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THE IMPACT OF INTEGRATED STEM APPROACHES ON STUDENT'S ACADEMIC WRITING SKILLS: A SYSTEMATIC REVIEW

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Abstract

Integrated STEM approaches have increasingly been implemented in educational settings to support students' academic writing development through authentic and interdisciplinary learning experiences. This study employed a Systematic Literature Review (SLR) following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to synthesize previous research regarding the impact of integrated STEM approaches on students' academic writing skills. The data were collected from Scopus, Web of Science, and ERIC databases, focusing on peer-reviewed journal articles published between 2016 and 2026. Following the screening and eligibility process, 30 eligible studies were selected and analyzed using thematic analysis. The findings revealed that integrated STEM approaches positively contribute to students' academic writing development, particularly in improving structural logic, scientific argumentation, text cohesion, technical organization, and iterative revision practices. Furthermore, STEM integration supports cognitive development, critical thinking, learner autonomy, and students' motivation toward writing activities through contextualized and collaborative learning environments. However, several challenges remain, including institutional separation between disciplines, limited teacher readiness, lack of shared assessment rubrics, and curriculum time constraints. Overall, this review highlights that integrated STEM approaches have strong potential to enhance academic writing instruction when supported by balanced interdisciplinary collaboration and effective pedagogical guidance.

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INTRODUCTION

Despite the close relationship between scientific inquiry and written communication, academic writing instruction and STEM education are often taught separately in educational settings (Burns, 2026). Writing courses commonly emphasize general composition skills, while STEM classrooms frequently focus on technical problem-solving with limited attention to argumentative and analytical writing practices. As a result, many students continue to experience difficulties in organizing technical ideas, developing scientific arguments, and synthesizing evidence into coherent academic texts (Hossain, 2022)

Integrated STEM approaches offer a potential solution to this issue by embedding writing activities into authentic scientific and engineering contexts (Dieterle et al., 2022).

Through Project-Based Learning, Problem-Based Learning, and Engineering Design Processes, students are encouraged to explain findings, justify design decisions, and communicate evidence systematically through writing (Harrison & Parks, 2016). These interdisciplinary learning environments position writing as an essential component of inquiry rather than as a separate language task.

Integrated STEM approaches offer a potential solution to this pedagogical crisis by providing students with hands-on, high-stakes contexts that naturally demand rigorous documentation, peer review, and argumentative justification (K. Larkin & Lowrie, 2022). When writing is embedded into authentic STEM projects, it ceases to be a superficial chore and becomes an essential component of the scientific process where students must defend their designs or explain their findings textually (Harrison & Parks, 2016). While an increasing number of primary studies have begun exploring this intersection of STEM interventions and literacy, the existing body of literature remains highly fragmented and decentralized (López et al., 2022). Individual studies often focus on narrow contexts, such as evaluating a specific writing to learn strategy in a single middle school science classroom or assessing engineering logbooks in a university seminar, without offering a unified picture of the broader educational landscape.

To date, there is a distinct lack of a comprehensive synthesis that maps out the intersection of integrated STEM and literacy, as existing systematic reviews in the STEM domain heavily favor outcomes related to mathematical achievement, spatial reasoning, or career choices while ignoring linguistic dimensions. Therefore, a systematic literature review is urgently needed to address these gaps by aggregating the scattered empirical evidence regarding integrated STEM and writing outcomes into a unified framework (Ortiz-Revilla et al., 2022). This review serves to categorize the dominant pedagogical strategies that successfully bridge these two domains, providing actionable insights for educators worldwide. Furthermore, it critically evaluates the qualitative and quantitative impacts of these approaches on specific dimensions of student writing while highlighting the pedagogical, logistical, and operational friction points that educators encounter during implementation (Kazemy et al., 2026).

Although previous studies have explored the relationship between STEM integration and literacy development, the existing findings remain fragmented across different educational levels, instructional models, and writing contexts. Most previous reviews in STEM education primarily focus on mathematical achievement, scientific reasoning, or career readiness, while limited attention has been given specifically to academic writing development. Therefore, a comprehensive synthesis is needed to identify how integrated STEM approaches contribute to students' academic writing skills, cognitive development, motivation, and instructional challenges across educational contexts.

Consequently, this systematic literature review aims to synthesize previous studies examining the impact of integrated STEM approaches on students' academic writing skills. Specifically, this review investigates: (1) the integrated STEM instructional models most frequently used in academic writing instruction, (2) the impacts of integrated STEM approaches on students' academic writing development, and (3) the major challenges associated with STEM integration in writing instruction.

RESEARCH METHOD

This study employed a Systematic Literature Review (SLR) design conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The SLR approach was selected to systematically identify, evaluate, and synthesize previous studies concerning the impact of integrated STEM approaches on students' academic writing skills. This method enables a comprehensive and transparent review process

while identifying major research trends, pedagogical patterns, and research gaps within the existing literature.

The data collection process was conducted by searching several major academic databases, including Scopus, Web of Science, and ERIC. The review focused on peer-reviewed journal articles published between 2016 and 2026. The search process employed Boolean search strings combining keywords related to integrated STEM and academic writing, such as "integrated STEM," "STEM education," "STEM approach," "STEAM," "academic writing," "scientific writing," "writing skills," "argumentative writing," and "research writing."

To ensure methodological rigor, specific inclusion and exclusion criteria were applied throughout the screening process. The inclusion criteria consisted of: (1) peer-reviewed journal articles, (2) studies written in English, (3) studies examining integrated STEM approaches, and (4) studies investigating the impact of STEM integration on academic or scientific writing skills. Meanwhile, conference abstracts, dissertations, book chapters, non-English publications, duplicate studies, and studies focusing solely on technical STEM outcomes without writing-related variables were excluded from the review.

The article selection procedure followed several stages, including title screening, abstract screening, and full-text eligibility assessment. Following the screening and eligibility process, 30 studies were finally selected and analyzed in this review. The selected studies were systematically organized using a standardized data extraction matrix focusing on educational contexts, instructional STEM models, writing assessment indicators, and reported learning outcomes.

The collected data were analyzed qualitatively using thematic analysis. This analysis process involved identifying recurring concepts, grouping similar findings into broader categories, and generating major themes related to integrated STEM and academic writing instruction. The thematic synthesis ultimately produced four major themes: (1) improvement of academic writing skills, (2) cognitive benefits and learner autonomy, (3) students' motivation and perceptions toward STEM tools, and (4) challenges and limitations of STEM implementation in academic writing.

RESEARCH FINDINGS AND DISCUSSION

Result

The PRISMA-based article selection process resulted in 30 eligible articles that met the inclusion criteria for this systematic literature review. The selected studies mainly discussed the implementation of integrated STEM approaches in academic writing instruction across various educational contexts. The reviewed studies explored the impacts of integrated STEM on students' writing performance, cognitive development, learner autonomy, motivation, and instructional challenges.

The thematic analysis identified four major themes related to integrated STEM implementation in academic writing instruction: (1) improvement of academic writing skills, (2) cognitive benefits and learner autonomy, (3) students' motivation and perceptions toward STEM tools, and (4) challenges and limitations of STEM implementation.

The integration of STEM approaches within the educational landscape has advanced rapidly, particularly concerning academic writing instruction across different educational levels. Integrated STEM frameworks such as Project-Based Learning, Problem-Based Learning, and the Engineering Design Process are increasingly used to create authentic and contextualized learning environments. These approaches assist students in improving structural logic, scientific argumentation, evidence synthesis, and technical writing organization.

Furthermore, integrated STEM promotes collaborative learning, active inquiry, and iterative revision practices that support the development of academic writing skills. However, several challenges remain, including institutional separation between disciplines, limited

teacher readiness, lack of shared assessment rubrics, and curriculum time constraints. Based on these findings, the discussion can be categorized into the following major dimensions:

Table 1. Previous Studies on STEM-Assisted Academic Writing

No	Area or Focus	Authors	Insight and Variable Riset
1.	Improvement of academic writing skills through integrated STEM	Awad (2023); Siekmann et al. (2022); Chen & Zhang (2019); Apridayani & Waluyo (2025); Jelodari et al. (2026)	Improvement in structural logic, text cohesion, scientific argumentation, technical organization, and iterative writing practices through STEM-based learning environments.
2.	Cognitive benefits and learner autonomy through STEM integration	Malik et al. (2023); Wang et al. (2025); Papaneophytou & Nicolaou (2025); Çini et al. (2023); Rasmi et al. (2025)	Reduction of cognitive load, enhancement of critical thinking, metacognitive awareness, self-regulated learning, and learner autonomy in academic writing.
3.	Students' motivation and perceptions toward STEM tools	Davies et al. (2022); Teng et al. (2021); Mcdonald (2016); Waller & Papi (2017); Long & Magerko (2020)	STEM-assisted writing is perceived as engaging, practical, and motivating. Students become more confident in generating ideas and revising texts through real-world learning contexts.
4.	Challenges and limitations of STEM implementation in academic writing	Burns (2026); Kazemy et al. (2026); Nadelson & Seifert (2017); Fei et al. (2024); Margot & Kettler (2019)	Institutional separation between disciplines, lack of shared assessment rubrics, limited teacher readiness, and curriculum time constraints remain significant implementation challenges.

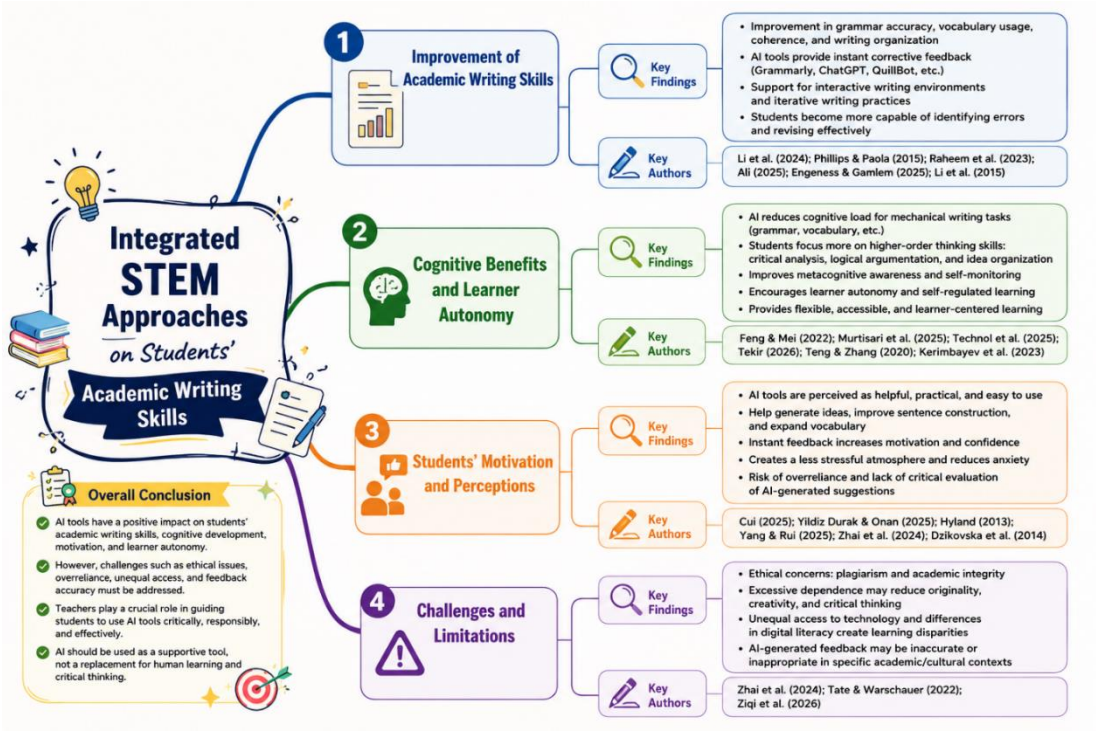


Figure 1. Mind map of Integrated STEM Approaches in Academic Writing

The mind map illustrates the synthesis of previous studies regarding the implementation of integrated STEM approaches in academic writing. Overall, the reviewed literature highlights four major areas of discussion, namely the improvement of academic writing skills, cognitive benefits and learner autonomy, students' motivation and perceptions toward STEM tools, as well as the challenges and limitations associated with STEM integration in writing instruction.

The first area, Improvement of Academic Writing Skills Through Integrated STEM, demonstrates that frameworks such as Project-Based Learning and the Engineering Design Process contribute significantly to the enhancement of students' writing performance. Previous studies indicate that the use of integrated STEM approaches improves several essential components of academic writing, including structural logic, text cohesion, data reporting, and technical writing organization. In addition, the provision of contextualized writing environments enables students to identify evidence gaps more effectively and revise their writing continuously, resulting in improved clarity and overall writing quality.

The second area focuses on Cognitive Benefits and Learner Autonomy Through STEM Integration. Research findings suggest that integrated STEM approaches function as supportive scaffolding systems that help reduce students' cognitive burden regarding abstract conceptualization during the writing process, particularly in lower-level descriptive tasks. As a result, students are able to concentrate more on higher-order thinking skills, including critical analysis, data-driven scientific argumentation, and complex idea organization. Furthermore, continuous interaction with active peer evaluation enhances students' metacognitive awareness and promotes self-regulated learning, leading to greater learner autonomy in academic writing activities.

The third discussion concerns Students' Motivation and Perceptions Toward STEM Tools. Various studies reveal that students generally perceive integrated STEM writing platforms as practical, engaging, and beneficial for supporting the writing process. STEM projects assist learners in generating ideas, constructing data-backed sentences, and enhancing technical vocabulary selection, which subsequently increases students' confidence and

motivation in completing writing tasks. Moreover, the availability of real-world relevance creates a more flexible and less stressful learning environment, particularly for students who experience traditional writing boredom during academic writing activities. Nevertheless, some studies also emphasize the potential risk of superficial data analysis, as certain students may focus heavily on the physical project outcome without critically evaluating their written reports.

The final area, Challenges and Limitations of STEM Implementation in Academic Writing, addresses several concerns related to the use of interdisciplinary frameworks in educational settings. Pedagogical issues, particularly strict separation between science and language disciplines, remain significant challenges in integrated STEM writing practices. Excessive time constraints in already packed curricula may reduce students' opportunities for multiple revisions and deep critical thinking abilities. In addition, disparities in teacher professional development regarding cross-disciplinary work may create unequal learning opportunities among students. Another limitation is that teachers often report a lack of shared assessment rubrics, which indicates that institutional collaboration and instructional guidance remain necessary throughout the learning process.

In conclusion, the mind map demonstrates that integrated STEM approaches provide substantial benefits for the development of academic writing skills from linguistic, cognitive, and motivational perspectives. However, the effective implementation of integrated STEM in academic writing requires balanced integration, cross-disciplinary rubrics, and continuous guidance from educators to ensure that STEM serves as a supportive learning tool that enhances human reasoning and critical thinking.

DISCUSSION

1. Improvement of Academic Writing Skills Through Integrated STEM Approaches

Various studies indicate that integrated STEM approaches have a significant contribution in improving university students' academic writing skills (Awad, 2023). The integration of science, technology, engineering, and mathematics into a single framework allows students to engage with language in a practical context (Chalmers et al., 2017). The aspects that showed the greatest improvement include structural logic, text cohesion, data reporting, technical organization, and overall writing quality (Siekmann et al., 2022).

STEM-powered frameworks such as Project-Based Learning and the Engineering Design Process provide immediate data or physical feedback that helps students revise and refine their writing more effectively. When students encounter physical or mathematical discrepancies in their projects, they are forced to adjust their written explanations immediately (Schoenfeld, 2022). This practical loop helps them understand that accuracy in technical communication is just as vital as accuracy in calculations.

Several reviewed studies reported that students became more capable of identifying logical flaws, improving technical sentence structure, and organizing arguments systematically after regularly participating in integrated STEM writing contexts. The availability of instant feedback from experimental outcomes also supports iterative writing practices (Menzel et al., 2023). This repetition allows students to continuously revise their drafts until higher levels of clarity and accuracy are achieved (Chen & Zhang, 2019).

In addition, STEM approaches create a more interactive writing environment that encourages students to engage actively in the revision process (Struyf et al., 2019). The active inquiry system enables learners to recognize mistakes independently and improve their writing performance without relying entirely on teacher correction (Apridayani & Waluyo, 2025). Consequently, students become more familiar with academic writing conventions and develop stronger technical writing fluency over time, making the writing process more manageable and productive (Tabari et al., 2024).

2. Cognitive Benefits and Learner Autonomy Through STEM Integration

Beyond linguistic improvement, STEM integration also contributes significantly to students' cognitive development during the writing process (Malik et al., 2023). Academic writing is historically known to be a demanding task that requires learners to manage multiple complex cognitive activities simultaneously (A. F, 2018). These activities include idea generation, data control, coherence building, and critical argument development which can easily overwhelm developing scholars (Wise & Schwarz, 2017).

STEM frameworks function as supportive scaffolding systems that reduce this cognitive load by assisting students with active, concrete visualization (Wang et al., 2025). Through hands-on evidence and real-world experiments, abstract writing concepts become physically visible (Carreira & Baioa, 2018). This immediate connection between action and text helps students map out their thoughts more systematically before transforming them into formal academic prose (Van Drie & van de Ven, 2017).

Several studies reveal that the use of STEM feedback enables students to focus more on higher-order thinking skills, including critical analysis, data-driven scientific argumentation, and complex organization of ideas (Papaneophytou & Nicolaou, 2025). Repeated interaction with engineering or scientific problem-solving also increases students' metacognitive awareness (Çini et al., 2023). As a result, learners gradually become more capable of evaluating and monitoring their own writing performance based on physical project results (Yan & Brown, 2017).

Consequently, students develop stronger self-regulated learning strategies and become more independent writers over time (Abadikhah et al., 2018). Furthermore, STEM-assisted learning encourages students to take greater responsibility for their own academic progress (Rasmi et al., 2025). The flexibility and accessibility of integrated STEM writing tools allow students to practice writing through active observation and receive immediate empirical responses, creating a more autonomous and learner-centered learning experience (Article, 2020).

3. Students' Motivation and Perceptions Toward STEM Tools

In addition to improving technical writing abilities, integrated STEM tools also positively influence students' motivation and attitudes toward academic writing. Many studies report that students perceive STEM-assisted writing applications as helpful, practical, and highly engaging compared to traditional methods. Writing ceases to be seen as an isolated language requirement and is embraced as a natural extension of scientific inquiry.

STEM projects help students generate writing ideas more easily, improve sentence construction through direct observation, and enhance technical vocabulary selection (Davies et al., 2022). This concrete foundation directly increases students' confidence in completing complex writing tasks (Teng et al., 2021). The availability of real-world relevance is considered one of the most beneficial aspects of STEM integration because it supports independent learning and encourages frequent revision (Mcdonald, 2016).

Students become more motivated to write because they can immediately identify and correct empirical mistakes based on their project outcomes without waiting for teacher feedback (Waller & Papi, 2017). Moreover, STEM-assisted learning environments create a less stressful atmosphere, particularly for students who often experience high levels of anxiety during traditional abstract writing activities (Panuganti & Education, n.d.). This shift in perception turns writing into a rewarding phase of discovery.

However, several studies also indicate that some students tend to focus too heavily on the physical project design without critically evaluating their written text (Long & Magerko, 2020). In some cases, learners accept superficial observations automatically without fully understanding the underlying linguistic or contextual reasons (English, 2019). Therefore,

teacher guidance remains essential to ensure that students use STEM tools critically, responsibly, and effectively within the learning process (Slavit et al., 2016).

4. Challenges and Limitations of STEM Implementation in Academic Writing

Despite the numerous benefits identified in the reviewed studies, several challenges and limitations regarding integrated STEM implementation in academic writing are consistently reported (Nadelson & Seifert, 2017). Pedagogical concerns, particularly the deep-rooted institutional separation between science and language disciplines, remain major issues in higher education (Bayne & Dopico, n.d.). This separation often isolates teachers into rigid departmental silos.

Furthermore, excessive time constraints within an already packed STEM curriculum may reduce students' originality, creativity, and deep reflective writing abilities (Fei et al., 2024). If STEM is used inappropriately without balanced scheduling, writing tasks are often rushed or reduced to simple summaries (T. L. Larkin, 2013). This structural issue limits the potential of interdisciplinary learning and places undue stress on both instructors and students (Ozkan et al., 2018).

Another important challenge relates to teacher professional development and unequal access to cross-disciplinary resourcesm (Olaboye et al., 2024). Teachers who have limited experience in combining literacy with science may experience difficulties in utilizing STEM tools effectively, which can create disparities in learning outcomes (Margot & Kettler, 2019). STEM instructors frequently feel underprepared to grade grammar, while language teachers may struggle with technical scientific accuracy (Besterman et al., 2011).

Additionally, STEM-generated assessment is not always pedagogically balanced, as some instructors may provide writing suggestions that are technically correct but structurally weak within specific academic or cultural contexts. To address these limitations, teachers play an important role as facilitators and supervisors (Becuwe et al., 2016). Effective implementation of STEM requires balanced integration, proper instructional guidance, and shared assessment rubrics to ensure a successful cross-disciplinary process (Tytler et al., n.d.).

CONCLUSION

This systematic literature review underscores that integrated STEM approaches serve as a powerful catalyst for enhancing students' academic writing skills. By embedding writing tasks into authentic, data-driven frameworks like Project-Based Learning and the Engineering Design Process, students are able to develop stronger structural logic and scientific argumentation. The concrete feedback from physical experiments effectively scaffolds the writing process, turning an abstract language task into a meaningful communication tool. This integration not only improves the overall quality of technical texts but also boosts student motivation and fosters greater learner autonomy.

However, the successful integration of STEM and academic writing is not without significant structural challenges. The persistent institutional silos between science and language disciplines, coupled with a widespread lack of cross-disciplinary assessment rubrics, often hinder effective implementation. Additionally, time constraints within packed STEM curricula can lead to cognitive overload if not managed with balanced scheduling. To overcome these limitations, future educational models must prioritize professional development that equips STEM and literacy educators with shared pedagogical tools, ensuring that interdisciplinary writing becomes a sustainable and deeply reflective practice.

REFERENCES

A. F, N. (2018). Cognitive load theory in the context of second language academic writing. *Higher Education Pedagogies*, *3*(1), 385–402.

Abadikhah, S., Aliyan, Z., & Talebi, S. H. (2018). *EFL students ' attitudes towards self-regulated learning strategies in academic writing*. *28*(1), 1–17.

Apridayani, A., & Waluyo, B. (2025). Valuing students' mindsets in essay compositions: Active learning and feedback approaches. *Social Sciences & Humanities Open*, *11*, 101273.

Article, O. (2020). *Exploring Active Learning Strategies in Science among Senior*. *35*(4), 369–381.

Awad, N. (2023). Exploring STEM integration: assessing the effectiveness of an interdisciplinary informal program in fostering students' performance and inspiration. *Research in Science & Technological Education*, *41*(2), 675–699.

Bayne, G. U., & Dopico, E. (n.d.). *This is the accepted version of the article Pedagogical challenges involving race , gender and the unwritten rules in settings of higher education Authors : Gillian U . Bayne and Eduardo Dopico This paper was published in Cultural Studies of Science Education , 15 . 623-637 Doi : https://doi.org/10.1007/s11422-020-09972-w Pedagogical challenges involving race , gender and the unwritten rules in settings of higher education*.

Becuwe, H., Tondeur, J., Roblin, N. P., & Thys, J. (2016). *Teacher design teams as a strategy for professional development : the role of the facilitator Teacher design teams as a strategy for professional development : the role of the facilitator*. *3611*(October), 0–14. https://doi.org/10.1080/13803611.2016.1247724

Besterman, K., Williams, T. O., & Ernst, J. J. V. (2011). *STEM Teachers ' Preparedness for English Language Learners*. *19*(3), 33–39.

Burns, F. M. (2026). Pedagogical Integration of the Humanities and Sciences. In *Insights into the Relationships between Humanities and Sciences: A Working Outlook* (pp. 379–412). Springer.

Carreira, S., & Baioa, A. M. (2018). Mathematical modelling with hands-on experimental tasks: On the student's sense of credibility. *Zdm*, *50*(1), 201–215.

Chalmers, C., Carter, M., Cooper, T., & Nason, R. (2017). Implementing "big ideas" to advance the teaching and learning of science, technology, engineering, and mathematics (STEM). *International Journal of Science and Mathematics Education*, *15*(Suppl 1), 25–43.

Chen, J., & Zhang, L. J. (2019). Assessing student-writers' self-efficacy beliefs about text revision in EFL writing. *Assessing Writing*, *40*, 27–41.

Çini, A., Järvelä, S., Dindar, M., & Malmberg, J. (2023). How multiple levels of metacognitive awareness operate in collaborative problem solving. In *Metacognition and Learning*. Springer US. https://doi.org/10.1007/s11409-023-09358-7

Davies, P. M., Passonneau, R. J., & Muresan, S. (2022). Analytical Techniques for Developing Argumentative Writing in STEM : A Pilot Study. *IEEE Transactions on Education*, *65*(3), 373–383. https://doi.org/10.1109/TE.2021.3116202

Dieterle, E., Dede, C., & Walker, M. (2022). The cyclical ethical effects of using artificial intelligence in education. *AI & SOCIETY*, *0123456789*. https://doi.org/10.1007/s00146-022-01497-w

English, L. (2019). Explicit reading strategy instruction or daily use of strategies ? Studying the teaching of reading. *Reading and Writing*, *32*(9), 2281–2310. https://doi.org/10.1007/s11145-019-09951-w

Fei, M., Yu, C., Lo, H., & Ho, C. (2024). The impact of STEM curriculum on students ' engineering design abilities and attitudes toward STEM. *International Journal of Technology and Design Education*, *1*. https://doi.org/10.1007/s10798-024-09883-9

Harrison, R. L., & Parks, B. (2016). How STEM can gain some STEAM: Crafting meaningful collaborations between STEM disciplines and inquiry-based writing programs. In *Writing program and writing center collaborations: Transcending boundaries* (pp. 117–139).

Springer.
Hossain, Z. (2022). University freshmen recollect their academic integrity literacy experience during their K-12 years: Results of an empirical study. *International Journal for Educational Integrity*, *18*(1), 4.
Kazemy, H., Ravari, A., Kamiab, Z., Iranmanesh, F., & Mirzaei, T. (2026). Integrating AI-Supported Adaptive Learning with Cooperative Jigsaw Strategy for Generation Z Nursing Students: A Mixed-Methods Study. *Next Research*, 101426.
Larkin, K., & Lowrie, T. (2022). STEM education in the early years. *Thinking About Tomorrow; Springer: Berlin/Heidelberg, Germany*.
Larkin, T. L. (2013). *Writing in STEM : A Synthesis of Two Adaptive Approaches Writing in STEM : A Synthesis of Two Adaptive Approaches*. *January 2014*.
Long, D., & Magerko, B. (2020). *What is AI Literacy ? Competencies and Design Considerations*. 1–16.
López, N., Morgan, D. L., Hutchings, Q. R., & Davis, K. (2022). Revisiting critical STEM interventions: A literature review of STEM organizational learning. *International Journal of STEM Education*, *9*(1), 39.
Malik, A. R., Pratiwi, Y., Andajani, K., Numertayasa, I. W., Suharti, S., & Darwis, A. (2023). Exploring artificial intelligence in academic essay: higher education student's perspective. *International Journal of Educational Research Open*, *5*, 100296.
Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, *6*(1), 2.
Mcdonald, C. V. (2016). *STEM Education : A review of the contribution of the disciplines of science , technology , engineering and mathematics*. *27*(4), 530–569.
Menzel, L., Gombert, S., Weidlich, J., Fink, A., Frey, A., & Drachsler, H. (2023). Why you should give your students automatic process feedback on their collaboration: Evidence from a randomized experiment. *European Conference on Technology Enhanced Learning*, 198–212.
Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined : Contexts , challenges , and the future. *The Journal of Educational Research*, *110*(3), 221–223. https://doi.org/10.1080/00220671.2017.1289775
Olaboye, J. A., Maha, C. C., & Kolawole, T. O. (2024). *Promoting health and educational equity : Cross-disciplinary strategies for enhancing public health and educational outcomes*. *6*(6), 1178–1193. https://doi.org/10.51594/ijarss.v6i6.1179
Ortiz-Revilla, J., Greca, I. M., & Arriassecq, I. (2022). A theoretical framework for integrated STEM education. *Science & Education*, *31*(2), 383–404.
Ozkan, D. S., Mcnair, L. D., & Bairaktarova, D. (2018). *Teacher Learner , Learner Teacher : Parallels and Dissonance in an Interdisciplinary Design Education Minor*. *24061*.
Panuganti, S., & Education, P. E. (n.d.). *Bridging Support Networks : The Role of Formal and Informal Mentors in Undergraduate Engineering Students ' Emotional Well-Being and Academic Success*.
Papaneophytou, C., & Nicolaou, S. A. (2025). Promoting critical thinking in biological sciences in the era of artificial intelligence: The role of higher education. *Trends in Higher Education*, *4*(2), 24.
Rasmi, D. P., Wibisana, S. S., & Hendri, M. (2025). *Integrating STEM in Hooke ' s Law and Elasticity Worksheets : Enhancing Student Collaboration and Learning Outcomes*. *11*(2), 573–581. https://doi.org/10.29303/jppipa.v11i2.10166
Schoenfeld, A. H. (2022). Why are learning and teaching mathematics so difficult? In *Handbook of cognitive mathematics* (pp. 1–35). Springer.
Siekmann, L., Parr, J. M., & Busse, V. (2022). Structure and coherence as challenges in composition: A study of assessing less proficient EFL writers' text quality. *Assessing*

Writing, *54*, 100672.

Slavit, D., Nelson, T. H., & Lesseig, K. (2016). The teachers ' role in developing , opening , and nurturing an inclusive STEM-focused school. *International Journal of STEM Education*. https://doi.org/10.1186/s40594-016-0040-5

Struyf, A., De Loof, H., Boeve-de Pauw, J., & Van Petegem, P. (2019). Students' engagement in different STEM learning environments: Integrated STEM education as promising practice? *International Journal of Science Education*, *41*(10), 1387–1407.

Tabari, M. A., Latif, M. M. M. A., & Tian, Y. (2024). The impact of computer-mediated task complexity on writing fluency: A comparative study of L1 and L2 writers' fluency performance. *Computers and Composition*, *73*, 102863.

Teng, M. F., Huang, J., & Teng, M. F. (2021). The effects of incorporating metacognitive strategies instruction into collaborative writing on writing complexity , accuracy , and fluency fluency. *Asia Pacific Journal of Education*, *00*(00), 1–20. https://doi.org/10.1080/02188791.2021.1982675

Tytler, R., Williams, G., Hobbs, L., & Anderson, J. (n.d.). *Challenges and Opportunities for a STEM Interdisciplinary Agenda*. Springer International Publishing. https://doi.org/10.1007/978-3-030-11066-6

Van Drie, J., & van de Ven, P.-H. (2017). Moving ideas: An exploration of students' use of dialogue for writing in history. *Language and Education*, *31*(6), 526–542.

Waller, L., & Papi, M. (2017). *Journal of Second Language Writing Motivation and feedback : How implicit theories of intelligence predict L2 writers ' motivation and feedback orientation*. *35*, 54–65.

Wang, F., Huang, J., Zheng, X.-L., Wu, J.-Q., & Zhao, A.-P. (2025). STEM activities for boosting pupils' computational thinking and reducing their cognitive load: Roles of argumentation scaffolding and mental rotation. *Journal of Research on Technology in Education*, *57*(6), 1370–1389.

Wise, A. F., & Schwarz, B. B. (2017). Visions of CSCL: Eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning*, *12*(4), 423–467.

Yan, Z., & Brown, G. T. L. (2017). Assessment & Evaluation in Higher Education A cyclical self-assessment process : towards a model of how students engage in self-assessment. *Assessment & Evaluation in Higher Education*, *2938*(September), 0. https://doi.org/10.1080/02602938.2016.1260091