation practices, and manuscript organization. Wulandari et al. (2022) similarly found that students' scientific writing ability was influenced by their understanding of academic writing structures, language accuracy, and appropriate use of scholarly references.

Another important finding emerging from this review concerns the development of evidence-based argumentation. Scientific writing was consistently reported as more effective when students were encouraged to formulate arguments supported by empirical evidence. Zulfah and Senam (2022) demonstrated that disciplinary literacy instruction enabled students to construct stronger scientific arguments by integrating reading, writing, and analytical reasoning within disciplinary contexts. Likewise, Yuliarti and Mulyono (2024) found that problem-oriented learning improved students' scientific writing by encouraging them to analyze authentic issues and formulate evidence-based solutions. Furthermore, Lee and De La Paz (2021) concluded that student-centered science writing interventions improved students' ability to organize arguments, synthesize scientific information, and communicate ideas effectively through iterative writing and revision processes.

Overall, the reviewed studies consistently indicate that Student-Centered Learning creates an active learning environment in which students develop scientific writing competence through inquiry, collaboration, critical reflection, and evidence-based reasoning. These pedagogical characteristics contribute not only to improved writing quality but also to the development of essential academic competencies required for scientific communication.

b. Student-Centered Learning and Academic Literacy

The synthesis of the selected studies further revealed that Student-Centered Learning contributes substantially to the development of students' academic literacy. Rather than focusing solely on writing products, learner-centered instruction promotes academic reading, critical analysis, scientific reasoning, communication, and independent learning. Across the reviewed studies, academic literacy emerged as a multidimensional competence encompassing the ability to access, evaluate, synthesize, and communicate scientific information effectively.

A consistent finding across the reviewed literature was the enhancement of academic reading and writing literacy through active learning approaches. Scientific writing activities encouraged students to read scholarly sources critically, evaluate the credibility of evidence, and integrate information into coherent academic texts. Maula and Harahap (2024) reported that the Authentic Literacy Program improved students' reading comprehension, academic writing ability, literacy motivation, and reflective learning through collaborative and technology-supported activities. Likewise, Aisah and Sukiman (2022) found that scientific writing instructional materials integrating twenty-first-century (4C) skills enabled students to develop stronger writing competence while simultaneously improving communication, creativity, collaboration, and critical thinking. These findings indicate that scientific writing training functions as an effective medium for strengthening students' overall academic literacy.

The reviewed studies also consistently demonstrated improvements in critical thinking and scientific reasoning. Student-Centered Learning provides opportunities for learners to investigate authentic problems, analyze evidence, formulate conclusions, and defend their arguments through academic discussion and writing. Irwandi et al. (2025) showed that discussion-based learning combined with critical analysis significantly enhanced students' scientific literacy and analytical thinking. Similarly, Listiana et al. (2023) reported that investigation-based learning effectively strengthened students' critical thinking and collaborative skills, both of which are essential components of academic literacy. Comparable findings were reported by Susilowati et al. (2024),

who found that integrating the School Literacy Movement into classroom instruction improved students' scientific literacy while fostering higher-order thinking skills.

Another important theme identified in this review was the improvement of academic communication and learner autonomy. Student-Centered Learning encourages students to communicate scientific ideas through discussion, presentation, collaborative writing, and peer review. Wei and Liu (2024) concluded that peer feedback significantly improved academic writing quality by helping students revise arguments, refine language, and strengthen the organization of their manuscripts. Likewise, Shofiah et al. (2024) found that collaborative inquiry writing provided meaningful opportunities for students to exchange ideas, evaluate peer work, and improve the quality of academic arguments. These collaborative activities gradually promoted learner autonomy, as students became increasingly responsible for evaluating, revising, and improving their own academic work.

Project-oriented learning also emerged as an effective strategy for strengthening academic literacy. Rediani (2024) demonstrated that Project-Based Learning enhanced students' scientific literacy, self-directed learning, and problem-solving abilities by engaging them in authentic academic tasks. Similarly, Moku et al. (2024) reported that project-based scientific writing activities encouraged students to integrate academic knowledge with practical experiences, thereby improving literacy skills and communication competence. Furthermore, Saputri et al. (2025) found that digital project-based learning significantly enhanced scientific literacy, critical thinking, and conceptual understanding by combining collaborative inquiry with technology-supported learning environments.

Overall, the findings synthesized in this review indicate that Student-Centered Learning contributes to academic literacy through multiple interconnected pathways. Active participation, inquiry, collaboration, project-based learning, peer feedback, and technology integration collectively enhance students' academic reading and writing abilities, critical thinking, scientific reasoning, communication skills, and independent learning. These findings suggest that Student-Centered Learning not only improves scientific writing competence but also supports the broader development of academic literacy required for successful participation in higher education and lifelong learning.

Figure 1 summarizes the synthesized findings of the systematic literature review regarding the contribution of Student-Centered Learning (SCL) to scientific writing training and the enhancement of academic literacy among senior high school students. The figure presents the key pedagogical processes and learning outcomes identified across the reviewed empirical studies.

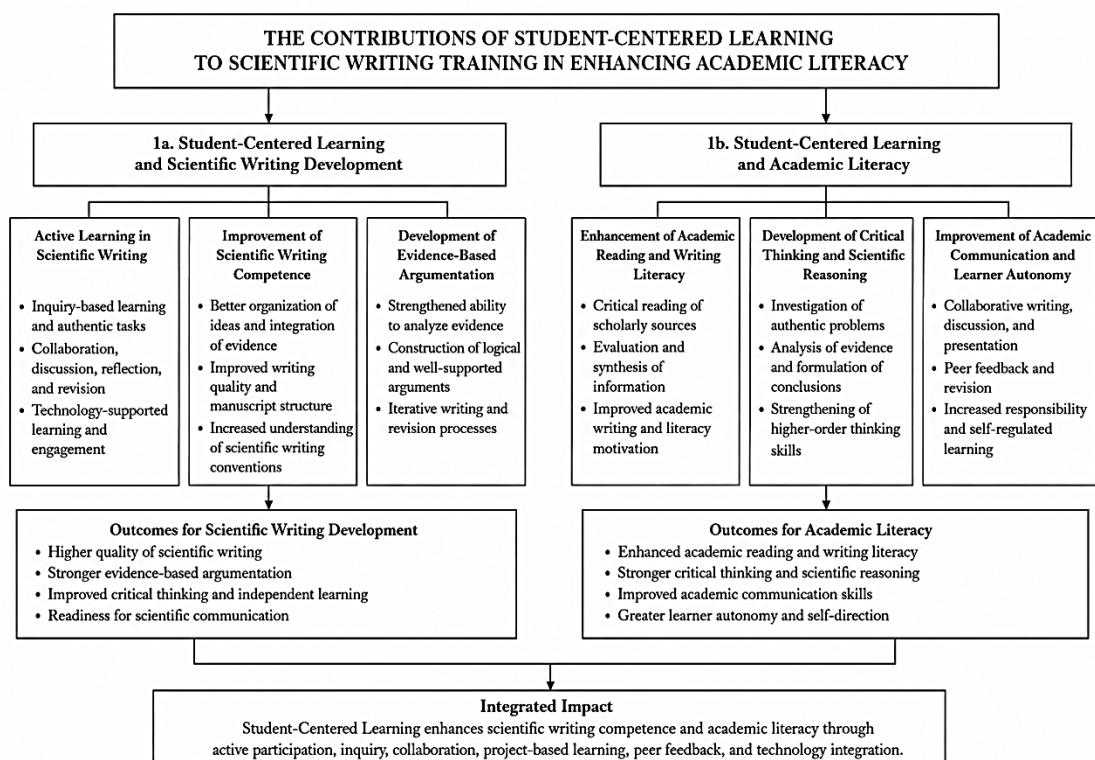


Figure 1. The contributions of Student-Centered Learning to scientific writing training in enhancing academic literacy: A synthesis of the reviewed studies.

Figure 1 illustrates that Student-Centered Learning serves as the central pedagogical approach that facilitates the development of scientific writing competence and academic literacy through active, inquiry-driven, and collaborative learning experiences. The synthesis indicates that instructional strategies such as inquiry-based learning, collaborative learning, project-based learning, peer feedback, and technology-supported learning encourage students to actively construct knowledge, develop evidence-based arguments, and engage in scientific communication. These learning experiences strengthen students' scientific writing skills by improving idea organization, academic writing conventions, and the integration of credible evidence. Simultaneously, they foster broader academic literacy outcomes, including academic reading and writing proficiency, critical thinking, scientific reasoning, communication skills, and learner autonomy. Overall, the figure demonstrates that Student-Centered Learning functions as an integrated pedagogical framework that connects active learning processes with the development of higher-order academic competencies essential for scientific writing and lifelong learning.

2. Effective Pedagogical Strategies Identified in Recent Empirical Studies

The systematic review identified several pedagogical strategies that consistently enhanced students' scientific writing competence and academic literacy. Although the reviewed studies employed different instructional models and learning contexts, they shared a common characteristic: positioning students as active participants in constructing knowledge through authentic learning experiences. Among the most frequently reported approaches were Inquiry-Based Learning, Project-Based Learning, Collaborative Learning with Peer Review, Problem-Based and Contextual Learning, and Technology-Enhanced Student-Centered Learning. These approaches collectively promoted scientific writing skills, critical thinking, collaboration, academic communication, and learner autonomy.

a. Inquiry-Oriented Pedagogical Strategies

The reviewed studies consistently identified inquiry-oriented learning as one of the most effective strategies for improving scientific writing. Inquiry-Based Learning encouraged students to investigate authentic problems, collect and analyze evidence, formulate scientific explanations, and communicate their findings systematically. Through this process, scientific writing became an integral component of knowledge construction rather than merely a final assessment task.

Putri and Novita (2024) reported that Inquiry-Based Learning significantly improved students' writing achievement by promoting active investigation, reflective thinking, and independent learning. Likewise, Lin et al. (2023) found that inquiry-based writing instruction strengthened students' ability to organize scientific ideas, integrate evidence, and develop coherent academic texts. Furthermore, Lee and De La Paz (2021) demonstrated that inquiry-oriented science writing interventions enhanced scientific reasoning, conceptual understanding, and academic writing quality because students continuously revised and refined their ideas through evidence-based writing activities.

b. Collaborative and Project-Oriented Learning Strategies

Another dominant strategy identified in the reviewed studies was collaborative and project-oriented learning. These instructional approaches encouraged students to work together in designing projects, solving authentic problems, exchanging ideas, and producing scientific writing collaboratively. Such activities strengthened not only writing competence but also communication skills, teamwork, and learner responsibility.

Rediani (2024) found that Project-Based Learning improved scientific literacy, learner autonomy, and problem-solving abilities through authentic project implementation. Similarly, Mokalulu et al. (2024) reported that project-based scientific writing activities enabled students to integrate theoretical knowledge with practical experiences while simultaneously enhancing literacy and academic communication. Shofiah et al. (2024) further revealed that collaborative inquiry writing and peer interaction significantly improved critical thinking and the quality of students' academic arguments. Complementing these findings, Wei and Liu (2024) concluded that peer feedback facilitated manuscript revision, strengthened evidence-based argumentation, and improved the overall quality of academic writing.

c. Technology-Enhanced Student-Centered Learning

Technology integration emerged as another important pedagogical strategy supporting scientific writing instruction. Digital learning environments provided students with opportunities to access academic resources, collaborate virtually, exchange feedback, and develop scientific writing through technology-supported platforms. These environments also encouraged students to become more independent and reflective learners.

Kerimbayev et al. (2023) reported that technology-supported Student-Centered Learning significantly enhanced learner engagement, collaboration, self-regulated learning, and critical thinking in various educational settings. Likewise, Saputri et al. (2025) found that digital Project-Based Learning effectively improved scientific literacy, critical thinking, and conceptual understanding through technology-assisted inquiry and collaborative problem-solving. These findings suggest that integrating digital technologies into Student-Centered Learning creates more flexible and interactive learning environments that support scientific writing development and academic literacy.

Figure 2 presents the synthesis of effective pedagogical strategies identified across the reviewed empirical studies. It illustrates how various Student-Centered Learning approaches collectively enhance scientific writing competence and academic literacy.

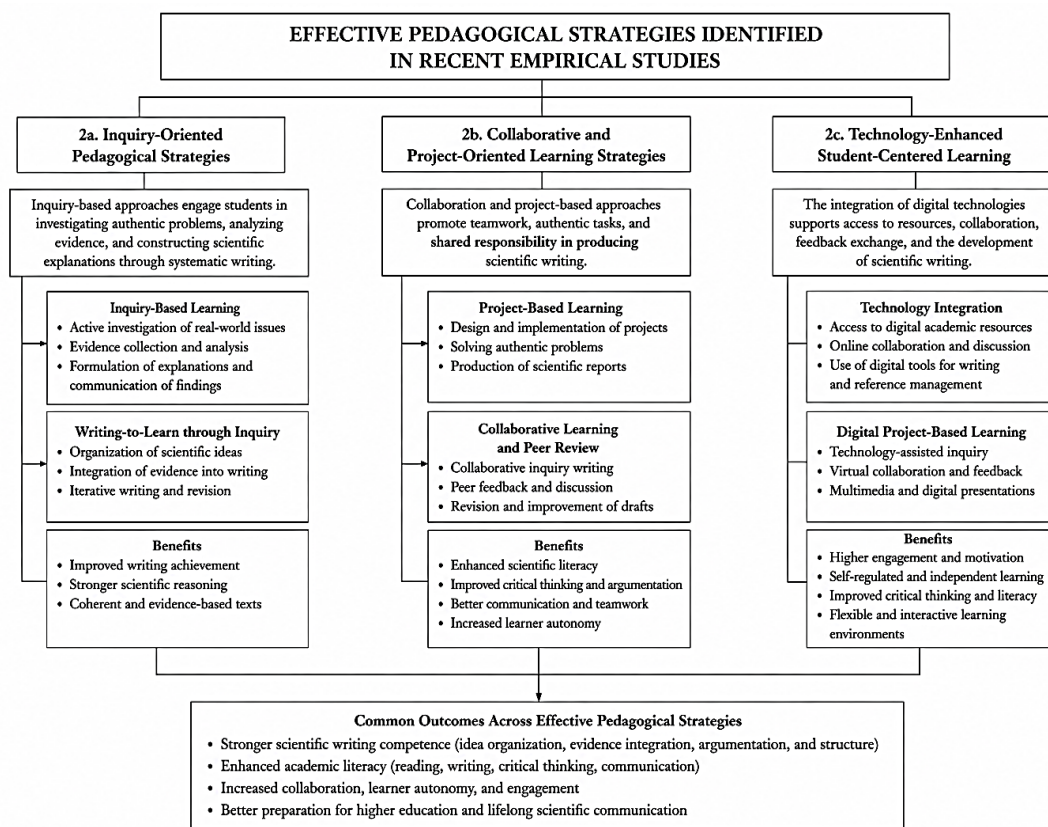


Figure 2. Effective pedagogical strategies identified in recent empirical studies for enhancing scientific writing and academic literacy.

Figure 2 demonstrates that effective scientific writing instruction is achieved through the integration of multiple Student-Centered Learning strategies rather than the application of a single instructional approach. Inquiry-Based Learning promotes scientific investigation, evidence analysis, and reflective writing, enabling students to construct well-organized academic arguments. Collaborative and Project-Based Learning strengthen communication, teamwork, problem-solving, and learner autonomy by engaging students in authentic writing tasks and peer interaction. Meanwhile, technology-enhanced learning supports flexible access to academic resources, online collaboration, and continuous feedback, thereby improving scientific writing quality, critical thinking, and digital literacy. Collectively, these pedagogical strategies create an active and learner-centered environment that fosters scientific communication, evidence-based reasoning, academic literacy, and independent learning, highlighting Student-Centered Learning as a comprehensive framework for scientific writing education.

DISCUSSION

1. Analysis of Results

a. Student-Centered Learning and Scientific Writing Development

The findings of this systematic literature review demonstrate that Student-Centered Learning (SCL) provides a comprehensive pedagogical framework for improving students' scientific writing competence. Rather than positioning writing as a final product, the reviewed studies indicate that scientific writing develops through an active learning process in which students investigate authentic problems, construct knowledge collaboratively, evaluate evidence, and continuously refine their written arguments. This finding directly addresses the first research question by demonstrating that the contribution of Student-Centered Learning lies in transforming scientific writing into a process of inquiry, reflection, and knowledge construction.

From a conceptual perspective, the effectiveness of Student-Centered Learning can be explained by its emphasis on learner agency. Students actively participate in identifying problems, interpreting information, organizing ideas, and communicating scientific evidence, thereby strengthening both procedural and conceptual understanding of academic writing. Consequently, scientific writing competence extends beyond mastering writing conventions to encompass the ability to construct logical arguments, integrate scholarly evidence, and communicate ideas systematically. This interpretation indicates that scientific writing training becomes substantially more meaningful when students function as active knowledge producers rather than passive recipients of information.

Furthermore, the synthesis suggests that inquiry-oriented activities, collaborative discussion, and iterative writing practices create an authentic learning environment that continuously supports writing development. Through repeated cycles of planning, drafting, receiving feedback, revising, and reflecting, students gradually develop stronger analytical reasoning and evidence-based argumentation. These learning experiences enable scientific writing to become an integral component of higher-order learning rather than merely an academic assignment. Such findings reinforce the argument that learner-centered instruction promotes deeper engagement with disciplinary knowledge and facilitates sustainable improvement in scientific writing competence.

The present findings are conceptually supported by previous literature emphasizing that Student-Centered Learning strengthens critical thinking, scientific communication, and collaborative knowledge construction through active participation in learning activities (Irwandi et al., 2025). Likewise, disciplinary literacy approaches demonstrate that scientific writing competence develops more effectively when students are encouraged to construct arguments based on empirical evidence rather than simply following formal writing structures (Zulfah & Senam, 2022). In addition, the integration of systematic writing practice accompanied by constructive feedback has been reported to facilitate continuous improvement in academic writing quality and students' ability to organize scientific ideas coherently (Wulandari et al., 2022).

Overall, the analysis indicates that the contribution of Student-Centered Learning extends beyond improving technical writing skills. Instead, it establishes scientific writing as a reflective, inquiry-driven, and evidence-based learning process that simultaneously develops critical reasoning, scientific communication, and academic competence, which collectively constitute essential components of academic literacy.

b. Student-Centered Learning and Academic Literacy

The synthesis of the reviewed studies demonstrates that Student-Centered Learning contributes substantially to the enhancement of students' academic literacy by integrating reading, writing, critical analysis, scientific reasoning, communication, and independent learning into a unified educational process. This finding directly addresses the first research question by indicating that the contribution of Student-Centered Learning extends beyond improving scientific writing competence to fostering broader academic literacy skills required for successful participation in higher education and lifelong learning.

From a conceptual perspective, academic literacy should be understood as a multidimensional competence rather than merely the ability to read and write academic texts. Within Student-Centered Learning, students actively engage in locating scholarly information, evaluating the credibility of evidence, synthesizing multiple sources, constructing logical arguments, and communicating scientific ideas through collaborative learning activities. Consequently, literacy development becomes an interactive process in which learners continuously construct and reconstruct knowledge through inquiry, discussion, reflection, and scientific writing. This learning

process strengthens not only academic performance but also students' capacity for independent learning and evidence-based decision-making.

The findings further indicate that critical thinking and scientific reasoning function as fundamental mechanisms connecting Student-Centered Learning with academic literacy development. When students investigate authentic problems, analyze empirical evidence, justify conclusions, and revise their written work based on feedback, they simultaneously strengthen higher-order cognitive skills. These experiences enable learners to evaluate scientific information critically, formulate well-supported arguments, and communicate complex ideas more effectively. Therefore, scientific writing serves as both a learning strategy and an assessment process through which academic literacy is continuously developed.

Another important finding concerns the role of collaboration and learner autonomy in strengthening academic literacy. The reviewed studies consistently suggest that collaborative writing, peer discussion, project-based learning, and technology-supported learning environments provide opportunities for students to exchange perspectives, negotiate meaning, evaluate peer work, and improve the quality of their academic communication. Such learning experiences gradually encourage students to become self-regulated learners who are capable of monitoring, evaluating, and improving their own learning processes. Consequently, academic literacy is developed not only through individual cognitive activities but also through meaningful social interaction and collaborative knowledge construction.

These findings are conceptually supported by previous studies emphasizing that Student-Centered Learning encourages students to actively construct knowledge through discussion, investigation, and collaborative problem-solving, thereby strengthening critical thinking and scientific literacy (Listiana et al., 2023). Similarly, the integration of authentic literacy activities into scientific writing instruction has been shown to improve students' reading comprehension, writing competence, literacy motivation, and reflective learning (Maula & Harahap, 2024). Furthermore, strengthening literacy-oriented learning environments through systematic literacy programs contributes significantly to the development of scientific literacy and higher-order thinking skills, which are fundamental dimensions of academic literacy (Susilowati et al., 2024).

Overall, the present findings indicate that Student-Centered Learning develops academic literacy through interconnected learning processes involving inquiry, collaboration, reflection, communication, and independent learning. Rather than treating literacy as an isolated academic skill, Student-Centered Learning establishes academic literacy as a comprehensive educational outcome that integrates scientific writing competence, critical reasoning, effective communication, and lifelong learning capabilities.

2. Comparison with Previous Studies

The findings of the present review are highly consistent with previous empirical evidence demonstrating that Student-Centered Learning is an effective pedagogical approach for improving scientific writing competence. Across the reviewed studies, students developed stronger writing abilities when they actively engaged in inquiry, collaborative learning, critical reflection, and evidence-based writing rather than relying on teacher-centered instruction. This consistency suggests that scientific writing is most effectively developed when students actively construct knowledge throughout the writing process.

The present findings support the systematic review conducted by Kerimbayev et al. (2023), which concluded that technology-supported Student-Centered Learning enhances learner engagement, collaboration, critical thinking, and independent learning. Similarly, the current review found that these learning characteristics provide a strong foundation for scientific writing

development by encouraging students to investigate problems, organize ideas systematically, and communicate scientific knowledge through authentic learning experiences. Both studies therefore emphasize that learner engagement is a prerequisite for developing higher-quality scientific writing.

The findings are also consistent with Lee and De La Paz (2021), who reported that student-centered science writing interventions significantly improve students' ability to organize scientific ideas, construct evidence-based arguments, and communicate disciplinary knowledge effectively. Likewise, the present review identified inquiry, iterative writing, and continuous revision as central mechanisms through which scientific writing competence is strengthened. These similarities indicate that active participation throughout the writing process consistently produces better academic writing outcomes than conventional writing instruction.

Furthermore, the present synthesis aligns with Lin et al. (2023), who found that inquiry-based writing instruction promotes deeper conceptual understanding and improves students' ability to integrate scientific evidence into coherent academic texts. The reviewed studies similarly demonstrate that inquiry-oriented learning enables students to develop logical reasoning and evidence-based argumentation while simultaneously strengthening their scientific writing competence. Overall, no substantial contradictions were identified between the current synthesis and previous international research, indicating a strong convergence of evidence regarding the effectiveness of Student-Centered Learning in scientific writing instruction.

The findings concerning academic literacy are likewise consistent with previous studies emphasizing the multidimensional impact of Student-Centered Learning. The present review indicates that learner-centered instruction improves not only scientific writing but also reading comprehension, critical thinking, scientific reasoning, communication skills, collaboration, and learner autonomy. These findings reinforce the growing consensus that academic literacy is developed through authentic learning experiences integrating inquiry, reflection, collaboration, and meaningful communication.

The current findings correspond closely with Maula and Harahap (2024), who demonstrated that the Authentic Literacy Program successfully enhanced students' academic reading, writing competence, literacy motivation, and reflective learning through collaborative and technology-supported instructional activities. Similarly, the present review identified authentic scientific writing activities as an effective mechanism for developing comprehensive academic literacy rather than isolated writing skills. Both studies therefore emphasize the importance of integrating literacy development into authentic classroom learning.

The present findings also support Irwandi et al. (2025), who concluded that discussion-based learning combined with critical analysis significantly improves scientific literacy and analytical thinking. Likewise, the reviewed studies consistently demonstrate that Student-Centered Learning strengthens students' ability to analyze information critically, evaluate evidence, formulate scientific arguments, and communicate ideas effectively. This similarity suggests that scientific literacy and academic literacy are complementary educational outcomes that develop through inquiry-oriented learning environments.

Furthermore, the current review is consistent with Listiana et al. (2023), who found that investigation-oriented learning effectively improves critical thinking and collaborative skills. These competencies also emerged as dominant outcomes across the reviewed studies included in the present review. Although previous studies were conducted in different educational contexts and subject areas, they consistently reported that active learner participation, collaborative inquiry, and problem-solving activities contribute substantially to the development of academic literacy. Consequently, the present systematic review strengthens existing empirical evidence by

demonstrating that Student-Centered Learning provides a coherent pedagogical framework capable of simultaneously improving scientific writing competence and broader academic literacy outcomes across diverse educational settings.

3. Implications of the Findings

The findings of this systematic literature review contribute to the growing body of evidence supporting Student-Centered Learning as an effective pedagogical framework for scientific writing instruction and academic literacy development. Theoretically, the review extends current understanding by demonstrating that scientific writing competence develops most effectively when integrated with inquiry, collaboration, critical reflection, and evidence-based reasoning rather than through product-oriented instruction alone. Practically, the findings suggest that teachers should adopt learner-centered instructional strategies, such as Inquiry-Based Learning, Project-Based Learning, collaborative writing, and technology-enhanced learning, to create authentic learning experiences that simultaneously strengthen scientific writing, critical thinking, communication, and learner autonomy. These implications provide useful guidance for curriculum developers, educators, and policymakers seeking to improve academic literacy among senior high school students.

4. Limitations of the Study

This review has several limitations that should be considered when interpreting the findings. First, the analysis included only studies published between 2021 and 2025, which may have excluded earlier influential research on Student-Centered Learning and scientific writing. Second, the review synthesized findings from studies conducted across different educational contexts, disciplines, and participant characteristics, which may influence the generalizability of the results. Third, because this study relied exclusively on published empirical literature, variations in research design, instructional implementation, and outcome measures among the selected studies may have introduced methodological heterogeneity. Future systematic reviews are therefore encouraged to include a broader publication period, conduct meta-analytic investigations, and compare findings across specific educational levels and disciplinary contexts.

5. Partial Conclusion

Overall, the discussion indicates that Student-Centered Learning provides a comprehensive pedagogical approach for strengthening scientific writing competence and academic literacy. The synthesized evidence consistently demonstrates that inquiry-oriented learning, collaboration, project-based instruction, peer feedback, and technology-supported learning create meaningful learning experiences that promote scientific reasoning, evidence-based writing, critical thinking, and academic communication. These findings establish a strong conceptual foundation for the final conclusion by highlighting Student-Centered Learning as an effective and sustainable instructional framework for developing the academic competencies required in twenty-first-century education.

CONCLUSION

This systematic literature review demonstrates that Student-Centered Learning (SCL) makes a substantial contribution to scientific writing training by enhancing the academic literacy of senior high school students. The synthesized evidence indicates that learner-centered instructional practices promote active engagement in inquiry, collaboration, reflection, and evidence-based reasoning, enabling students to develop stronger scientific writing competence while simultaneously improving critical thinking, academic communication, scientific reasoning, and learner autonomy. These findings answer the research question by confirming that Student-

Centered Learning supports scientific writing not merely as a technical writing activity but as a comprehensive process of knowledge construction and academic literacy development.

The review also identifies several pedagogical strategies that have consistently demonstrated positive outcomes across recent empirical studies. Inquiry-Based Learning, Project-Based Learning, collaborative writing with peer feedback, and technology-enhanced learning emerged as the most effective approaches for improving students' scientific writing and academic literacy. Collectively, these strategies provide authentic learning experiences that encourage students to investigate problems, evaluate evidence, construct scientific arguments, and communicate ideas effectively within meaningful academic contexts.

The findings contribute both theoretically and practically to the field of educational research. Theoretically, this review strengthens the conceptual understanding of Student-Centered Learning as an integrated pedagogical framework that connects scientific writing instruction with broader academic literacy competencies. Practically, the findings provide evidence-based guidance for teachers, curriculum developers, and educational policymakers to design scientific writing programs that emphasize active learning, collaboration, inquiry, and digital learning environments in secondary education.

Future research should expand the scope of systematic reviews by incorporating studies from broader publication periods, additional international databases, and meta-analytic approaches to quantify the effectiveness of specific Student-Centered Learning strategies. Further investigations focusing on senior high school contexts across different cultural and educational settings are also recommended to provide more comprehensive evidence regarding the long-term impact of learner-centered scientific writing instruction.

Overall, this review highlights that Student-Centered Learning represents an effective and sustainable pedagogical approach for developing scientific writing competence and academic literacy. By integrating inquiry, collaboration, reflective learning, and evidence-based communication, Student-Centered Learning equips students with the academic competencies required to meet the demands of twenty-first-century education and lifelong learning.

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