International Journal of Ethnoscience and Technology in Education (IJETE)
https://e-journal.undikma.ac.id/index.php/ijete/index

March 2025 Vol. 2, No. 1
pp. 129-157

Research Trends in Analytical Thinking Skills for Science Education: Insights, Pedagogical Approaches, and Future Directions

Faizul Bayani[1,2]*, Joni Rokhmat[1,3], Aliefman Hakim[1,4], & AA Sukarso[1,5]

[1] Doctoral Program in Natural Science Education, Mataram University, Mataram, INDONESIA
[2] Bachelor's Program in Natural Science Education, Universitas Qamarul Huda Badaruddin Bagu, Lombok Tengah, INDONESIA
[3] Bachelor's Program in Physics Education, Mataram University, Mataram, INDONESIA
[4] Bachelor's Program in Chemistry Education, Mataram University, Mataram, INDONESIA
[5] Bachelor's Program in Biology Education, Mataram University, Mataram, INDONESIA

*Corresponding author e-mail: faizulbayani@uniqhba.ac.id

Article Info

Article History
Received: December 2024
Revised: January 2025
Published: March 2025

Keywords
Analytical thinking skills; Science education; Pedagogical strategies; Systematic literature review; Educational technology

10.33394/ijete.v2i1.14142

Abstract

In the rapidly evolving 21st century, fostering analytical thinking skills has become a critical objective in science education, enabling students to solve complex problems and adapt to knowledge-driven economies. This systematic literature review, covering research from 2013 to 2024 and focusing on Scopus-indexed journals (Q1–Q3), aims to identify trends in analytical thinking research, explore effective pedagogical approaches, and analyze methodological diversity in the field. Using the PRISMA framework, 60 peer-reviewed studies were systematically selected and analyzed through both quantitative and qualitative methods, with thematic coding and tools like Vosviewer employed to uncover patterns and themes. The findings highlight a surge in research during 2020–2021, driven by the global shift to remote learning, and emphasize the effectiveness of innovative teaching strategies such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Inquiry-Based Learning (IBL) in fostering analytical skills. The review also underscores the role of technological interventions, such as virtual labs and simulations, in enhancing student engagement and cognitive development. However, gaps were identified, including the need for longitudinal studies and standardized evaluation metrics to assess long-term impacts. The study concludes that integrating evidence-based, scalable strategies across diverse educational contexts is essential for promoting analytical thinking as a core competency. Future research should prioritize interdisciplinary approaches and leverage emerging technologies to address these gaps. These findings provide actionable insights for educators, researchers, and policymakers aiming to advance science education and prepare students for the challenges of a dynamic world.

How to Cite: Bayani, F., Rokhmat, J., Hakim, A., & Sukarso, A. (2025). Research Trends in Analytical Thinking Skills for Science Education: Insights, Pedagogical Approaches, and Future Directions. *International Journal of Ethnoscience and Technology in Education, 2*(1), 129-157. doi:https://doi.org/10.33394/ijete.v2i1.14142

INTRODUCTION

In an era characterized by accelerated technological advancement and global interconnectedness, the ability to think analytically has emerged as an indispensable skill. Analytical thinking entails the capacity to deconstruct complex problems, evaluate diverse perspectives, and apply logical reasoning to generate solutions. This skillset is especially critical in scientific fields, where the nature of inquiry and discovery necessitates rigorous analysis of data and the formulation of evidence-based conclusions (Farah & Ayoubi, 2020; Prayitno et al., 2017; Ramadani et al., 2021; Yurt, 2022; Khusmawardani et al., 2022). This review examines research trends on analytical thinking within the domain of science education, drawing insights from articles published in Scopus-indexed journals (Q1-Q3) between 2013 and 2024.

The global emphasis on fostering analytical thinking skills stems from its pivotal role in enabling individuals to navigate modern challenges. Today's educational systems are under increasing pressure to cultivate these competencies as part of broader efforts to prepare students for the demands of knowledge-based economies. These economies prioritize problem-solving, critical thinking, and the ability to adapt to rapidly changing circumstances (Utami et al., 2017; Maričić & Špijunović, 2015; Yosintha & Arochman, 2020; Manshaee et al., 2014). Over the last decade, educational institutions have introduced innovative pedagogical strategies aimed at embedding analytical thinking into curricula, thus ensuring that learners acquire the intellectual tools needed to thrive in their chosen careers (Parrish, 2016; Blyznyuk, 2019; Gilchrist et al., 2021).

Science education represents a crucial arena for the cultivation of analytical thinking, given its emphasis on evidence-based inquiry. The core practices of formulating hypotheses, designing experiments, interpreting data, and drawing conclusions are intrinsically linked to analytical skills. Consequently, fostering these abilities in students not only enhances their scientific proficiency but also equips them with lifelong problem-solving tools (Valibeigi et al., 2020; White et al., 2014; Ali & Awan, 2021; Kanani, 2016; Sujana & Komariah, 2020). Research underscores that students proficient in analytical thinking are better equipped to dissect complex scientific problems, evaluate empirical evidence, and construct logical arguments that contribute meaningfully to the scientific discourse (Wongpinunwatana, 2019; Hidayatulloh et al., 2020; Darmawan, 2020).

The pursuit of enhanced analytical thinking has spurred a proliferation of research exploring innovative teaching methodologies. Notably, experimental and quasi-experimental studies have been instrumental in assessing the efficacy of specific interventions, such as collaborative problem-solving exercises, inquiry-based learning modules, and the use of real-world case studies. These studies frequently employ quantitative measures, such as pre- and post-test comparisons, to evaluate improvements in students' analytical capabilities (Inayah, 2023; Astuti et al., 2021; Al-Hanifah et al., 2023; Nurlaelah et al., 2021). Complementary qualitative research provides rich descriptive insights into the nuances of how analytical thinking evolves within educational contexts (Putri et al., 2020; Suyatman et al., 2021;

Thaneerananon et al., 2016; Prawita et al., 2019). Mixed-methods research, which integrates quantitative rigor with qualitative depth, has gained prominence for its ability to provide a holistic understanding of teaching outcomes (Weis et al., 2019; Mahato et al., 2018; Santos et al., 2020; McCrackin, 2020; Lazure et al., 2019).

Advancements in educational technology have opened new avenues for the development of analytical thinking skills. Digital platforms, such as virtual laboratories, gamified learning environments, and interactive simulations, offer immersive and personalized learning experiences that mirror real-world scientific challenges. These technologies not only enhance student engagement but also facilitate deeper cognitive processing by enabling hands-on experimentation in a risk-free environment (Rohim, 2020; Odeh et al., 2015; Kontra et al., 2015; Starčič et al., 2018). Empirical studies have documented the significant impact of such tools on students' ability to analyze data, identify patterns, and apply theoretical knowledge to practical problems.

Despite the progress made, several challenges persist in the integration of analytical thinking into science education. One notable obstacle is the variability in instructional quality and resource availability across different educational settings. Schools in resource-constrained environments often struggle to implement advanced pedagogical techniques or acquire state-of-the-art technological tools. Moreover, existing research highlights a gap in the systematic evaluation of long-term outcomes, such as the transferability of analytical thinking skills beyond the classroom (Ramadani et al., 2021; Ali & Awan, 2021; Maison et al., 2022). Nevertheless, these challenges present opportunities for further exploration. Future research could focus on developing scalable, cost-effective teaching strategies that can be implemented in diverse educational contexts. Additionally, longitudinal studies are needed to assess the enduring impact of analytical thinking training on students' academic and professional trajectories (Sefhedi et al., 2021; Boichenko et al., 2021; Rosadi et al., 2018; Bilgin & Kala, 2022).

Objectives of the Current Study

The primary objective of this systematic literature review is to synthesize existing research on analytical thinking skills in science education, with a focus on publications from 2013 to 2024. This review aims to provide a comprehensive understanding of how analytical thinking has been studied, the strategies employed to enhance these skills, and the research methodologies used. Specifically, the review focuses on:

1. Identifying trends in research on analytical thinking skills in science education. This includes analyzing the temporal distribution of studies, key themes, and areas of concentrated research, particularly the impact of global shifts such as the adoption of remote learning.
2. Exploring effective pedagogical approaches for fostering analytical thinking skills. The review evaluates innovative instructional strategies, including Problem-Based Learning (PBL), Project-Based Learning (PjBL), Inquiry-Based Learning (IBL), and specific treatments such as metacognitive scaffolding and debate, which aim to enhance students' cognitive abilities and engagement.

3. Analyzing the methodological diversity in research on analytical thinking skills. The study examines the range of quantitative, qualitative, and mixed-method approaches employed in research, including quasi-experimental designs, thematic analysis, and visualization techniques like those provided by Vosviewer, to understand their contributions to the field.

By addressing these objectives, the review aims to contribute to the growing body of knowledge on analytical thinking in science education and provide actionable insights for educators, policymakers, and researchers. This effort bridges theoretical frameworks with practical applications, emphasizing the importance of fostering analytical thinking as a cornerstone of 21st-century education. Developing these skills is critical for promoting critical inquiry, adaptability, and innovation, equipping students to thrive in a dynamic, knowledge-driven world (Anagün, 2018; Bers, 2018; Al-Mohammadi, 2017; Noor et al., 2023).

Study Novelty

This study presents a novel contribution to the field of science education by systematically identifying trends in research on analytical thinking skills, exploring effective pedagogical approaches for fostering these skills, and analyzing the methodological diversity employed in this area. By synthesizing findings from a decade of research (2013–2024) and leveraging tools such as Vosviewer for visualizing thematic relationships, this review offers a comprehensive and integrative perspective. Unlike prior studies that often focus on isolated aspects of analytical thinking, this work bridges temporal trends, instructional innovations, and methodological practices, providing actionable insights to guide educators, researchers, and policymakers in advancing analytical thinking as a cornerstone of 21st-century education.

METHODS

This study employed a systematic literature review (SLR) methodology, following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure methodological rigor and replicability. The focus of the review was to explore research trends related to analytical thinking skills in science education from 2013 to 2024, specifically within articles published in Scopus-indexed Q1, Q2, and Q3 journals. The systematic approach was designed to ensure that the findings reflect a comprehensive and detailed understanding of existing research. Articles included in this study were required to meet specific criteria: they needed to address analytical thinking skills in the context of science education, be peer-reviewed, and available in full text. Both quantitative and qualitative studies were considered, allowing for a broad spectrum of methodologies and findings to be captured (Rahman, 2016; Salvador, 2016).

The data collection process began with a structured search of electronic databases, primarily Scopus, using predefined keywords such as “analytical thinking,” “science education,” “critical thinking,” and “STEM education.” Boolean operators were applied to refine the search, and filters for publication year, journal quality, and relevance were utilized. Duplicates were systematically removed using reference management software, and the remaining articles underwent a rigorous screening process based on their titles and abstracts. Articles that aligned with the inclusion criteria were selected for full-text review. During this phase, each article was carefully evaluated to confirm its relevance and extract key information, including study objectives, methodologies, and findings. Ultimately, a total of 60 articles were included in the final dataset, providing a robust foundation for the analysis.

Data analysis was conducted through both manual coding and software-assisted techniques to identify trends and extract meaningful insights. Key indicators analyzed included publication year, research type, research subjects, topics, treatments, data collection instruments, and data analysis techniques. Quantitative data were summarized using descriptive statistics, allowing for an overview of the frequency and distribution of various research characteristics. Qualitative data were analyzed through thematic coding, revealing recurring patterns, themes, and methodological trends within the literature (Sukmawati, 2023; Ganesha & Aithal, 2022). Vosviewer software was employed to examine the relationships between article titles and abstracts, identifying clusters of co-occurring keywords and themes (Fatima et al., 2017; Su et al., 2021; Shrivastava, 2023).

The PRISMA framework structured the entire process into four stages: identification, screening, eligibility, and inclusion. The identification phase involved retrieving articles based on the predefined search criteria. The screening phase ensured that only relevant articles proceeded to the eligibility stage, where full-text reviews confirmed their alignment with the study's objectives. Finally, the inclusion stage yielded the dataset used for analysis. This rigorous process was documented in a PRISMA flow diagram, ensuring transparency and replicability.

A synthesis of the results provided a comprehensive overview of research trends in analytical thinking skills within science education. Quantitative findings highlighted the frequency and distribution of research outputs over the years, while qualitative insights captured the depth of pedagogical strategies and challenges reported in the studies. Themes such as the use of technology, inquiry-based learning, and collaborative problem-solving emerged as focal points in the literature. Additionally, gaps in the research, including limited longitudinal studies and inconsistent evaluation metrics, were identified and discussed (Karami, 2024).

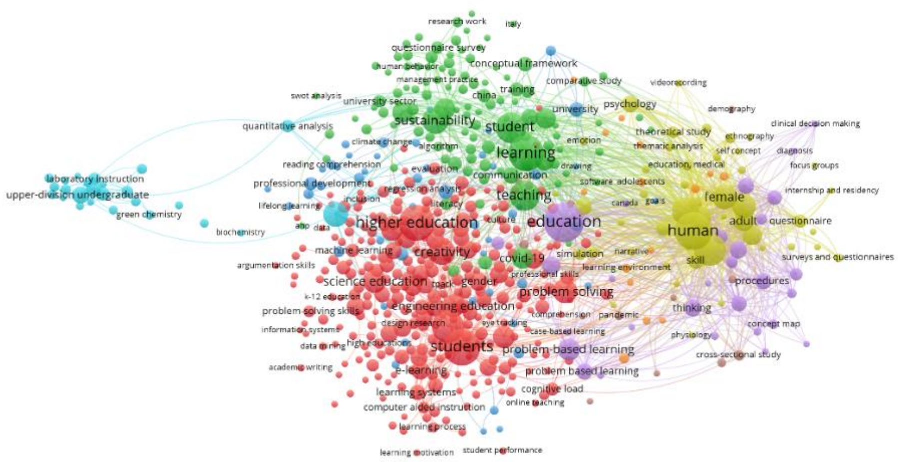
Although this review is comprehensive, it acknowledges several limitations. The focus on Scopus-indexed journals may exclude relevant studies from other platforms, and the reliance on English-language articles could introduce linguistic bias. Despite these limitations, the systematic approach ensures that the findings contribute valuable insights to the field of science education. This review underscores the importance of analytical thinking as a critical skill for the 21st century, offering evidence-based recommendations for enhancing its integration into educational practices.

RESULTS AND DISCUSSION

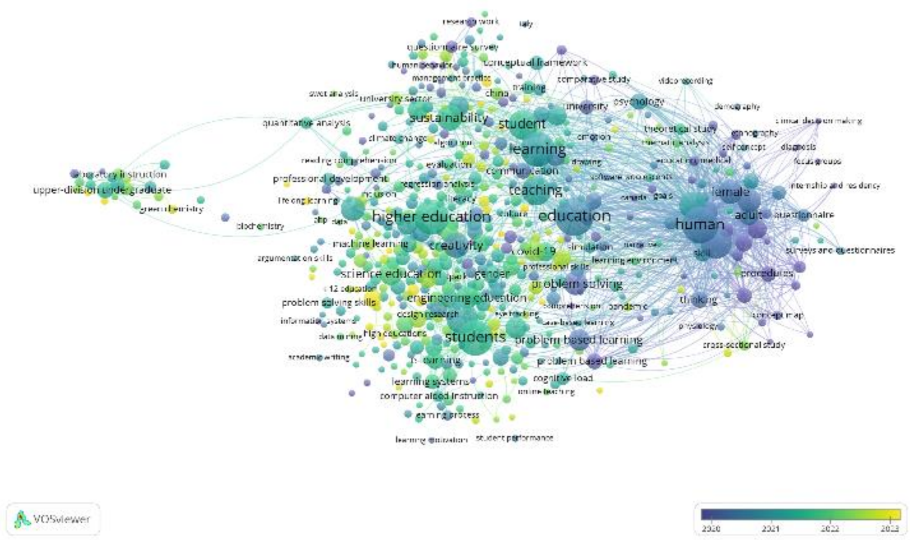
The VOSviewer analysis depicted in Figure 1 highlights intricate relationships among various topics associated with analytical thinking skills in science education. Figure 1(a) presents the network visualization, showcasing clusters of interconnected keywords that reflect thematic relationships within the reviewed literature. This visualization identifies areas of concentrated research, including teaching methodologies, curriculum development, and evaluation techniques, which are pivotal in advancing analytical thinking skills.

Figure 1(b) illustrates the overlay visualization, which captures the temporal distribution of research themes. This visualization reveals how certain topics, such as technology integration, have gained prominence in recent years, reflecting the evolving focus of science education research. Clusters associated with problem-based teaching, collaborative learning, and the use of digital tools emerge as central themes, demonstrating their relevance in fostering analytical thinking.

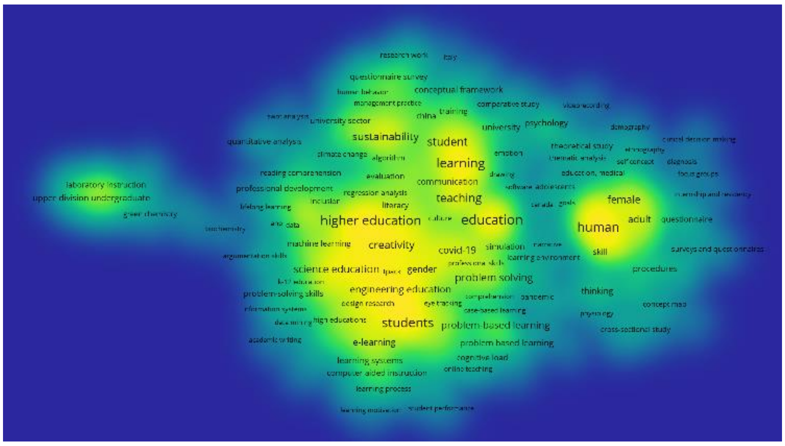
Figure 1(c) provides the density visualization, indicating the intensity of research focus within specific areas. Warmer colors in the density map signify frequent co-occurrence of keywords related to critical themes, such as problem-solving and technological interventions. This visualization emphasizes the dominant role of innovative methodologies and digital tools in supporting students' analytical thinking development.



(a)



(b)



(c)

Figure 1. Results of the VOSviewer analysis: (a) network visualization of co-occurring keywords, (b) overlay visualization showing the temporal distribution of keywords, and (c) density visualization illustrating the concentration of research focus areas

These findings align closely with trends identified in the literature review, which highlights the critical contributions of technology, problem-based methodologies, and evaluation grounded in critical thinking principles. For example, studies suggest that integrating digital tools and simulations enhances students' comprehension of scientific concepts while fostering higher-order thinking skills necessary for solving real-world challenges. Furthermore, problem-based learning approaches are consistently recognized for their ability to cultivate logical reasoning and creative problem-solving in students.

Research Trends and Publication Years

The analysis of publication trends demonstrates a significant increase in research focusing on analytical thinking skills, particularly in 2020 and 2021. As shown in Figure 2, the number of publications rose sharply during this period, highlighting a growing emphasis on cognitive skills essential for the 21st century. This trend reflects the increasing recognition of analytical thinking as a crucial competency for preparing students to address real-world challenges. The surge in research activity aligns with the global shift to remote learning necessitated by the COVID-19 pandemic, which demanded innovative educational approaches to support analytical thinking in a rapidly changing context.

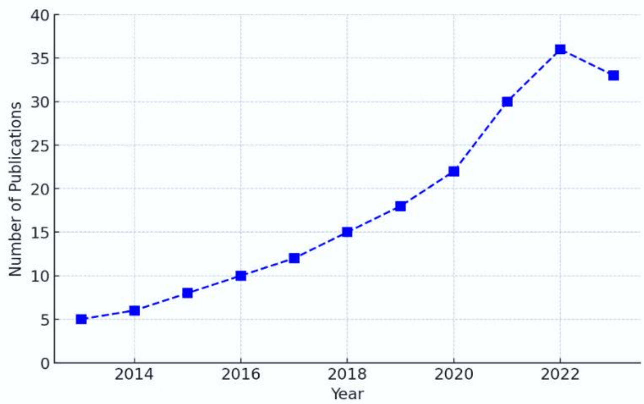


Figure 2. Number of publications by year in 2013-2024

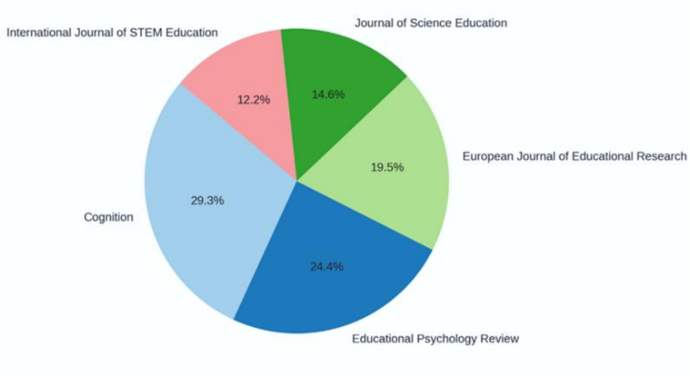


Figure 3. Top trends research in their journal in 2020-2021

High-impact journals such as Cognition, Educational Psychology Review, and the European Journal of Educational Research played a pivotal role in disseminating research on cognitive development during this period, as depicted in Figure 3. Cognition contributed significantly by publishing studies examining the integration of digital tools in virtual classrooms, offering practical insights into enhancing students' analytical skills through remote teaching strategies. Similarly, Educational Psychology Review focused on empirical studies investigating the relationship between instructional design and the development of analytical thinking, while the European Journal of Educational Research published comparative studies exploring how various educational systems foster cognitive skill development.

The educational challenges posed by the pandemic underscored the urgent need for innovative strategies to integrate analytical thinking across curricula, particularly in science education. The surge in research during this period reflects efforts to address this need, with studies exploring diverse pedagogical approaches such as problem-based learning in chemistry and inquiry-based methods in physics. These findings illustrate the interdisciplinary nature of research on cognitive skill development and the growing trend of embedding analytical thinking into various domains of science education.

The sharp increase in publications focusing on analytical thinking skills during 2020 and 2021 underscores the recognition of these skills' critical importance. Driven by the demands of remote learning during the pandemic, this research provided valuable insights into effective strategies for fostering analytical thinking. Future studies should build on these findings, prioritizing the development of adaptable, evidence-based approaches to enhance students' analytical skills across diverse educational settings. This work will ensure that learners are equipped to meet the evolving demands of a complex and knowledge-driven world.

Methods in Studies Examining Analytical Thinking Skills in Science Education

Quantitative research methods have been the primary approach in studies examining analytical thinking skills in science education. This preference is driven by the need for objective, measurable, and replicable data to assess the effectiveness of various educational interventions. Among these, quasi-experimental designs are the most prevalent. Unlike true experiments, quasi-experimental designs do not rely on random assignment but still use control and experimental groups to compare outcomes. This design is particularly suited for educational research where random assignment may not be feasible or ethical.

Quasi-experimental studies typically involve pre-tests and post-tests to measure changes in analytical thinking skills before and after an intervention. For instance, a typical study might compare the analytical thinking skills of students exposed to Problem-Based Learning (PBL) with those taught using traditional lecture methods. Such studies provide critical insights into how innovative teaching strategies enhance cognitive abilities.

Table 1. Common quasi-experimental designs in analytical thinking research

No.	Study Design	Description
1.	Pre-test/post-test control group	Measures outcomes before and after the intervention in both groups.
2.	Nonequivalent control group	Similar to pre-test/post-test but without random group assignment.
3.	Interrupted time series	Measures outcomes at multiple points before and after the intervention.
4.	Matched groups	Participants are matched based on certain characteristics to form comparable groups.

Quasi-experimental designs offer several advantages, including the ability to control for confounding variables and establish causal relationships. Their flexibility makes them suitable for diverse educational contexts where strict randomization may not be practical.

While quantitative methods yield valuable data, mixed-method approaches, which integrate both quantitative and qualitative data, have become increasingly popular. These approaches capture the complexity of educational experiences that may be missed by quantitative methods alone. Mixed-method studies typically begin with a quantitative phase, such as a survey or standardized test, followed by a qualitative phase involving interviews or focus groups. This sequential design allows researchers to use quantitative results to inform the qualitative phase, deepening the understanding of the findings.

Table 2. Common mixed-method designs in analytical thinking research

No.	Study Design	Description
1.	Explanatory sequential	Starts with quantitative data, followed by qualitative data to explain results.
2.	Exploratory sequential	Begins with qualitative data collection, followed by quantitative testing.
3.	Convergent parallel	Quantitative and qualitative data are collected and analyzed simultaneously.
4.	Embedded design	One type of data (quantitative or qualitative) is embedded within the other.

The integration of quantitative and qualitative data provides a comprehensive view of analytical thinking development. Quantitative data offers broad patterns across large samples, while qualitative data provides contextual insights into individual experiences. This mixed-method approach offers a richer understanding of the development and impact of educational interventions on analytical thinking skills.

Predominant Subjects in Research on Analytical Thinking Skills

High school and university students were the predominant subjects in research on analytical thinking skills, highlighting the critical period during which cognitive abilities are refined. The focus on secondary and tertiary education emphasizes these stages as pivotal for developing higher-order thinking skills necessary for academic success and future professional careers. Research involving these groups underscores the educational community's recognition of the importance of nurturing analytical thinking during formative years.

High school students, particularly in grades 10 to 12, are ideal for studies investigating cognitive development, as they are transitioning from concrete to more abstract thinking, aligning with Piaget's cognitive development theory. A study in the Journal of Educational Psychology, for instance, showed that students engaged in Problem-Based Learning (PBL) exhibited significant improvements in analytical thinking compared to those receiving traditional instruction.

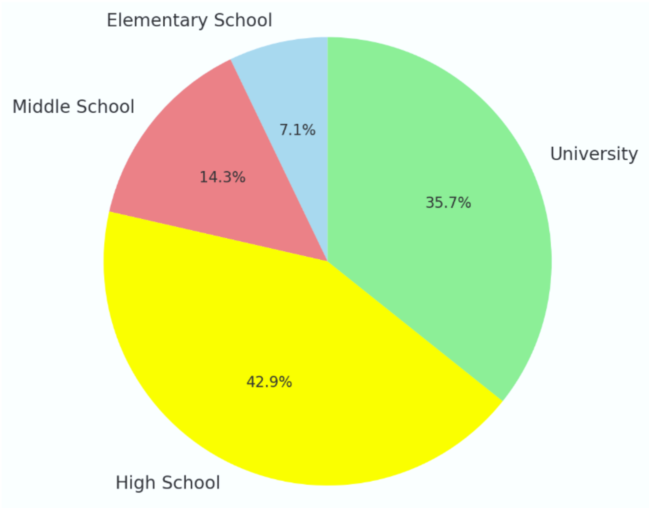


Figure 4. Distribution of research subjects by education level

University students are also key participants in research on analytical thinking. As university education requires deep cognitive engagement, students frequently analyze complex texts, conduct independent research, and critically engage with their disciplines. For example, a study conducted at a major university found that students who participated in debates exhibited enhanced analytical reasoning and critical thinking, further emphasizing the importance of these cognitive skills at the tertiary level.

Table 5. Key studies on analytical thinking skills by subject group

No.	Study Title	Education Level	Key Findings
1.	The impact of problem-based learning on high school students.	High School	Significant improvement in problem-solving abilities.
2.	Enhancing analytical thinking in university students through debate.	University	Increased analytical reasoning and critical thinking.
3.	Inquiry-based learning and its effect on high school students.	High School	Enhanced ability to analyze scientific problems.
4.	The role of metacognition in university students' analytical thinking.	University	Improved self-regulation and analytical skills.

These studies reflect the range of approaches used to enhance analytical thinking at secondary and tertiary levels. From PBL and debates to inquiry-based learning and metacognitive strategies, each method offers unique advantages in fostering cognitive development during these crucial educational stages.

While research largely focuses on high school and university students, a growing body of work has begun to examine younger students, highlighting the importance of early interventions. These studies suggest that foundational cognitive abilities, including analytical thinking, can be nurtured from a young age. Introducing these skills early in elementary and middle school lays the groundwork for advanced cognitive development.

Research involving younger students often explores age-appropriate strategies to foster analytical thinking. For instance, a study published in the Journal of Science Education and Technology found that middle school students participating in inquiry-based learning showed improved questioning, experiment design, and data analysis skills. These abilities are essential for scientific literacy and serve as a foundation for more complex thinking in later years.

Table 6. Examples of early interventions in analytical thinking

No.	Study Title	Education Level	Key Findings
1.	Inquiry-Based Learning in Middle School Science.	Middle School	Enhanced questioning and data analysis skills.
2.	Critical Thinking Development in Elementary Students.	Elementary School	Improved logical reasoning and narrative analysis.
3.	Project-Based Learning in Early Grades.	Elementary School	Increased engagement and problem-solving abilities.
4.	The Role of Play in Developing Analytical Thinking in Young Children.	Early Childhood	Enhanced cognitive flexibility through play.

The inclusion of younger students in analytical thinking research demonstrates that cognitive development is a continuous process. By engaging students in analytical thinking activities at earlier stages, educators can lay a strong foundation for later academic success.

For example, a study using storytelling as a tool for developing analytical thinking in elementary students showed improved logical reasoning and narrative analysis skills. Similarly, research on project-based learning in early grades has shown that hands-on approaches foster student engagement and problem-solving skills, preparing them for future analytical thinking tasks. Studies on the role of play in early childhood have also demonstrated that structured play activities can enhance cognitive flexibility and problem-solving abilities, supporting long-term cognitive growth.

Table 7. Benefits of early interventions in analytical thinking

No.	Benefit	Description
1.	Early skill development	Lays the foundation for advanced analytical thinking.
2.	Increased engagement	Makes learning more engaging for young students.
3.	Enhanced cognitive flexibility	Develops flexible thinking and problem-solving skills.
4.	Improved academic performance	Positively impacts overall academic achievement.
5.	Long-term cognitive benefits	Supports continuous cognitive development.

In conclusion, although high school and university students remain the primary focus of analytical thinking research, there is a growing recognition of the importance of early interventions. Studies involving younger students highlight the potential to build essential cognitive skills that will serve students throughout their educational journey. The findings across different age groups provide valuable insights into how analytical thinking can be effectively nurtured at all stages of education, ensuring students are equipped to face future academic and professional challenges.

Topics and Treatments

Research on educational interventions aimed at improving analytical thinking skills frequently focuses on pedagogical approaches such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Inquiry-Based Learning (IBL). These methods have been extensively studied and proven effective in fostering critical and analytical thinking. They provide students with practical tools to engage with complex problems and projects, thereby promoting deeper learning.

- Problem-based learning (PBL): This method encourages students to learn by solving open-ended problems, promoting self-directed learning, research, and critical thinking. Studies have shown that PBL not only enhances analytical thinking but also improves students' ability to apply knowledge to real-world situations. For example, a study published in the Journal of Educational Psychology demonstrated that high school students involved in PBL showed significant improvements in analytical thinking skills compared to those who received traditional lecture-based instruction.
- Project-based learning (PjBL): PjBL involves students working on long-term projects, emphasizing collaboration, communication, and practical application of knowledge. This approach deepens student engagement with subject matter while fostering analytical and critical thinking. Research published by the International Journal of STEM Education

indicated that PjBL enhances students' abilities in planning, execution, and evaluation of complex tasks, all key components of analytical thinking.

- Inquiry-based learning (IBL): IBL focuses on encouraging students' curiosity, asking questions, conducting investigations, and developing solutions. It promotes hands-on learning and is particularly effective in scientific contexts. A study from the Journal of Science Education and Technology found that students engaged in IBL activities showed marked improvement in their ability to analyze data, formulate hypotheses, and draw meaningful conclusions.

These pedagogical approaches—PBL, PjBL, and IBL—share a focus on active learning, student engagement, and the real-world application of knowledge. They have consistently been found to effectively enhance analytical thinking skills, essential for both academic and professional success.

In addition to broader pedagogical approaches, specific treatments like metacognitive scaffolding, debate, and Research-Based Learning (RBL) have been used to target and improve students' analytical thinking abilities. These methods provide targeted support to deepen cognitive processing and promote self-regulated learning.

- Metacognitive scaffolding: This technique provides structured support to help students develop metacognitive skills, such as planning, monitoring, and evaluating their learning. A study in the Educational Psychology Review found that students who received metacognitive scaffolding showed significant improvement in their ability to monitor and evaluate their problem-solving processes, which enhanced their overall analytical thinking skills.
- Debate: Debate provides a platform for students to engage in structured arguments, which fosters critical and analytical thinking. It requires students to construct logical arguments, evaluate evidence, and respond to counterarguments. Research from the Journal of Argumentation in Context demonstrated that students who participated in debates improved their analytical reasoning and ability to defend their viewpoints.
- Research-based learning (RBL): RBL encourages students to engage in authentic research activities, applying analytical thinking skills throughout the process of inquiry—from formulating research questions to analyzing data and presenting findings. A study published in the International Journal of Research in Education and Science revealed that students involved in RBL projects exhibited significant improvements in their ability to analyze and synthesize information through evidence-based research.

In summary, combining broader approaches such as PBL, PjBL, and IBL with specific treatments like metacognitive scaffolding, debate, and RBL provides a comprehensive framework for improving analytical thinking skills. Research supports the effectiveness of these methods in fostering critical cognitive skills, crucial for both academic achievement and professional readiness. By integrating these approaches into educational practices, educators can create engaging learning environments that help students develop the analytical skills needed for the challenges of the modern world.

Primary Data Collection Instruments in Research on Analytical Thinking Skills

In research focusing on analytical thinking skills, tests and assessments serve as essential tools for evaluating outcomes and measuring students' abilities to think critically, solve problems, and apply knowledge in diverse contexts. Among the methods used, standardized tests and custom-designed rubrics are the primary instruments for data collection. These tools provide reliable, quantifiable data that researchers analyze to determine the effectiveness of educational interventions and the development of students' analytical thinking skills.

- Standardized tests are widely employed due to their consistency in assessing students' performance against national or state benchmarks. These tests are designed to measure a range of skills, including analytical thinking, under controlled conditions. Examples such as the SAT, ACT, and other state assessments often feature sections specifically assessing critical thinking and analytical reasoning. For instance, the SAT's Critical Reading and Math sections require students to analyze texts, solve complex problems, and apply logical reasoning, making it a valuable tool for measuring analytical abilities.
- Custom-designed rubrics are tailored to specific research studies and instructional methods. These rubrics provide detailed criteria for assessing students' performance on tasks that involve analytical thinking. They are particularly useful in project-based, inquiry-based, and other complex learning activities. For example, a rubric designed for a science project might evaluate problem identification, hypothesis formulation, experimental design, data analysis, and conclusions. Custom rubrics allow researchers to assess targeted aspects of analytical thinking that are directly relevant to the intervention being studied.

Both standardized tests and custom rubrics offer robust frameworks for measuring analytical thinking across different educational contexts. Standardized tests provide comparability and reliability, allowing researchers to benchmark performance, while custom rubrics offer flexibility and specificity, aligning assessments with the instructional methods under evaluation.

The reliability and validity of these instruments are essential for ensuring that the data accurately reflect students' analytical thinking abilities. Researchers frequently pilot test their instruments and use statistical methods such as Cronbach's alpha to evaluate reliability. Validity is often assessed through content, construct, and criterion-related validity, ensuring that the instruments measure what they are intended to.

While tests and assessments provide valuable quantitative data, surveys and interviews capture qualitative insights into students' learning experiences and perceptions. These tools allow researchers to explore the contextual and subjective aspects of learning that standardized tests cannot measure. Surveys and interviews help provide a more nuanced understanding of how students engage with educational interventions and develop their analytical thinking skills.

- Surveys are widely used to collect data on students' attitudes, beliefs, and self-reported behaviors. They may include Likert-scale questions, which measure the degree of agreement with certain statements, as well as open-ended questions that allow students to elaborate on their thoughts. For example, a survey examining the effectiveness of project-based learning might ask students about their engagement levels, perceived challenges, and improvements in their analytical thinking abilities.

- Interviews offer even deeper insights into students' experiences and perceptions. Depending on the research objectives, interviews can be structured, semi-structured, or unstructured. While structured interviews follow a fixed set of questions, semi-structured and unstructured formats allow flexibility, enabling researchers to ask follow-up questions based on participants' responses. Interviews are particularly useful for revealing students' thought processes, motivations, and specific applications of analytical thinking in different contexts.

By combining quantitative data from tests and assessments with qualitative data from surveys and interviews, researchers gain a comprehensive view of students' analytical thinking skills. This mixed-methods approach not only validates findings but also provides deeper insights into the effectiveness of educational interventions. For instance, while test scores may show improvements in analytical thinking, survey and interview data can explain students' experiences, challenges, and which aspects of the learning activities they found most helpful.

The integration of these data collection methods ensures that researchers capture both measurable outcomes and the contextual factors influencing students' learning. This holistic approach is crucial for understanding the complexities of educational interventions and for designing strategies to effectively enhance analytical thinking skills.

In conclusion, standardized tests and custom-designed rubrics are the primary data collection instruments used in research on analytical thinking skills, providing reliable and quantifiable data. Surveys and interviews complement these tools by offering qualitative insights into students' learning experiences. Together, these methods form a comprehensive framework for assessing and understanding the development of analytical thinking skills in various educational contexts.

Data Analysis Techniques in Research on Analytical Thinking Skills

In educational research, particularly in studies focusing on analytical thinking skills, statistical analyses play a critical role in assessing the effectiveness of interventions. Two of the most common techniques used are t-tests and Analysis of Variance (ANOVA), both essential for determining whether observed differences in student performance are statistically significant. These methods provide rigorous evidence for the impact of various educational strategies.

- t-tests are used to compare the means of two groups, making them especially useful when evaluating interventions by comparing the performance of an experimental group to a control group. For instance, a t-test could assess the impact of problem-based learning (PBL) on analytical thinking by comparing the average scores of students who participated in PBL activities with those who underwent traditional instruction. If a significant difference is found, it suggests the intervention had a notable effect on students' analytical thinking skills.

- ANOVA is a statistical method used to compare the means of three or more groups. This technique determines whether any statistically significant differences exist between groups based on different interventions. For example, a study comparing the effectiveness of PBL, Project-Based Learning (PjBL), and traditional lectures on analytical thinking could use ANOVA to evaluate the mean scores across the groups. A significant ANOVA result would indicate that at least one teaching method led to superior outcomes.

Both t-tests and ANOVA provide valuable insights into the effectiveness of educational interventions by rigorously analyzing whether differences in performance are due to the interventions rather than random chance. This objectivity is essential for establishing evidence-based educational practices.

In addition to these methods, other techniques such as regression analysis and chi-square tests are employed. Regression analysis helps explore relationships between multiple variables and their combined effect on analytical thinking skills, while chi-square tests assess associations between categorical variables like specific teaching strategies and performance outcomes.

While statistical techniques provide quantitative insights, qualitative analysis is vital for understanding the contextual factors influencing students' analytical thinking skills. Thematic analysis is commonly used to explore qualitative data by identifying and reporting recurring patterns and themes. This method offers a nuanced understanding of students' experiences, thoughts, and the factors shaping their learning processes. Thematic analysis begins with researchers familiarizing themselves with the data, typically by reading and re-reading transcripts from interviews, focus groups, or open-ended survey responses. After this, the researchers generate initial codes to categorize key features related to the research questions. These codes are then grouped into broader themes that capture significant patterns in the data.

For example, in a study on project-based learning, thematic analysis might reveal themes such as engagement with real-world problems, collaborative learning, and development of critical thinking skills. These themes help explain how students perceive learning and how their analytical skills develop in specific contexts. Thematic analysis is crucial for exploring the qualitative aspects of educational interventions, revealing the mechanisms behind observed changes in analytical thinking skills. It helps researchers understand why certain interventions succeed and how they influence students' cognitive development.

The combination of t-tests and ANOVA for quantitative data, alongside thematic analysis for qualitative data, provides a comprehensive framework for evaluating educational interventions. This mixed-methods approach not only establishes robust evidence of effectiveness but also offers deep insights into the factors that shape students' learning experiences. By integrating these methods, researchers can derive actionable insights to improve educational practices, fostering the development of analytical thinking skills in diverse contexts.

The increasing emphasis on analytical thinking skills in science education aligns with the overarching goal of preparing students for the complex demands of the modern world (Yuan et al., 2016; Bilgin & Kala, 2022; Yurt, 2022). In an era marked by rapid technological progress and scientific breakthroughs, analytical thinking enables students to deconstruct problems, evaluate evidence critically, and develop reasoned solutions. These competencies are not only essential for academic success but also play a vital role in personal and professional development (Prawita et al., 2019; Pennycook et al., 2015; Finley et al., 2015; Egitim, 2022). As the global landscape becomes increasingly complex, fostering these skills has become a priority in education systems worldwide.

Integrating analytical thinking into science curricula through innovative pedagogical strategies has been shown to significantly enhance cognitive abilities among students (Blatti et al., 2019; Banerjee et al., 2018; Ioannidou & Erduran, 2022). Traditional teaching methods, often characterized by teacher-centered approaches, passive student engagement, and a focus on rote memorization, are gradually being replaced by innovative methods such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Inquiry-Based Learning (IBL). As shown in Figure 5, innovative teaching methods emphasize student-centered approaches, active engagement, and comprehensive skill development. Unlike traditional methods, which often prioritize memorization, innovative approaches encourage deeper understanding and critical engagement with scientific concepts. These methods immerse students in real-world contexts, compelling them to conduct experiments, collaborate with peers, and explore solutions to authentic problems (Kuter & Özer, 2020; Setyono et al., 2018).

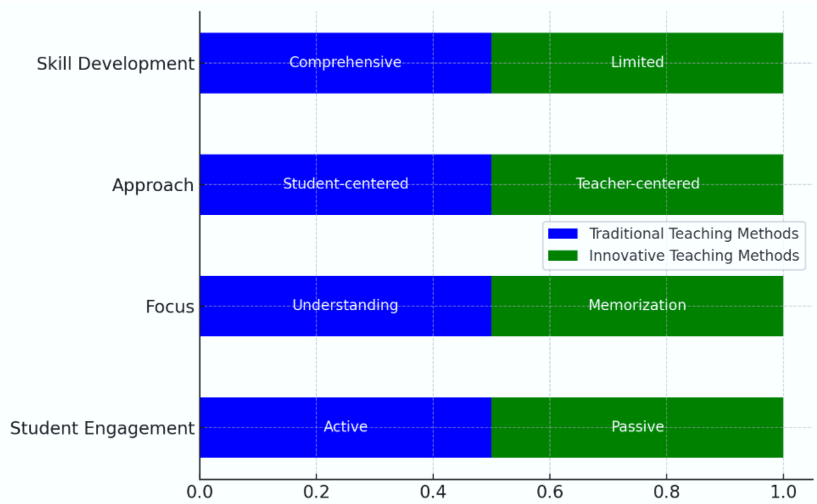


Figure 5. Comparison of traditional and innovative teaching methods in science education

Evidence from multiple studies supports the efficacy of these pedagogical innovations. For example, research published in the Journal of Science Education and Technology showed that students engaged in inquiry-based learning exhibited improved skills in data analysis, hypothesis formulation, and conclusion drawing compared to peers taught via traditional methods. Such outcomes highlight the transformative potential of active learning in cultivating analytical thinking. These methods not only enhance understanding but also improve problem-solving abilities and higher-order cognitive skills, which are crucial in navigating academic and real-world challenges (Jaganathan, 2024; Desrani et al., 2022; Payán, 2021; Ganapathy et al., 2017).

The diversity of research methodologies in the study of analytical thinking underscores the complexity of this field (Alkhatib, 2024; Cockburn et al., 2020; Vlegels & Daenekindt, 2021). Quantitative approaches, such as pre- and post-test evaluations, offer measurable insights into students' cognitive progress. Statistical methods like t-tests and ANOVA are frequently used to determine the significance of observed changes, providing robust evidence of the impact of various teaching strategies (Wai et al., 2018; Accettone et al., 2022; Badawi et al., 2023; Kimaru et al., 2017; Miftahulkhairah, 2024). These tools allow researchers to assess the effectiveness of specific interventions in a structured and objective manner.

Qualitative methods, including interviews, focus groups, and thematic analysis, complement quantitative findings by capturing students' subjective experiences and perceptions (Abrar, 2018; Kegler et al., 2018; Parsons et al., 2023; Cooper et al., 2015). These insights reveal the motivational and emotional aspects of learning, as well as the challenges students face in adapting to new teaching approaches. For instance, thematic analysis often uncovers recurring themes such as enhanced collaboration, increased motivation, and a sense of ownership over the learning process. Such insights are invaluable for refining teaching methodologies to better address students' needs (Kozleski, 2017).

The integration of quantitative and qualitative approaches provides a comprehensive understanding of how analytical thinking develops. This triangulation of data strengthens the validity of research findings and offers nuanced insights into the factors that promote cognitive growth (Rosadi et al., 2018; Al-Mohammadi, 2017; Permana et al., 2019; Mayarni & Nopiyanti, 2021; Wilkin, 2017). This dual approach enables educators to design more effective interventions that are grounded in both empirical evidence and an understanding of students' lived experiences.

As a cornerstone of scientific inquiry, analytical thinking enables students to systematically tackle complex problems, formulate hypotheses, and accurately interpret data (Demir, 2022; Al-Mohammadi, 2017). The importance of nurturing these skills has only grown in the face of multifaceted 21st-century challenges (Foster & Lemus, 2015; Čipková & Karolčík, 2018; Maddens et al., 2020; Nurlaelah et al., 2021; Erman et al., 2018). The review highlights several effective methods for achieving this, including problem-based learning (PBL), project-based learning (PjBL), and inquiry-based learning (IBL). Each method emphasizes active participation and critical engagement, allowing students to deepen their understanding while honing their reasoning abilities.

Additional strategies, such as metacognitive scaffolding and debate, further enhance analytical skills by encouraging reflective thinking and critical evaluation of ideas. Debate fosters argumentation and reasoning, while research-based learning immerses students in authentic scientific investigations, enabling them to synthesize and analyze data effectively. These treatments are instrumental in complementing broader pedagogical approaches and addressing specific cognitive skills.

Data collection methods used in this field range from standardized assessments and rubrics to interviews and surveys, ensuring that both objective and subjective aspects of learning are captured. Statistical analyses, including t-tests and ANOVA, provide compelling evidence of intervention effectiveness, while qualitative analyses delve into the nuances of student experiences. This combination ensures a holistic view of how analytical thinking develops and evolves over time.

Despite these advances, there is a need for further research to explore new strategies and extend their applicability to diverse educational contexts (Magrath et al., 2019). Emerging technologies, such as artificial intelligence and virtual reality, hold significant potential for creating immersive learning environments that support analytical thinking. These tools can simulate complex phenomena, providing real-time feedback and enabling students to engage deeply with the material.

Future studies must also address issues of scalability and sustainability. While many strategies have proven successful in controlled settings, their adaptation to different cultural and educational contexts remains a challenge (Barnes et al., 2021; Grady, 2023; Zamboni et al., 2019). Collaboration among educators, policymakers, and researchers is essential to ensure the global integration of best practices.

Interdisciplinary approaches offer another avenue for enhancing analytical thinking. By integrating science education with subjects such as mathematics, engineering, and technology, educators can provide students with a more holistic understanding of interconnected concepts. Projects that require cross-disciplinary knowledge encourage students to apply their analytical skills in diverse contexts, preparing them for the complexities of the modern world.

Teacher professional development is critical in this endeavor. Educators must be equipped with the skills and knowledge necessary to implement innovative teaching methods effectively. Ongoing training in pedagogy, data-driven decision-making, and technology integration ensures that teachers are prepared to foster analytical thinking in their students. Supporting educators is a fundamental step in delivering high-quality, impactful instruction.

CONCLUSION

This systematic literature review highlights the significance of analytical thinking skills in science education, emphasizing their critical role in preparing students for the demands of the 21st century. By analyzing research trends from 2013 to 2024, the review identifies key areas of focus, including the integration of innovative teaching strategies such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Inquiry-Based Learning (IBL). These approaches have proven effective in fostering analytical thinking, equipping students with the cognitive tools needed for solving complex problems and adapting to dynamic, knowledge-driven environments.

The findings also underscore the diversity of research methodologies used to study analytical thinking, ranging from quantitative approaches such as quasi-experimental designs to mixed-method studies that combine statistical analysis with qualitative insights. This methodological variety provides a comprehensive understanding of how analytical thinking skills develop and how they can be effectively cultivated. The review further highlights the pivotal role of technology, including digital platforms and virtual labs, in supporting these efforts, especially during the shift to remote learning prompted by the COVID-19 pandemic.

Despite these advances, the review identifies gaps in the literature, such as limited longitudinal studies and inconsistent evaluation metrics. These challenges underline the need for a more robust framework to assess the long-term impact of interventions aimed at enhancing analytical thinking. By addressing these gaps, future research can contribute to the development of scalable, evidence-based strategies that promote cognitive growth across diverse educational contexts. This review thus serves as a foundation for advancing science education and fostering analytical thinking as a cornerstone of lifelong learning and professional success.

LIMITATION

While this review provides valuable insights into analytical thinking in science education, it is not without limitations. The focus on Scopus-indexed journals may exclude relevant studies published in other databases or lower-tier journals, potentially limiting the breadth of perspectives captured. Additionally, the reliance on English-language articles may introduce linguistic bias, overlooking contributions from non-English-speaking regions. These factors highlight the need for broader inclusion criteria in future reviews to ensure a more comprehensive understanding of the global landscape of analytical thinking research.

RECOMMENDATION

Based on the findings, future research should focus on developing scalable, cost-effective teaching strategies that are adaptable to diverse educational contexts. Longitudinal studies are necessary to assess the lasting impact of interventions on students' cognitive abilities and professional trajectories. Researchers should also explore the potential of emerging technologies, such as artificial intelligence and virtual reality, to create immersive learning environments that support analytical thinking. Collaboration among educators, researchers, and policymakers will be essential to implement evidence-based practices that enhance science education and ensure students are equipped to meet the challenges of an ever-evolving world.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

Funding

This research received no external funding

Acknowledgment
The authors acknowledge the contributions of the research team, whose dedication and collaborative efforts were instrumental in the completion of this study.

Conflict of Interests
The authors declare no conflict of interest.

REFERENCES

Abrar, M. (2018). A critical evaluation of qualitative reports and their contributions to educational research. *PAROLE: Journal of Linguistics and Education, 7*(1), 13-22. https://doi.org/10.14710/parole.v7i1.13-22

Accettone, S. L. W., DeFrancesco, C., Belle, L. V., Smith, J. B., & Giroux, E. (2022). A problem-based approach to teaching the internal standard method by atr-ftir spectroscopy. *Journal of Chemical Education, 99*(11), 3735-3746. https://doi.org/10.1021/acs.jchemed.2c00548

Al-Hanifah, J. A., Cholily, Y. M., & Ummah, S. K. (2023). Analysis of students' analytical thinking ability and mathematical communication using online group investigation learning model. *Mathematics Education Journal, 7*(1), 100-113. https://doi.org/10.22219/mej.v7i1.23342

Ali, G. & Awan, R. (2021). Thinking based instructional practices and academic achievement of undergraduate science students: exploring the role of critical thinking skills and dispositions. *Journal of Innovative Sciences, 7*(1), 56-70. https://doi.org/10.17582/journal.jis/2021/7.1.56.70

Alkhatib, A., Jaber, K., Alzo'by, H., Abdallah, M., & Salah, M. (2024). Exploring progress in forest fire detection, prediction, and behavior: an in-depth survey. *International Journal of Computing and Digital Systems, 15*(1), 789-800. https://doi.org/10.12785/ijcds/150157

Al-Mohammadi, N. (2017). Effectiveness of using infographics as an approach for teaching programming fundamentals on developing analytical thinking skills for high school students in the city of makkah in saudi arabia. *Global Journal of Educational Studies, 3*(1), 22-42. https://doi.org/10.5296/gjes.v3i1.10854

Anagün, Ş. S. (2018). Teachers' perceptions about the relationship between 21st century skills and managing constructivist learning environments. *International Journal of Instruction, 11*(4), 825-840. https://doi.org/10.12973/iji.2018.11452a

Astuti, Y., Febrianti, S. A., Akbar, B., & Safahi, L. (2021). Students' analytical thinking ability through the strategy of giving feedback on excretion system learning. *Bioeduscience, 5*(3), 196-200. https://doi.org/10.22236/j.bes/537767

Badawi, M., Hussain, H. O., Badawi, M., Shawwa, L. A. A., Jamjoom, R., Park, Y. S., … & Tekian, A. (2023). Learning transfusion medicine through scoring objective structured clinical examination. *Transfusion, 63*(S1), 20-27. https://doi.org/10.1111/trf.17199

Banerjee, Y., Azar, A. J., Tuffnell, C., Lansberg, P., Bayoumi, R., & Davis, D. A. (2018). A novel 6d-approach to radically transform undergraduate medical education: preliminary reflections from MBRU. *BMC Medical Education, 18*(1), 1-12. https://doi.org/10.1186/s12909-018-1402-0

Barnes, C., Grady, A., & Yoong, S. L. (2021). Prioritising scalability during the evaluation of a web-based intervention to improve the implementation of evidence-based nutrition practices in early childhood education and care. *Health Promotion Journal of Australia, 33*(3), 779-781. https://doi.org/10.1002/hpja.558

Bers, M. U. (2018). Coding and computational thinking in early childhood: the impact of ScratchJr in Europe. *European Journal of STEM Education, 3*(3), 1-13. https://doi.org/10.20897/ejsteme/3868

Bilgin, A. K. & Kala, N. (2022). Using case-based science scenarios to analyze preservice teachers' analytical thinking skills. *Kuramsal Eğitimbilim, 15*(4), 867-883. https://doi.org/10.30831/akukeg.1095368

Blatti, J. L., Garcia, J. A. S., Cave, D., Monge, F., Cuccinello, A., Portillo, J., … & Schwebel, F. (2019). Systems thinking in science education and outreach toward a sustainable future. *Journal of Chemical Education, 96*(12), 2852-2862. https://doi.org/10.1021/acs.jchemed.9b00318

Blyznyuk, T. (2019). Educational innovations and technological advancement in english language teaching: training teachers for NUS. *Educational Horizons, 49*(2), 93-96. https://doi.org/10.15330/obrii.49.2.93-96

Boichenko, V., Yovenko, L., Remekh, T., Tsyhanok, O., Kyrychenko, V., & Huba, B. (2021). Formation of pedagogical thinking of future teachers. *Studies of Applied Economics, 39*(5), 1-9. https://doi.org/10.25115/eea.v39i5.4832

Bowen, R. S., Flaherty, A., & Cooper, M. M. (2022). Investigating student perceptions of transformational intent and classroom culture in organic chemistry courses. *Chemistry Education Research and Practice, 23*(3), 560-581. https://doi.org/10.1039/d2rp00010e

Chang, Y. (2023). A meta-analysis based study of the factors influencing students' engagement in classroom learning. *Proceedings of the 2022 3rd International Conference on Artificial Intelligence and Education (IC-ICAIE 2022),* 772-777. https://doi.org/10.2991/978-94-6463-040-4_117

Čipková, E. & Karolčík, Š. (2018). Assessing of scientific inquiry skills achieved by future biology teachers. *Chemistry-Didactics-Ecology-Metrology, 23*(2), 71-80. https://doi.org/10.1515/cdem-2018-0004

Cockburn, J., Schoon, M., Cundill, G., Robinson, C. J., Aburto, J., Alexander, S. M., … & Thondhlana, G. (2020). Understanding the context of multifaceted collaborations for social-ecological sustainability: a methodology for cross-case analysis. *Ecology and Society, 25*(3), 7. https://doi.org/10.5751/es-11527-250307

Cooper, R., Chenail, R., & Fleming, S. (2015). A grounded theory of inductive qualitative research education: results of a meta-data-analysis. *The Qualitative Report, 17*(52), 1-26. https://doi.org/10.46743/2160-3715/2012.1695

Darmawan, P. (2020). Students' analytical thinking in solving problems of polygon areas. Kontinu: *Jurnal Penelitian Didaktik Matematika, 4*(1), 17. https://doi.org/10.30659/kontinu.4.1.17-32

Demir, E. (2022). An examination of high school students critical thinking dispositions and analytical thinking skills. *Journal of Pedagogical Research, 6*(4), 190-200. https://doi.org/10.33902/jpr.202217357

Desrani, A., Arifa, Z., & Susanto, S. (2022). The impact of discovery learning model based on high order thinking skills (hots) in learning arabic on students analytical thinking skills. *Taqdir, 7*(2), 213-228. https://doi.org/10.19109/taqdir.v7i2.9910

Egitim, S. (2022). Do japanese students lack critical thinking? addressing the misconception. *Power and Education, 14*(3), 304-309. https://doi.org/10.1177/17577438221107203

Erman, E., Wasis, W., Susantini, E., & Azizah, U. (2018). Scientific thinking skills: why junior high school science teachers cannot use discovery and inquiry models in classroom. *Proceedings of the International Conference on Science and Technology (ICST 2018).* https://doi.org/10.2991/icst-18.2018.43

Farah, N. & Ayoubi, Z. (2020). Enhancing the critical thinking skills of grade 8 chemistry students using an inquiry and reflection teaching method. *Journal of Education in Science, Environment and Health.* https://doi.org/10.21891/jeseh.656872

Fatima, A., Abbas, A., Wan, M., Zaheer, A. N., & Akhtar, M. (2017). Analyzing the academic research trends by using university digital resources: a bibliometric study of electronic commerce in china. *Universal Journal of Educational Research, 5*(9), 1606-1613. https://doi.org/10.13189/ujer.2017.050918

Foster, J. S. & Lemus, J. D. (2015). Developing the critical thinking skills of astrobiology students through creative and scientific inquiry. *Astrobiology, 15*(1), 89-99. https://doi.org/10.1089/ast.2014.1219

Freeman, S., Eddy, S. L., McDonough, M. J., Smith, M. K., Okoroafor, N., Jordt, H., … & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410-8415. https://doi.org/10.1073/pnas.1319030111

Ganapathy, M., Singh, M. K. M., Kaur, S., & Kit, L. W. (2017). Promoting higher order thinking skills via teaching practices. *3L the Southeast Asian Journal of English Language Studies, 23*(1), 75-85. https://doi.org/10.17576/3l-2017-2301-06

Ganesha, H. R. & Aithal, P. S. (2022). Choosing an appropriate data collection instrument and checking for the calibration, validity, and reliability of data collection instrument before collecting the data during Ph.D. program in India. *International Journal of Management Technology and Social Sciences, 7*(2), 497-513. https://doi.org/10.47992/IJMTS.2581.6012.0235

Gilchrist, P. O., Alexander, A. B., Green, A., Sanders, F. E., Hooker, A. Q., & Reif, D. M. (2021). Development of a pandemic awareness stem outreach curriculum: utilizing a computational thinking taxonomy framework. *Education Sciences, 11*(3), 109. https://doi.org/10.3390/educsci11030109

Grady, A., Jackson, J., Wolfenden, L., Lum, M., & Yoong, S. L. (2023). Assessing the scalability of healthy eating interventions within the early childhood education and care setting: secondary analysis of a cochrane systematic review. *Public Health Nutrition, 26*(12), 3211-3229. https://doi.org/10.1017/s1368980023002550

Hidayatulloh, R., Suyono, S., & Azizah, U. (2020). Development of stem-based chemistry textbooks to improve students' problem solving skills. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika, 4*(3), 308-318. https://doi.org/10.36312/e-saintika.v4i3.306

Inayah, N. & Lubab, A. (2023). Enhancing analytical thinking skills and scientific attitudes of prospective science teacher students through pre-practicum virtual simulation. *Edusains, 15*(2), 176-185. https://doi.org/10.15408/es.v15i2.35431

Ioannidou, O. & Erduran, S. (2022). Policymakers' views of future-oriented skills in science education. *Frontiers in Education, 7*. 1-15. https://doi.org/10.3389/feduc.2022.910128

Jaganathan, S., Bhuminathan, S., & Ramesh, M. (2024). Problem-based learning – an overview. *Journal of Pharmacy and Bioallied Sciences, 16*(2), 1435-1437. https://doi.org/10.4103/jpbs.jpbs_820_23

Kanani, N. (2016). The role of intellectual capital value in the organization. *NG-Journal of Social Development, 5*(3), 156-163. https://doi.org/10.12816/0033114

Karami, M., Hashemi, N., & Van Merrienboer, J. (2024). From obese to lean curriculum: exploring students' experiences about developing competencies in medical education. *Frontiers in Medicine, 11*. https://doi.org/10.3389/fmed.2024.1309548

Kegler, M. C., Raskind, I. G., Comeau, D. L., Cooper, H. L., & Shelton, R. C. (2018). Study design and use of inquiry frameworks in qualitative research published in health education. *Health Education & Behavior, 46*(1), 24-31. https://doi.org/10.1177/1090198118795018

Khusmawardani, E., Muntholib, M., & Yahmin, Y. (2022). Impact of explicit scientific inquiry instruction hybrid mode with socioscientific issue context on students' critical thinking skills in chemical kinetics. *JCER (Journal of Chemistry Education Research), 6*(2), 131-137. https://doi.org/10.26740/jcer.v6n2.p131-137

Kimaru, I., Koether, M., Chichester, K. D., & Eaton, L. (2017). Teaching analytical method transfer through developing and validating then transferring dissolution testing methods for pharmaceuticals. *Journal of Chemical Education, 94*(8), 1066-1073. https://doi.org/10.1021/acs.jchemed.6b00878

Kontra, C., Lyons, D., Fischer, S. M., & Beilock, S. L. (2015). Physical experience enhances science learning. *Psychological Science, 26*(6), 737-749. https://doi.org/10.1177/0956797615569355

Kozleski, E. B. (2017). The uses of qualitative research. *Research and Practice for Persons With Severe Disabilities, 42*(1), 19-32. https://doi.org/10.1177/1540796916683710

Kuter, S. & Özer, B. (2020). Student teachers' experiences of constructivism in a theoretical course built on inquiry-based learning. *Journal of Qualitative Research in Education, 8*(1), 135-155. https://doi.org/10.14689/issn.2148-2624.1.8c.1s.7m

Lazure, P., Munn, J., Labbé, S., Murray, S., Butler, R. B., Khair, K., … & Newall, F. (2019). Education needs of nurses in thrombosis and hemostasis: an international, mixed-methods study. *Research and Practice in Thrombosis and Haemostasis, 3*(1), 99-108. https://doi.org/10.1002/rth2.12155

Maddens, L., Depaepe, F., Janssen, R., Raes, A., & Elen, J. (2020). Research skills in upper secondary education and in first year of university. *Educational Studies, 47*(4), 491-507. https://doi.org/10.1080/03055698.2020.1715204

Magrath, B., Aslam, M., & Johnson, D. (2019). Raising learning outcomes in the education systems of developing countries: research designs, methods, and approaches. *Research in Comparative and International Education, 14*(1), 3-6. https://doi.org/10.1177/1745499918824183

Mahato, P., Angell, C., Teijlingen, E. v., & Simkhada, P. (2018). Using mixed-methods research in health education in Nepal. *Journal of Health Promotion, 6*, 45-48. https://doi.org/10.3126/jhp.v6i0.21803

Maison, M., Kurniawan, D. A., Wirayuda, R. P., & Chen, D. (2022). Process skills-based e-module: impact on analytical thinking skills. *Jurnal Penelitian & Pengembangan Pendidikan Fisika, 8*(1), 23-34. https://doi.org/10.21009/1.08103

Manshaee, G., Dastnaee, T. M., Seidi, A., & Davoodi, A. (2014). Comparison of critical thinking in students interested and uninterested in learning a second language. *Theory and Practice in Language Studies, 4*(4). https://doi.org/10.4304/tpls.4.4.792-799

Maričić, S. & Špijunović, K. (2015). Developing critical thinking in elementary mathematics education through a suitable selection of content and overall student performance. *Procedia - Social and Behavioral Sciences, 180,* 653-659. https://doi.org/10.1016/j.sbspro.2015.02.174

Mayarni, M. & Nopiyanti, E. (2021). Critical and analytical thinking skill in ecology learning: a correlational study. *Jurnal Pendidikan Biologi Indonesia, 7*(1), 63-70. https://doi.org/10.22219/jpbi.v7i1.13926

McCrackin, S. D. (2020). Quantitatively assessing the success of your critical thinking teaching strategies. *Teaching Innovation Projects, 9*(1), 1-15. https://doi.org/10.5206/tips.v9i1.10342

Miftahulkhairah, M., Rahmi, N., Ekasasmita, W., S, A. F., & Adhalia H, N. F. (2024). Quantitative skills training for snbt preparation at sma negeri 2 parepare south sulawesi. *Jurnal Pengabdian UNDIKMA, 5*(1), 20. https://doi.org/10.33394/jpu.v5i1.9917

Noor, A. F., Yunus, R., Suyidno, S., & Fahmi, F. (2023). Development of predict-observe-explain (poe) based authentic problems' instructional package to improve students' critical thinking skills. *Jurnal Pendidikan Matematika Dan IPA, 14*(1), 69. https://doi.org/10.26418/jpmipa.v14i1.53932

Nurlaelah, I., Handayani, H., & Lismaya, L. (2021). Training higher order thinking skills (hots) and the ability to design experiments through the inquiry lab. *Proceedings of the 1st Universitas Kuningan International Conference on Social Science, Environment and Technology, UNiSET 2020*. https://doi.org/10.4108/eai.12-12-2020.2305019

Odeh, S., Shanab, S. A., & Anabtawi, M. (2015). Augmented reality internet labs versus its traditional and virtual equivalence. *International Journal of Emerging Technologies in Learning (iJET), 10*(3), 4. https://doi.org/10.3991/ijet.v10i3.4354

Parrish, D. (2016). Promoting quality teaching: phase 1 of a case study and research initiative for progressing evidence-based educational innovations. *Literacy Information and Computer Education Journal, 7*(1), 2198-2205. https://doi.org/10.20533/licej.2040.2589.2016.0290

Parsons, C. C., Hehn, M. T., Loudenback, A. J., Burke, H. K., Fox, A., Spratt, L. M., … & Zarestky, J. (2023). Cultivating qualitative researchers: lessons learned during a pandemic. *International Journal of Qualitative Methods, 22*, 160940692311577. https://doi.org/10.1177/16094069231157705

Payán, D. D. (2021). Cultivating health policy analysis and communication skills in undergraduate public health education: an active learning approach. *Pedagogy in Health Promotion, 7*(3), 235-241. https://doi.org/10.1177/23733799211003248

Pennycook, G., Fugelsang, J. A., & Koehler, D. J. (2015). Everyday consequences of analytic thinking. *Current Directions in Psychological Science, 24*(6), 425-432. https://doi.org/10.1177/0963721415604610

Permana, T. I., Hindun, I., Rofi'ah, N. L., & Azizah, A. S. N. (2019). Critical thinking skills: the academic ability, mastering concepts, and analytical skill of undergraduate students. *Jurnal Pendidikan Biologi Indonesia, 5*(1), 1-8. https://doi.org/10.22219/jpbi.v5i1.7626

Prawita, W., Prayitno, B. A., & Sugiyarto, S. (2019). Effectiveness of a generative learning-based biology module to improve the analytical thinking skills of the students with high and low reading motivation. *International Journal of Instruction, 12*(1), 1459-1476. https://doi.org/10.29333/iji.2019.12193a

Prayitno, B. A., Corebima, D., Susilo, H., Zubaidah, S., & Ramli, M. (2017). Closing the science process skills gap between students with high and low level academic achievement. *Journal of Baltic Science Education, 16*(2), 266-277. https://doi.org/10.33225/jbse/17.16.266

Putri, R. A., Hidayati, Y., Rosidi, I., & Hadi, W. P. (2020). The implementation of lks based on the concept attainment model to improving student's analytical thinking ability. *Jurnal Bioedukatika, 8*(2), 102. https://doi.org/10.26555/bioedukatika.v8i2.12492

Rahman, S. (2016). The advantages and disadvantages of using qualitative and quantitative approaches and methods in language "testing and assessment" research: a literature review. *Journal of Education and Learning, 6*(1), 102. https://doi.org/10.5539/jel.v6n1p102

Ramadani, A., Supardi, Z., & Hariyono, E. (2021). Profile of analytical thinking skills through inquiry-based learning in science subjects. *Studies in Learning and Teaching,* 2(3), 45-60. https://doi.org/10.46627/silet.v2i3.83

Rohim, F. (2020). Need analysis of virtual laboratories for science education in jambi, indonesia. *Jurnal Sains Sosio Humaniora, 4*(2), 744-755. https://doi.org/10.22437/jssh.v4i2.11539

Rosadi, I., Maridi, M., & Sunarno, W. (2018). The effectiveness of process-oriented guided inquiry learning to improve students' analytical thinking skills on excretory system topic. *Biosaintifika: Journal of Biology & Biology Education, 10*(3), 684-690. https://doi.org/10.15294/biosaintifika.v10i3.15990

Salvador, J. T. (2016). Exploring quantitative and qualitative methodologies: a guide to novice nursing researchers. *European Scientific Journal, 12*(18), 107. https://doi.org/10.19044/esj.2016.v12n18p107

Santos, J. L. G., Escalante-Barrios, E. L., Creamer, E. G., & Onwuegbuzie, A. J. (2020). Mixed methods research in latin america: initiatives and opportunities for expansion. *Texto Contexto - Enfermagem, 29*. https://doi.org/10.1590/1980-265x-tce-2020-0001-0001

Sefhedi, S. T., Omidire, M. F., Ebersöhn, L., & Murphy, P. K. (2021). Promoting critical-analytic thinking through teacher discourse moves and pedagogical principles: the case of a rural south african secondary school. *Journal for Language Teaching, 54*(2), 95-117. https://doi.org/10.4314/jlt.v54i2.5

Setyono, D., Prasetyo, K., & Turhan, M. Y. (2018). Influence of problem based learning model on thinking skills critical and student learning outcomes elementary school. *Proceedings of the 2nd International Conference on Education Innovation (ICEI 2018).* https://doi.org/10.2991/icei-18.2018.72

Shrivastava, S. K. (2023). Recent trends in supply chain management of business-to-business firms: a review and future research directions. *Journal of Business: Industrial Marketing, 38*(12), 2673-2693. https://doi.org/10.1108/jbim-02-2023-0122

Starčič, A. I., Terlevic, M., Lin, L., & Lebeničnik, M. (2018). Designing learning for sustainable development: digital practices as boundary crossers and predictors of sustainable lifestyles. *Sustainability, 10*(6), 2030. https://doi.org/10.3390/su10062030

Su, W., Chen, K., Lu, L. Y. Y., & Huang, Y. (2021). Identification of technology diffusion by citation and main paths analysis: the possibility of measuring open innovation. *Journal of Open Innovation: Technology, Market, and Complexity, 7*(1), 104. https://doi.org/10.3390/joitmc7010104

Sujana, A. & Komariah, A. (2020). Entrepreneurship competency training model of private high school principal through knowledge-based economy approach. *Proceedings of the 3rd International Conference on Research of Educational Administration and Management (ICREAM 2019)*. https://doi.org/10.2991/assehr.k.200130.151

Sukmawati, S. (2023). Development of quality instruments and data collection techniques. *Jurnal Pendidikan Dan Pengajaran Guru Sekolah Dasar (JPPGuseda), 6*(1), 119-124. https://doi.org/10.55215/jppguseda.v6i1.7527

Suyatman, S., Saputro, S., Sunarno, W., & Sukarmin, S. (2021). Profile of student analytical thinking skills in the natural sciences by implementing problem-based learning model. *Journal of Educational, Cultural and Psychological Studies (ECPS Journal), 23,* 89-111. https://doi.org/10.7358/ecps-2021-023-suya

Thaneerananon, T., Triampo, W., & Nokkaew, A. (2016). Development of a test to evaluate students' analytical thinking based on fact versus opinion differentiation. *International Journal of Instruction, 9*(2), 123-138. https://doi.org/10.12973/iji.2016.929a

Utami, B., Saputro, S., Ashadi, A., Masykuri, M., & Widoretno, S. (2017). Critical thinking skills profile of high school students in learning chemistry. *International Journal of Science and Applied Science: Conference Series, 1*(2), 124. https://doi.org/10.20961/ijsascs.v1i2.5134

Valibeigi, M., Mohammadi, A., & Valibeigi, N. M. (2020). Structural challenges of knowledge-based economy in iran. *Eko-Regional: Jurnal Pengembangan Ekonomi Wilayah, 15*(2), 12-22. https://doi.org/10.20884/1.erjpe.2020.15.2.1574

Vlegels, J. & Daenekindt, S. (2021). Combining topic models with bipartite blockmodelling to uncover the multifaceted nature of social capital. *Plos One, 16*(6), e0253478. https://doi.org/10.1371/journal.pone.0253478

Wai, J., Brown, M. I., & Chabris, C. F. (2018). Using standardized test scores to include general cognitive ability in education research and policy. *Journal of Intelligence, 6*(3), 37. https://doi.org/10.3390/jintelligence6030037

Weis, L., Eisenhart, M., Duncan, G. J., Albro, E., Bueschel, A. C., Cobb, P., … & Wilson, J. (2019). Mixed methods for studies that address broad and enduring issues in education research. *Teachers College Record: The Voice of Scholarship in Education, 121*(10), 1-16. https://doi.org/10.1177/016146811912101007

White, D. S., Gunasekaran, A., & Roy, M. H. (2014). Performance measures and metrics for the creative economy. *Benchmarking: An International Journal, 21*(1), 46-61. https://doi.org/10.1108/bij-03-2012-0017

Wilkin, C. (2017). Enhancing critical thinking: accounting students' perceptions. *Education and Training, 59*(1), 15-30. https://doi.org/10.1108/et-01-2015-0007

Wongpinunwatana, N. (2019). Enhancing students' creative thinking skills through the process of teaching business research. *Journal of Management Policy and Practice, 20*(2), 135-142. https://doi.org/10.33423/jmpp.v20i2.2100

Yuan, B., Wang, M., Kushniruk, A., Fellow, C., & Peng, J. (2016). Design of a computer-based learning environment to support diagnostic problem solving towards expertise development. *Knowledge Management & E-Learning: An International Journal, 8*(4), 540-549. https://doi.org/10.34105/j.kmel.2016.08.034

Yurt, E. (2022). Teachers' views and experiences regarding acquiring analytical thinking skills in the middle school mathematics curriculum. *International Journal on Social and Education Sciences, 4*(4), 599-619. https://doi.org/10.46328/ijonses.475

Zamboni, K., Schellenberg, J., Hanson, C., Betrán, A. P., & Dumont, A. (2019). Assessing scalability of an intervention: why, how and who? *Health Policy and Planning, 34*(7), 544-552. https://doi.org/10.1093/heapol/czz068