ISSN Online: 3006-4708
ISSN Print: 3006-4694

SOCIAL SCIENCE REVIEW ARCHIVES

https://policyjournalofms.com

Critical Thinking Skills of Secondary School Science Students: A Literature Review

Ms. Gulana[1], Dr. Iqbal Amin Khan[2]

[1] PhD, Scholar, Department of Education, University of Malkand.
Email: gulana.dcma.dirlower@gmail.com
[2] Lecturer, Department of Education, University of Malakand. Email: driqbalamainkhan@gmail.com

DOI: https://doi.org/10.70670/sra.v3i4.1244

Abstract

This study aims to review empirical studies and meta-analysis conducted on teaching critical thinking skills in secondary education published after 2012. This study analysed the instructional intervention used, test measure, different research designs used in previous studies. Study results suggested that science students need critical thinking skills to evaluate complicated data and reach well-informed conclusions, but students in underdeveloped countries frequently lack them, which hinders their success in both the classroom and the workplace. Critical thinking, which has its roots in psychology, philosophy, and education, includes dispositions (open-mindedness) and cognitive abilities (analysis, evaluation). There are ongoing discussions on whether it is domain-specific or transportable across disciplines, with varying opinions. Explicit instruction, group projects, and practical problem-solving are all examples of effective teaching techniques; however, critical thinking is frequently not adequately measured by conventional tests. Critical thinking can be taught, according to research, and the most successful treatments combine subject matter with critical thinking abilities. However, there are still issues with assessment design, which calls for authentic, open-ended activities to gauge higher-order thinking. To promote critical thinking at all educational levels, future efforts should concentrate on improving assessment instruments and improving teaching strategies.

Keywords: Critical Thinking Skills, High Order Thinking, Assessment Instruments, Teaching Strategies

Introduction

From Plato and Socrates to John Dewey, educational thinkers emphasized the value of critical thinking and the inherent worth of teaching that goes beyond rote memorization of facts (Oyewumi, 2019). One of education's stated goals is to teach pupils to think critically because it transcends all nearly every aspect of life). Also, it enables people to assess the information that is offered to them to make better decisions, as Facione (1990) rightly argued that “the personal and civic life of all members of society” (p. 32).

Three disciplines provide the foundation of the literature on critical thinking i.e. education, philosophy, and psychology (Lau, 2024). Different approaches to critical thinking are reflected in these disciplines. According to Dwyer (2017), the psychological tradition places a strong emphasis on mastering specific abilities and dispositions that are applicable in a variety of settings. These abilities include synthesis, interpretation, analysis, and evaluation. The possibility of transfer across contexts is increased by explicit critical thinking instruction (Peppen, 2022). The psychological tradition thus tends to emphasize what makes critical thinking sound. The philosophical tradition, on the other hand, emphasizes the ideal critical thinker and their traits rather than the actions or behaviors that they are

capable of (Paul, 2018). The philosophical approach has typically concentrated on applying formal principles of logic to content-specific knowledge, as seen in the study of Paul and Elder (2007). Philosophers contend that critical thinking skills are inextricably linked to content, which is how this approach varies from the psychological one. For instance, philosophers contend that depending on the topic matter, critical thinking abilities are not required nor enough in all situations (Mcpeck, 2016). Lastly, Benjamin Bloom's work is the foundation of the critical thinking tradition in education. Teachers have traditionally taught and assessed higher-order thinking skills using Bloom's taxonomy of hierarchical cognitive processing capabilities. It is generally considered that critical thinking skills is concerned with the last three levels of Bloom's taxonomy i.e. analysis, synthesis and evaluation-as these categories are concerned with the high order thinking skills, while on the other hand, the first three levels i.e. knowledge, comprehension and application, which are considered as lower order skills are based on factual information and recalling (Lai, 2011).

Focusing on all these three traditional thoughts, the main purpose of this paper was to seek to obtain answers of the following research questions:

1. What does critical thinking mean?
2. To what degree or extent critical thinking develop over time?
3. These basic and fundamental information will be significantly used (a) to critically examine instructional approaches which helps in promoting critical thinking (b) ways to measure and assess critical thinking skills.

What does Critical Thinking mean?

The existence of critical thinking among science students is an essential and compulsory requirement for making them enabled to critically evaluate and analyze the complex and diverse scientific information towards an informed decision (Guerrero & Sjöström, 2024). However, research suggests that in developing countries, science students often face difficulty and struggle with critical thinking, which not only obstructs the academic journey but also influences their professional success (Aston, 2024). Tohani and Aulia (2022) in their studies have stressed on the importance of critical thinking for students in the 21st century and according to Reid and Ali (2020), it is the compulsory requirement of gaining knowledge skills in science education, research inquires, analyzing scientific data, along with other digital literacies (Haavind, 2024). Besides, imparting students with skills, capacity building and resolving issues of serious nature with reasoning, educational institutions in the developed world are making policies for consolidating the transformation of teaching- learning process through a planned mechanism which according to Liesa-Orús *et al.,* (2020) is called the 21st century skills in literature. However, Caner (2024) has categorized these skills into three categories i.e., knowledge, life and professional skills, media, and technology skills, and learning and innovative skills. Thus, critical thinking and problem solving, teamwork and communication, creativity, and innovation are some of the examples of learning and innovative skills, which according to the researchers are vital for students to become critical thinkers, innovators, problem solvers, collaborators, effective communicators, and self-directed learners (Burieva, 2025; Tang, 2024).

Three Different Positions to Place Critical Thinking Skills in Instruction

Does critical thinking vary depending on the subject matter and setting in which it is taught and used, or are critical thinking abilities universal, transferable, and relevant across disciplinary boundaries? Indeed, this is a crucial question. It is arguable that critical thinking could be taught separately in different courses if it is generic, with the development of critical thinking abilities being the only goal. However, critical thinking should be taught as part of the subject matter if it is thought to be unique to discipline. On this subject, at least three points of view exist. According to the generalist position, many parts of the critical thinking like informal myths, inconsistent and faulty reasoning are generalizable across many fields (Lie, 2023).

Furthermore, Ennis (2018: 165) viewed it as "it is difficult to consider broad type of thinking that has no significant application in general context", even though critical thinking may have subject-specific

components. For example, the basic and fundamental concepts of a research or inquiry, such as framing and evaluating hypotheses, seem to be very general concepts that can be applicable in each and every context rather than necessitating new knowledge and understanding in each area. The viewpoint makes the case that content knowledge is essential to the process of critical thinking. McPeck (2018) rejected the generalist's argument because of three main reasons: (a) all thinking involves and needs something to think about; (b) having a broad critical thinking skill is impossible since critical thinking requires subject-matter expertise; and (c) that critical thinking varies significantly from discipline to discipline.

For instance, the critical thinking needed in the subject of chemistry might be totally different in the areas of arts and history. In summary, the blended position is a combination of the two (Farhan, 2024). Those who follow and support the blended position believed that "the best ways to learn critical thinking is within the content" (p. 32), although acknowledging that these abilities can be separated from content knowledge (Facione, 1990). Furthermore, basic critical thinking abilities are required but insufficient for facilitating critical thinkinh within a particular discipline because what constitutes evidence differs from discipline to discipline (Lai, 2011).

Measurement and Assessment of Critical Thinking Skills

Additionally, it is imperative to comprehend how critical thinking is evaluated, taught, and encouraged in the curriculum, as well as how it differs from the predominance of international testing and information retention (Ali & Reid, 2020). While Gardner (2021) believes that teaching thinking skills is crucial for students of all ages and in all subject areas, Kavenuke et al. (2020) claim that the opportunity to teach thinking skills is underrepresented in curricula. The constraints of time management in handling this type of learning, however, have been brought to light by Ingana et al. (2023). It has been debated by Ali and Reid (2020) that exams and tests are mostly based on evaluation of students' memory to recall the material found in textbooks while contrary to this, Alhamuddin (2023) is of the opinion that students in schools should be able to acquire higher order thinking skills which is psychologically feasible.

Numerous research studies have found the effect of various interventions and teaching effects on promoting and developing the critical thinking skills of college students. However, the results of these studies remained inconclusive because of contextual differences. The reason might be using the same type of interventions in different contexts which yielded different statistical findings (Wang, Sheng & Song, 2024; Nykyporets, 2024). Many critical research review studies have been published on teaching critical thinking skills to students (Wang & Abdullah, 2024; Butler, 2024; Nor & Sihes, 2021; Anggraeni et al., 2023). However, to determine the effects of teaching and developing critical thinking skills on students' outcomes among college or university students has not received much attention in research. Given a lack of knowledge on this subject, a review of current empirical research on teaching critical thinking skills could produce significant and pertinent results.

Whether Critical Thinking Skills can be taught?

Philosophers and psychologists have different opinions about whether critical thinking abilities can be taught. But according to Bag and Gursoy (2021); Rivas, Saiz and Ossa (2022), critical thinking abilities are not a set thing. Rather, they assert that they are a teachable sort of intelligence. It is worth mentioning that stages of cognitive development are hierarchical and fixed and largely connected to intellectual development and environmental setting in which someone is living and getting experiences, therefore, the capacity to develop critical thinking abilities can be compared to Piaget's concrete and formal processes (Padmanabha, 2018). Students' capacity to use critical thinking abilities is probably constrained by their incapacity to deal with abstract concepts when they have not attained the formal operations stage. This is clear from the Piaget's stages of development that learning environments play crucial role in developing critical thinking skills of students, however, it is imperative teachers must be aware of the fact that what instructional strategies might be useful for developing critical thinking skills among students.

Whether Critical Thinking Skills can be developed?

When it's necessary, adults don't always use critical thinking. For instance, they are not always influenced by facts, logic, or proof; many find their own experiences to be more persuasive than reasoned arguments or factual data, which makes topics like global warming contentious. Given this innate inclination, Niu et al., (2013) caution that we shouldn't anticipate significant gains in critical thinking because of instructional interventions; instead, progress is likely to be gradual. According to Gardner (2021), perhaps there is no specific age limit at which students are taught or to make them ready to learn critical thinking skills through more sophisticated manners. On the other hand, the effectiveness of instructional interventions for enhancing critical thinking skills among students across different grade levels remained the same (Abrami et al., 2015). From a Piagetian standpoint, which considers young children's cognitive processes to be underdeveloped in comparison to those of older people, this finding is unexpected. However, the findings of research studies indicated that students are not mentally and socially prepared at any single stage for learning to think critically through more sophisticated ways (Gardner, 2021), which is in line with both socio-cultural and cognitive learning theories. "People should be taught... to reason, to seek relevant facts, to consider options, and to understand the views of others" (Facione, 1990, p. 27) is what the Delphi Report suggests. However, all these evidences showed that cognitive and social development do not related with the sophisticated ways of learning critical thinking abilities and dispositions, and nothing is known about how they develop (Lai, 2011). In fact, the Delphi Report warned against interpreting its critical thinking framework as suggesting a hierarchical taxonomy or developmental path (Facione, 1990). In contrast to socio-cultural and cognitive viewpoints, which do not limit when kids can begin learning to think deeply, there is only a single evidence of empirical study which has shown and suggested a developmental path of critical thinking skills and dispositions among the children (Kuhn, 1999).

Impact of Instruction on the Development of Critical Thinking Skills and Student Performance

To ascertain whether critical thinking was teachable, Huber (2016) presented the results of a meta-analysis of 71 papers on developing critical thinking during different time periods in college. These authors discovered that critical thinking varies depending on subject area, teaching style, length of intervention, and instructional tactics, and that students greatly enhance their critical thinking skills while attending college. However, this study did not establish whether collaborative problem-solving was beneficial in developing students' critical thinking skills or whether there were notable differences between the various components.

To evaluate the effect of problem-solving on college students' critical thinking, Liu et al., (2020) performed a meta-analysis of 31 educational literature articles. To enhance students' critical thinking, these authors suggested creating a sensible group structure for problem-solving in a follow-up study after discovering that problem-solving might foster the growth of critical thinking in college students. Furthermore, prior empirical research has produced conflicting and equivocal findings about the extent to which collaborative problem-solving raises or lowers critical thinking skills.

Arifin et al., (2025) looked more closely at how inquiry-based learning affected critical thinking abilities. The Scopus and ERIC databases were used to conduct a literature search for works published between 2000 and 2024. Pre-experimental or quasi-experimental designs of quantitative empirical studies were reviewed. These studies highlight variations in the application of inquiry-based learning and offer evidence-based recommendations to maximize its use in education, thereby making a significant contribution to the discussion of effective pedagogies for the development of critical thinking skills. In the same way, Abrami et al., (2008, 2015) also carried out two meta-analysis studies to provide empirical evidences related to how level of education impacted in the improvement and development of critical thinking skills and dispositions of students and in the latter study they also determined the effects on student achievement. A lot of experimental and quasi experimental studies have also been carried out to investigate the effect of teaching on the development of critical thinking skills and dispositions of students which found that instruction improves the development of critical

thinking skills and dispositions with an average effect size of +.30, or over one-third of a standard deviation.

Nevertheless, this educational impact is neither constant nor consistent throughout experiments. The authors 2008 meta-analysis, for example, concluded that K–12 students were more affected than undergraduates; however, their later meta-analysis did not support this conclusion. Furthermore, the 2008 study discovered that variations in instructional effects might also be explained by the type of critical thinking intervention. Immersion interventions considerably lagged all other approaches, while mixed-approach interventions-those that combined explicit critical thinking teaching with subject-matter content-significantly exceeded all other forms of instruction. That is, exposing students to challenging material without specifically utilizing critical thinking techniques was the least successful strategy. According to Abrami et al., (2015) meta-analysis study, two general instructional intervention types are essential for the development of critical thinking abilities: (a) utilizing cooperative or collaborative learning techniques; and (b) utilizing real-life issues, scenarios, and instances. Measures of both general critical thinking abilities and course-content learning (chemistry, for example) were present in many of the research that were part of this subsequent meta-analysis. Since most of these assessments were created by teachers, it is uncertain what their psychometric qualities are. However, like in the authors' previous meta-analysis, individual effects varied significantly between trials, with an average effect size of +.33. According to research, teachers' efficacy was more affected by professional development in teaching critical thinking skills than by seeing other teachers in action, getting comprehensive curriculum guides, or having critical thinking goals listed in their course objectives (Abrami et al., 2008). All the above discussion demonstrated that enhancing and developing attitude towards critical thinking of students is of utmost importance to all the stakeholders. It is of noteworthy that teachers must be sensitized about imparting critical thinking skills through pre and in-service training programmes and teachers must explicitly demonstrate and try to instil these skills among the students through instructional strategies and curriculum. The results also indicate that dialogue/question posing, and authentically placed training are useful methods for enhancing critical thinking abilities. Teachers can assist students in critical thinking activities because they provide a range of learning experiences in which students are provided opportunities to select the appropriate choices and also work to solve real life problems. In the same way teachers also provide opportunities to students to answer the open-ended questions and articulate and formulate solutions to problems; and apply abstract ideas in a real life situations.

Issues Related to Assessment of Critical Thinking?

When choosing (or creating) assessments of 21st century competencies, there are technological, practical, and instructional factors to consider (Soland et al., 2013). The use of assessment data is related to instructional considerations. For instance, is the metric designed for summative or formative use? Is it to give students insightful feedback or teachers' actionable information? Is the evaluation appropriate in terms of grade, context, or culture?

Cost and convenience of scoring, distribution, and administration are practical factors. Additionally, validity, dependability, and fairness are the main technological requirements. The evidence gathered will depend on the conclusions educators hope to draw from assessment outcomes (NRC, 2012; Wilson et al., 2012). The standard procedure for developing educational and psychological assessments is as follows: Establish the scores, codes, or values that will be applied to the student responses; determine the intended build; Choose item types, consider the different administration issues, and create tasks that elicit the desired responses; pilot the test using a large and diverse student population; Consider technical concerns such as test fairness, validity, and reliability when modeling and analyzing responses.

Previous studies have demonstrated that utilizing questionnaires to measure the cognitive ability of the students is highly ineffective (Cervin-Ellqvist, 2021), while using the conventional methods to use multiple choice questions may to some extent produce good results (Ali & Reid, 2020). Many studies have insisted on the development of critical thinking abilities at the school level (Bekele, 2022; Belda-

Medina, 2022). However, a few studies have created strategies and resources to improve and demonstrate such skills among students and have further recognized the shortcomings of traditional instructional methods and standardized, discipline-independent assessments of critical thinking (Dietrich & McWatt, 2025; Shanta, & Wells, 2022; Sutiani, 2021). From the result of literature, generic- specific approaches are: Academic Profile, California Critical Thinking Dispositions Inventory (CCTDI), Collegiate Assessment of Academic Proficiency (CAAP), Cornell Critical Thinking Test (CCTT), Critical Thinking Assessment Battery (CTAB) (Deegan, 2024). However these tests are generic-tests and measure critical thinking skills of science students in general context. What evidence educators choose to use will depend on the conclusions they hope to draw from assessment outcomes. It is desirable to test both cognitive abilities and dispositions to define the concept of critical thinking demands careful consideration of the test format (Ku, 2009). While multiple-choice questions might be a good way to gauge general critical thinking abilities, they might not be able to capture the dispositional components of critical thinking. For instance, students can choose answers to questions that require analysis, but choosing does not imply that they are using their analytical abilities in a contextualized way. Furthermore, evaluating critical thinking is challenging since it is unclear what kinds of conclusions (or assertions) may be drawn from assessment results due to the ongoing dispute about domain specificity in critical thinking (Lai, 2011). For instance, would pupils be able to apply their critical thinking abilities to another issue within the same subject area or to a different subject area entirely (far transfer) if they showed them in a certain subject area? Do students require more critical thinking education, more topic-area instruction, or both when they are unable to apply their critical thinking skills to another subject area? Critical thinking's dispositional components are confused with the capacity for critical thought, in addition to its cognitive components being confused with subject-specific knowledge (Lai, 2011). It is not possible to distinguish the distinct effects of cognitive skills and dispositions in practice, even though researchers agree that critical thinking encompasses both (Lai, 2011).

Discussion

This paper's goals were to construct and explain critical thinking from the literature on education, philosophy, and psychology; summarize research findings; and talk about the consequences for the design and application of assessments. Overall, research indicates that critical thinking requires both cognitive abilities and personality traits. A group of top academics and professors in critical thinking came up with a consensus definition that encompasses these two elements. “Purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based” is how the Delphi Report that followed defines critical thinking (Facione, 1999: 3).

The degree to which critical thinking is domain-specific or generic, as well as how critical thinking evolves, are still up for debate. However, studies indicate that even young toddlers exhibit some elements of critical thinking. Additionally, empirical evidence demonstrates that critical thinking is teachable and that some teaching philosophies and techniques encourage greater critical thinking. Similarly, the clear and concise content of subject matter in a course that simultaneously imparts critical thinking abilities is one of these instructional approaches.

These approaches may include of provision of multiple opportunities to students to solve problems with multiple options; a framework that enables students to formulate solutions to problems and respond to open-ended questions, and a range of learning activities that let students select and work through real-world problems are instructional strategies that foster critical thinking.

It can be difficult to evaluate 21st century abilities like critical thinking. Teachers need to pay attention to the ways that assessment design stimulates or provokes students' critical thinking. It is worth mentioning that assessments must be carefully planned and organized to elicit complicated judgments; they must involve open-ended, loosely structured tasks that provide several, convincing answers; they must involve students in real-world, authentic situations; and they must allow teachers to see how

students are reasoning. Developing critical thinking rubrics for student scoring and grading may conflict with instructional objectives. It is suggested that a series of continuous activities may be designed to develop critical thinking skills of students and these activities may be marked properly so that it may reflect the level and degree to which students' critical abilities may be categorized from less to more sophisticated form. These activities may also reflect the continuous development of critical thinking skills of students at the end of a specific activity and a period of time. It is also advised that to establish the validity of these continuous serial of activities to measure the degree of critical thinking skills which may be reflected through the performance of students in tests and their application abilities during teaching-learning process in secondary schools, testing and comparing them to students work may be worthwhile strategies.

Conclusion

This study summarizes important research findings, explains their important implications for assessment design, and synthesizes viewpoints from education, philosophy, and psychology to provide a cohesive picture of critical thinking. According to the consensus Delphi definition, critical thinking is a two-dimensional construct that combines fundamental cognitive abilities like analysis, assessment, and inference with crucial dispositional characteristics. There is still debate over how critical thinking develops and to what extent it is domain-specific or generic. However, research shows that some aspects of critical thinking are present in even young infants. Additionally, empirical studies revealed that critical thinking skills of students can be enhance through teaching and there are some educational philosophies, theories and strategies which can improve critical thinking skills. One of these teaching strategies is the written curriculum of a subject which is also responsible for nurturing critical thinking skills among the students. There are many instructional strategies which may be responsible to enhance the critical thinking skills among students, these include (a) asks students to solve a problem with multiple choice items (b) provide opportunities to students to challenge their abilities with the problems having multiple solutions, (c) giving them a framework that allows them to come up with solutions to problems and answer open-ended questions, and (d) offering a range of learning activities that permit students to select the best and work through real-world problems. The assessment and evaluation of 21st century skills for students like critical thinking skills is a challenging task. Teachers must be aware of development and assessments strategies to encourage critical thinking in their students. Assessments need to be well-thought-out and well organized to provoke complex judgments; they need to comprise of open-ended, loosely planned tasks with multiple choices, compelling answers; they need to place students in authentic, real-world scenarios; and they need to let teachers observe how students are thinking. It is also a matter of great concern that how students should become competent in the domain of critical thinking by the end of a specific period of time. This study recommends testing and comparison with student work to assess the validity of these tools and descriptions of student performance related to their suitability for teaching-learning in secondary school classrooms.

References

Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, C. A., & Persson, T. (2015). Strategies for teaching students to think critically: A meta-analysis. Review of Educational Research, 85(2), 275 314. https://doi.org/10.3102/0034654314551063

Abrami, P. C., Bernard, R. M., Borokhovski, E., Wade, A., Surkes, M. A., Tamim, R., & Zhang, D. (2008). Instructional interventions affecting critical thinking skills and dispositions: A stage 1 meta-analysis. Review of Educational Research, 78(4), 1102–1134. https://doi.org/10.3102/0034654308326084

Alhamuddin, A., Inten, D. N., Mulyani, D., Suganda, A. D., Juhji, J., Prachagool, V., & Nuangchalerm, P. (2023). Multiple intelligence-based differential learning on critical thinking skills of higher education students. *International Journal of Advanced and Applied Sciences, 10*(8), 132-139.

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, *49*, 101334.

Arifin, Z., Saputro, S., & Kamari, A. (2025). The effect of inquiry-based learning on students' critical thinking skills in science education: A systematic review and meta-analysis. *Eurasia Journal of Mathematics, Science and Technology Education*, *21*(3), em2592.

Aston, K. J. (2024). 'Why is this hard, to have critical thinking?' Exploring the factors affecting critical thinking with international higher education students. *Active Learning in Higher Education, 25*(3), 537-550.

Bekele, G., Olana, T., & Ali, S. (2022). Effect of Critical Thinking-infused Paragraph Writing Instruction on University First-year Students' Argumentative Paragraphs Writing Performance. *East African Journal of Education Studies, 5*(1), 170-181.

Belda-Medina, J. (2022). Promoting inclusiveness, creativity and critical thinking through digital storytelling among EFL teacher candidates. *International Journal of Inclusive Education, 26*(2), 109-123.

Burieva, K. E. (2025). Fostering critical thinking, communication, collaboration, and creativity in education: global experiences and local implications. *American Journal of Innovation in Science Research and Development, 2*(2), 33-37.

Butler, H. A. (2024). Predicting everyday critical thinking: A review of critical thinking assessments. *Journal of Intelligence*, *12*(2), 16-26.

Caner, M. (2024). *Education Sciences X*. Eğitim Yayınevi, Turkey.

Cervin-Ellqvist, M., Larsson, D., Adawi, T., Stöhr, C., & Negretti, R. (2021). Metacognitive illusion or self-regulated learning? Assessing engineering students' learning strategies against the backdrop of recent advances in cognitive science. *Higher Education, 82*(3), 477-498.

Deegan, M. J. (2024). *What is Critical Education? In Reflections on Criticality in Educational Philosophy: Critical Traditions, Freire and Wittgenstein* (pp. 205-221). Cham: Springer Nature Switzerland.

Dietrich, E. L., & McWatt, S. C. (2025). Exploring perceptions of alternative assessment and grading in graduate anatomy education. *Anatomical Sciences Education, 18*(2), 172-191.

Dwyer, C. P. (2017). *Critical thinking*. Cambridge University Press.

Ennis, R. H. (2018). Critical thinking across the curriculum: A vision. *Topoi*, *37*(1), 165-184.

Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction*. Newark, DE: American Philosophical Association.

Farhan, A. (2024). Collaborative Problem Solving in Promoting Students' Critical Thinking a Meta-Analysis Based on Empirical Literature. *Tamjeed Journal of AI Innovations in E-Learning and Education, 1*(1), 25-42.

Gardner, H. (2021). *Disciplined mind: What all students should understand*? Simon & Schuster.

Guerrero, G., & Sjöström, J. (2024). Critical scientific and environmental literacies: a systematic and critical review. *Studies in Science Education*, 1-47.

Haavind, S. (2024). A roadmap for virtual professional learning: Bringing inquiry science practices to life through a teacher professional community. *School Science and Mathematics, 124*(1), 60-67.

Huber, C. R., & Kuncel, N. R. (2016). Does college teach critical thinking? A meta-analysis. *Review of Educational Research, 86*(2), 431-468. https://doi.org/10.3102/0034654315605917

Inganah, S., Darmayanti, R., & Rizki, N. (2023). Problems, solutions, and expectations: 6C integration of 21 st century education into learning mathematics. *JEMS: Jurnal Edukasi Matematika Dan Sains, 1*1(1), 220-238.

Kavenuke, P. S., Kinyota, M., & Kayombo, J. J. (2020). The critical thinking skills of prospective teachers: Investigating their systematicity, self-confidence and skepticism. *Thinking Skills and Creativity, 37*(1), 1-22.

Ku, K. Y. L. (2009). Assessing students' critical thinking performance: Urging for measurements using multi- response format. Thinking Skills and Creativity, 4(1), 70–76. https://doi.org/10.1016/j.tsc.2009.02.001

Kuhn, D. (1999). A developmental model of critical thinking. Educational Researcher, 28(2), 16–25, 46. Retrieved from https://www.jstor.org/stable/1177186

Lai, E. (2011). Critical thinking: A literature review. Pearson. http://www.pearsonassessments.com/research

Lau, J. Y. (2024). Revisiting the origin of critical thinking. *Educational Philosophy and Theory*, *56*(7), 724-733.

Liesa-Orús, M., Latorre-Cosculluela, C., Vázquez-Toledo, S., & Sierra-Sánchez, V. (2020). The technological challenge facing higher education professors: Perceptions of ICT tools for developing 21st century skills. *Sustainability*, *12*(5339), 1-14.

McPeck, J. E. (1981). *Critical thinking and education*. London, UK: Routledge.

National Research Council. (2012). *Education for life and work: developing transferable knowledge and skills in the 21st century*. (J. W. Pellegrino & M. L. Hilton, Eds.). Washington, DC: National Academies Press.

Nor, H. M., & Sihes, A. J. (2021). Critical thinking skills in education: A systematic literature review. *International Journal of Academic Research in Business and Social Sciences*, *11*(11), 198-201.

Nykyporets, S. S., Melnyk, O. D., Ibrahimova, L. V., Hadaichuk, N. M., & Derun, V. H. (2024). Advancing critical thinking skills among higher education students through English language instruction: contemporary approaches and strategies. *Prospects and innovations of science.№ 1 (35): 34-45.*

Oyewumi, K. A. (2019). Plato's Dialectics and Freire's Decodification for Critical Thinking Pedagogy in the Nigerian Educational Practice (Doctoral dissertation).

Paul, R. W. (2018). Critical thinking and the critical person. In *Thinking* (pp. 373-403). Routledge.

Paul, R., & Elder, L. (2007). A guide for educators to critical thinking competency standards: Standards, principles, performance indicators, and outcomes. Foundation for Critical Thinking Press. Retrieved from http://www.criticalthinking.org/files/SAM_Comp Stand_07opt.pdf

Reid, N., & Ali, A. A. (2020). Making sense of learning. Springer International Publishing.

Rivas, S. F., Saiz, C., & Ossa, C. (2022). Metacognitive strategies and development of critical thinking in higher education. *Frontiers in psychology*, *13*, 913219.

Shanta, S., & Wells, J. G. (2022). T/E design-based learning: assessing student critical thinking and problem-solving abilities. *International Journal of Technology and Design Education*, *32*(1), 267-285.

Sutiani, A. (2021). Implementation of an inquiry learning model with science literacy to improve student critical thinking skills. *International Journal of Instruction*, *14*(2), 117-138.

Tohani, E., & Aulia, I. (2022). Effects of 21st century learning on the development of critical thinking, creativity, communication, and collaboration skills. *Journal of Non-formal Education*, *8*(1), 46-53

Van Peppen, L. M., van Gog, T., Verkoeijen, P. P., & Alexander, P. A. (2022). Identifying obstacles to transfer of critical thinking skills. *Journal of Cognitive Psychology*, *34*(2), 261-288.

Wang, J., Sheng, M., & Song, R. (2024). Enhancing classroom behaviors and creativity: The impact of a critical thinking workshop. *International Journal of Education and Cognitive Sciences*, *5*(1), 8-15.

Wilson, M., Bejar, I., Scalise, K., Templin, J., Wiliam, D., & Irribarra, D. T. (2012). Perspectives on methodological issues. In P. Griffin (Ed.), Assessment and Teaching of 21st Century Skills. Springer. https://doi.org/10.1007/978-94-007-2324-5