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Developing Critical Thinking in Schoolchildren: The Neuroscientific Aspect

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Abstract: *The article discusses the development of critical thinking in schoolchildren. This topic is significant because critical thinking is an essential cognitive skill that helps children adapt to society, engage in meaningful communication, respond effectively to various situations, and feel a sense of accomplishment. The article aims to define critical thinking, identify the characteristics of individuals who think critically, examine tools for promoting critical thinking in schoolchildren, highlight the relationship between neuroscience and critical thinking, and present effective strategies for fostering its development. Research methods include a detailed analysis of scientific literature and systematic analysis. Research methods include a detailed analysis of scientific sources, as well as systematic analysis. Research in this field confirms that critical thinking is a higher-order cognitive process that requires individuals to engage in intellectual self-improvement actively. It follows that schoolchildren with well-developed critical thinking skills can analyse information, assess arguments, and accept or reject ideas based on evidence rather than personal assumptions. The article also provides strategies for educators to enhance critical thinking in the educational process.*

Keywords: *critical thinking; analysis; synthesis; neuroscience; strategies; higher mental processes.*

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1. Introduction

In today's society, where a vast amount of information is easily accessible, both children and adults need to determine whether this information is accurate or misleading. Given the rapid changes in society, critical thinking is a key skill that can help. It allows individuals to handle various tasks and solve everyday problems effectively.

For schoolchildren, critical thinking plays an essential role in education. It helps them adapt to society, communicate actively, engage in meaningful discussions, respond quickly and effectively to different situations, and feel a sense of achievement. Critical thinking also supports effective learning and helps schoolchildren assess their progress, reflect on their actions, and find solutions to common challenges (da Silva Almeida & Rodrigues Franco, 2011; Rusmin et al., 2024). Therefore, developing critical thinking in schoolchildren is a highly relevant issue today.

This article is relevant because it explores critical thinking as a crucial tool for navigating today's information landscape, where the abundance of easily accessible data often raises concerns about its reliability. It also emphasises the role of critical thinking in helping schoolchildren adapt to social changes, communicate effectively, and achieve academic success.

Consequently, this article aims to explore the essence of critical thinking, the key factors that define a critically minded individual, and the tools that can enhance schoolchildren's critical thinking skills in the classroom. It also seeks to highlight the strong link between neuroscience and critical thinking and presents strategies for its development.

There are various definitions of the concept of "critical thinking". According to Browne and Keeley (2007), critical thinking is the ability to think carefully about topics that have been thoroughly examined and the willingness to ask and answer questions when needed. The researchers explore the concept in detail, explaining terms such as "conflict" and "assumption", offering advice on how to ask questions, identify problems, and avoid common mistakes when recognising axiological assumptions. They also examine whether mistakes in assumptions occur. Additionally, Browne, and Keeley (2007) claim that critical thinking is fundamentally about respecting others.

Ennis (1987) was the first to study the concept of critical thinking and made significant advancements in this field. He referred to it as "intelligent thinking" and established criteria to define critical thinking. They are the following: a) the ability to evaluate the credibility of sources, b) openness to alternatives, c) possession of solid knowledge, and d) the capacity to draw conclusions, reason, hypothesise, assess the quality of arguments, defend one's opinions, ask clarifying questions, design experiments, meet research deadlines, summarise carefully, and integrate information into work. As Ennis (2011) later emphasised, critical thinking represents the most advanced form of thought, combining cognitive abilities and skills, focusing on discerning truth from a wide range of data.

Cubukcu (2011) identifies three key components of critical thinking: 1) thinking ability, 2) judgment formation, and 3) problem-solving. Lipman (1988) describes critical thinking as a process characterised by skilled and accountable thought, enabling individuals to make reliable and reasonable judgments. This process is achieved by a) meeting specific conditions, b) possessing the ability to self-correct, and c) ensuring alignment with the relevant context.

Critical thinking is essential when faced with situations that require careful analysis and evaluation. It is notable because it does not follow a fixed standard or template, and there are no predetermined answers (Terno, 2016).

Critical thinking involves the ability to resist the influence of others' opinions on one's judgment. It requires objectively weighing the advantages and disadvantages of an issue. Individuals with this skill can examine their beliefs critically and evaluate their decisions thoughtfully.

This article is unique because it takes a holistic approach to analysing critical thinking as a fundamental cognitive skill. The authors not only synthesise existing concepts of critical thinking but also highlight its importance in tackling current educational challenges. These challenges

include misinformation, digital overload, and the increasing need to help schoolchildren develop their analytical skills for processing information.

This article takes an interdisciplinary approach, combining insights from educational science, neuroscience, and psychology to demonstrate the connection between cognitive processes and the development of critical thinking. A unique aspect of the article is its emphasis on the importance of critical thinking in promoting active communication, adapting to social changes, and making informed decisions in everyday life.

Accordingly, the article organises scientific perspectives on the concept of "critical thinking". It also provides a thorough analysis of its practical implications for today's education and society.

2. Training Future Teachers to Develop Critical Thinking in Schoolchildren

In 1980, the Centre for Critical Thinking was established, and significant literature was produced by Elder and Paul (1994), making a substantial contribution to the theory of critical thinking in the United States. According to the researchers, critical thinking is a dynamic process of reflecting on a specific issue or problem, during which one enhances the quality of their thinking, analyses, and evaluates skillfully. This process involves organising oneself to work, maintaining discipline, observing, and performing self-correction. Besides, Elder, and Paul (1994) developed a framework consisting of three components: 1) the elements of thinking (such as purpose, assumptions, point of view, data, evidence, ideas, generalisations, conclusions, and consequences), 2) intellectual standards (including clarity, precision, relevance, depth, breadth, logic, meaning, and honesty), and 3) intellectual qualities (such as humility, courage, empathy, independence, tenacity, perseverance, confidence, and honesty).

Terno (2011) further elaborates on the key components of critical thinking theory. These components include consciousness, freedom, reflectivity, intentionality, correctness, control, and self-organisation.

Kasemsap (2017) highlights the importance of applying current strategies in the educational process as they contribute to the development of critical thinking in schoolchildren. This, in turn, helps them absorb knowledge better, achieve success, and acquire skills that enhance their future competitiveness. One effective approach is STEM education, which promotes the development of computational thinking, programming skills, and engineering. In particular, robotics stimulates intellectual growth, builds teamwork skills, and engages schoolchildren in creating artificial intelligence. STEM, which stands for Science, Technology, Engineering, and Mathematics, promotes the development of logical thinking, analytical skills, problem-solving abilities, and the practical application of knowledge.

However, focusing excessively on STEM may have potential drawbacks for developing critical thinking skills. They are the following:

- *Narrow focus of learning*. STEM focuses primarily on specific subjects, which can limit critical thinking in broader areas such as philosophy, ethics, the humanities, and social sciences. Critical thinking requires the ability to consider and evaluate a wide range of perspectives and arguments, a skill that is not always emphasised in STEM disciplines.
- *Mechanistic approach*. STEM promotes a mechanistic approach to problem-solving, where clear solutions or algorithms are typically provided. This lack of ambiguity or complexity can limit opportunities for in-depth critical analysis and reflection, as the solutions in these fields are often straightforward and do not necessarily require creative thinking or deep contemplation.
- *Overlooking social and ethical concerns*. A strong emphasis on STEM can overlook the significance of social, cultural, and ethical issues that are essential for critical thinking. Decisions made in STEM fields often fail to take into account the social consequences and moral dilemmas that can arise from the use of new technologies.
- *Lack of interdisciplinary consideration*. Addressing existing challenges often requires an interdisciplinary approach that incorporates insights from various fields, including the humanities,

social sciences, and technical sciences. Focusing solely on STEM (Science, Technology, Engineering, and Mathematics) can restrict our understanding of complex, interconnected issues. Critical thinking is enhanced by integrating diverse disciplinary perspectives.

- *Limiting creativity and intuition*. STEM fields prioritise logical justification and mathematical reasoning. However, this can restrict the development of intuitive or creative approaches to problem-solving. Critical thinking should encompass not only structured algorithms but also the ability to make intuitive judgments, especially when faced with uncertainty (Kasemsap, 2017).

Thus, STEM plays a crucial role in developing technical and analytical skills. Nevertheless, an overemphasis on it may limit the broader development of critical thinking. To foster well-rounded critical thinking, it is essential to balance STEM with other areas of learning and development.

Lou (2018) suggests that strategic thinking can be used to enhance the critical thinking abilities of high school students. The author's program supports the growth of critical thinking, helping students navigate the vast amount of information they encounter and identify what is valuable and true.

Ostendorf and Thoma (2022) explore the requirements and principles for creating "heterodox" didactics to foster critical thinking. They not only discuss these principles theoretically but also demonstrate their practical application to higher education students. Additionally, they highlight that critical thinking in higher education focuses on three key aspects: a) philosophical (logic, language, metacognition), b) pedagogical (emphasising individual development of critical thinking), and c) socially active (transforming society). Didactic principles, in turn, are grounded in learning strategies realised through teaching methods and resources, illustrating the connection between goals, content, methods, and media.

Additionally, it is crucial to outline three didactic principles that promote the development of critical thinking:

- *Guiding student activities*. Teachers should actively guide students' activities to foster critical thinking. This involves using various discussion formats, such as those on online platforms or during consultations. Self-directed learning will only be effective if it is appropriately guided and structured.
- *Emphasising experience*. It is important to incorporate authentic experiences into the learning process, work on real-world problems, and simulate quasi-actions that help students apply critical thinking in practical contexts.
- *Encouraging group participation*. Teachers should encourage students to actively participate in group activities, such as role-playing exercises and thematic research, which promote collaboration and the development of critical thinking skills.
- *Student-led research*. Engaging students in independent research, where they search for and analyse information on their own, is key to developing their critical thinking abilities and fostering a deeper understanding of the subject matter (Kazuša, 2020).

3. Methodology

Research methods include a detailed analysis of scientific sources, as well as systematic analysis. Sources were selected from academic databases such as Scopus, Web of Science, Google Scholar, and ERIC. The inclusion criteria for the sources were as follows: 1) peer-reviewed scientific articles published between 2000 and 2023; 2) studies addressing both the conceptual and empirical aspects of critical thinking; 3) publications focusing on methods and strategies for fostering critical thinking within educational settings.

Unverified or non-scientific publications were excluded from the analysis. The selected works were analysed by organising concepts, identifying key trends, and comparing approaches to developing critical thinking in high school and university students. This approach enabled the

identification of current strategies for enhancing this cognitive skill and highlighted interdisciplinary aspects of its integration into the educational process.

4. Critical Thinking as a Key Competence of Today's Educational Applicants

Vidal-Sepúlveda, Olivares-Rodríguez, and Cárcamo-Ulloa (2021) strongly advocate for the use of critical thinking by educational applicants when navigating online information. They emphasise the importance of not blindly trusting search engine results and encourage students to evaluate the information they find critically. Without the ability to critically select information, students risk creating significant gaps in their knowledge. Given that much of the information online is often low quality or misleading, the researchers emphasise that critical thinking is an essential competence for students. They claim that critical thinking is the highest form of thought, requiring active intellectual effort. Students who possess strong critical thinking skills can evaluate information, reflect on it, and support or reject ideas with solid arguments rather than relying on personal beliefs. Additionally, they can manage their emotions effectively at all times.

Ku et al. (2019) underscore the importance of fostering critical thinking in children, especially as they are exposed to vast amounts of information from social media and spend extended periods online. In the postmodern era, adolescents need to be media literate, enabling them to distinguish between accurate, evidence-based information and content that is valuable for forming their conclusions and judgments.

As noted by Butler, Pentoney, and Bong (2017), critical thinking is more crucial than intelligence when it comes to addressing real-life challenges. Those with higher levels of critical thinking are less likely to encounter significant life problems. Therefore, developing critical thinking in schoolchildren is vital to helping them navigate and prevent negative situations in life.

5. Neuroscientific Knowledge as a Key Aspect of Developing Critical Thinking

Melnyk (2009) suggests that critical thinking arises from the integration of cognitive structures in an emotionally intelligent individual. The scholar defines emotional intelligence as the ability to apply reasoned judgement and reflection to emotional behaviour successfully.

Recent research in neuroscience shows that learning can reshape the human brain (Chang et al., 2021; Cunnington, 2019). Consequently, teachers are encouraged to integrate educational practices with insights from neuroscience to improve the cognitive environment in the classroom. Educators must prioritise social and emotional support, as these aspects are crucial for effective learning. Rigid discipline often results in psychological stress, trauma, and anxiety in children, which can hinder their development. Neuroconcepts, which combine research into brain function, can guide educators in organising the learning process more effectively, fostering higher psychological processes, and creating a safe learning space.

According to Terno (2011), teaching without neuropsychological knowledge is "uninformed" and can harm schoolchildren's mental development. Thus, incorporating neuropsychological research is vital when developing critical thinking techniques.

Bruer (1993) highlights several insights relevant to fostering critical thinking in schoolchildren: a) the brain can perform multiple functions simultaneously, such as thinking, emotions, and imagination; b) cognition and learning are innate to brain development; c) experience easily interacts with new information; d) effective memorisation requires patterns to be established; e) a positive emotional state is necessary for learning; f) the brain synthesises information holistically; g) attention and peripheral perception must be focused; h) the interaction between consciousness and subconsciousness is significant; i) visual-spatial memory enhances understanding and retention; j) freedom fosters creativity; and k) the human brain is unique in its complexity.

Human communication is closely tied to a child's mental and physical development. Panhelova and Krutsevych (2019) emphasise that a child's speech and communication depend on the peripheral speech apparatus, which is regulated by the brain and nervous system.

Neuroscientific research also shows that motor activity affects intellectual, emotional, and behavioural development.

Seo et al. (2019) provide compelling evidence that exercise can aid in combating mental illnesses and cognitive decline by activating mitochondrial function in the hippocampus and promoting neuroplasticity. The ongoing war in Ukraine has led to widespread post-traumatic stress disorder in children, resulting in anxiety, cognitive impairment, and mood disorders. These issues stem from excessive stress reactions that impair neuroplasticity and reduce neurotrophic factors in the brain. To help children recover their emotional well-being and cognitive abilities, physical exercises, especially aerobic ones, are beneficial as they enhance mitochondrial function and neuroplasticity.

Shcherbina (2017) assumes that understanding neuroscience helps teachers select appropriate educational methods and technologies based on a child's age. The researcher suggests that left-hemispheric learners benefit from logically structured lessons, while right-hemispheric learners thrive with role-playing, language immersion, and project-based activities. Teachers should also consider psychological factors such as emotional state, motivation, and the organisation of the learning process.

Consequently, knowledge of neuroscience enables teachers to create an educational environment that optimises cognitive processes, enhancing schoolchildren's attentiveness, memory, thinking, and imagination.

6. Some Strategies for Developing Critical Thinking in Schoolchildren

According to Sofii et al. (2017), critical thinking skills include a) evaluating the reliability of information sources; b) selecting and processing relevant information; c) analysing and assessing one's own or others' statements, assumptions, conclusions, arguments, hypotheses, and beliefs; d) asking questions to obtain or verify more accurate information; e) considering issues from different viewpoints and comparing various problem-solving strategies; f) expressing one's perspective clearly and choosing precise means of communication; and g) making informed decisions.

To cultivate critical thinking in younger students, teachers should dedicate time and provide opportunities for its practice (Sofii et al., 2017). They must create an environment that encourages independent thinking, welcomes diverse ideas, and actively engages students in the learning process. It is also important to establish a safe space where students can express their thoughts without fear of ridicule and to instill confidence in their ability to form critical judgements. Teachers should also empower students to value their own opinions, engage in their education, respect others' viewpoints, and develop the ability to both challenge and defend their ideas.

Teamwork is an effective way for children to develop critical thinking skills through active participation. When working together, schoolchildren exchange ideas, discuss opposing viewpoints, and collectively brainstorm strategies. This collaborative process enhances communication, stimulates creativity, and encourages the exploration of problems from new perspectives (Pylypenko & Pylypenko, 2021).

Moeller et al. (2013) highlight the benefits of critical and creative thinking through visual learning tools. Their approach is based on the idea that, when studying subjects such as science, children work together to examine, observe, investigate patterns, reason, and generate ideas, which forms the foundation for developing critical thinking skills.

Furthermore, using visual strategies improves literacy and enriches students' vocabulary. Teachers can create a learning space with simple tasks such as, "Look at the picture. What do you see? What's your reasoning? What assumptions do you have?" This method encourages relaxed communication, where children first observe the image, present their arguments, and discuss their observations. The teacher listens to all responses, thus fostering a safe learning environment. This type of training improves both teaching facilitation skills and students' ability to manage their learning environment. According to Moeller et al. (2013), critical thinking involves inductive and

deductive reasoning, systemic analysis, examining evidence, synthesising information, and concluding. Critical thinking builds upon both prior and newly acquired knowledge.

Crawford et al. (2005) explore the practical application of critical thinking techniques in the classroom, providing a detailed look at their execution and required timeframes.

Lipman (1988) emphasised that the goal of using critical thinking strategies is not just to teach but to foster the development of thinking itself. This ability is essential for helping children reason effectively, evaluate information, make judgements, and choose wisely.

Susanti (2024) focuses on exploring effective strategies for developing critical thinking skills in younger children. This research aims to identify and evaluate the most effective methods for fostering critical thinking in children, considering the complexity of cognitive development. The study looks into various educational strategies that cater to the needs of younger children. The author highlights that storytelling, fairy tales, problem-based methods, and social interaction are all effective approaches for enhancing critical thinking. Storytelling and fairy tales stimulate children's imagination and reflection, while problem-based methods encourage them to identify and solve problems critically. Social interaction, such as group discussions and teamwork, helps broaden children's perspectives and improve their critical thinking abilities.

Thus, there is a wide range of strategies currently used to develop critical thinking in children, with problem-based learning being the most prominent. This approach encourages children to engage in problem-solving tasks. Many methods rely on cooperative learning, which teaches children to work in groups, communicate effectively, respect different viewpoints, and form their judgments.

Table 1 compares different strategies for developing critical thinking.

Table 1. Comparison of strategies for developing critical thinking

Strategy	Core Concept	Key Techniques	Benefits
Evaluating information sources	Teaching students to critically assess information	Source analysis, news evaluation, comparing information	Enhances fact-checking skills, prevents manipulation
Extracting and Processing Information	Helping children identify key concepts and synthesise knowledge	Highlighting key points, creating diagrams, organising data	Strengthens skills in structuring knowledge
Debates and Perspective Analysis	Discussing various viewpoints to evaluate them	Debates, brainstorming sessions, role-playing	Fosters communication skills and promotes tolerance
Visual thinking	Using images and illustrations for analysis	Interpreting pictures, creating infographics, discussing visuals	Boosts creativity, improves memory retention
Problem-based learning	Solving real-world problems through investigation	Case studies, situational analysis, project-based activities	Builds problem-solving abilities, encourages responsibility
Collaborative learning	Promoting teamwork and group discussions	Pair work, group projects, team discussions	Enhances communication, promotes teamwork and cooperation
Storytelling and Fairy Tales	Using narratives to stimulate critical thinking	Plot analysis, moral discussions, drawing conclusions	Fosters imagination and teaches critical reflection
Practical application	Applying critical thinking to real-life situations	Case scenarios, experiments, discussions of current events	Reinforces learning, prepares for real-life challenges
Thinking-oriented approach	Focusing on developing thinking skills rather than just learning	Problem-solving analysis, reasoned decision-making, critical evaluation	Strengthens analytical thinking, deepens understanding

Source: the authors' own conception

7. Conclusions

The article emphasises the importance of critical thinking as an essential skill for today's schoolchildren, who must actively communicate, manage various tasks, solve problems, and navigate daily situations. The topic of "Developing Critical Thinking in Schoolchildren" is highly relevant in the current educational context.

The article reviews the work of both international scholars (Browne & Keeley, 2007; Ennis, 2011; Lipman, 1988) and Ukrainian scholars (Terno, 2011; 2016). It outlines the essence of critical thinking and identifies the key factors that distinguish a critically thinking individual.

The article also emphasises that critical thinking is more important than intelligence, as it equips individuals to effectively address life's challenges. It further explores the connection between critical thinking and neuroscience, which examines higher mental processes. Neuroeducators advocate for teaching children based on neuropsychological principles.

Additionally, the article highlights that physical activity can enhance children's cognitive functions. A unique contribution of this article is its detailed review of teaching strategies that educators can integrate into their daily practices. These strategies are grounded in cooperative learning, which encourages children to work in teams, communicate effectively, respect diverse viewpoints, and develop their judgments.

1. Main topic and purpose of the article. The article focuses on the importance of critical thinking as a key competency for today's learners. The authors explore its relevance in the digital information age, its connection with neuroscience, and the impact of physical activity on cognitive processes. The article also highlights methods for fostering critical thinking skills among students and schoolchildren.

2. Use of empirical data. While the article provides a comprehensive review of existing scientific research, it lacks original empirical data such as survey results, experiments, or case studies. This suggests that the article is primarily a theoretical analysis based on secondary sources.

3. Key ideas of the article.

- *The need for critical thinking*. In an era of information overload, critical thinking is essential for discerning reliable data.
- *The impact of the Internet and social media*. A lack of critical thinking skills can lead to misinformation and the development of distorted knowledge.
- *The role of higher education*. European universities are increasingly incorporating critical thinking courses, which help students develop analytical skills.
- *Connection with neuroscience*. Neuroeducation emphasises the importance of combining cognitive development, socio-emotional support, and physical activity to enhance learning outcomes.
- *Physical activity and cognitive function*. Research shows that physical activity positively influences brain function, which is crucial for the emotional and intellectual development of students.

4. Critical analysis of the argumentation. The article is well-supported by numerous academic references, enhancing its academic credibility. The absence of original empirical data may reduce the novelty of the research. Some assertions would benefit from further explanation and could be strengthened with additional studies.

5. Conclusions and significance of the research. This article makes a valuable contribution to understanding the importance of critical thinking and its interconnections with other areas (neuroscience, physical activity, and education). It underscores the need to teach critical information analysis from an early age and highlights the importance of incorporating relevant teaching methods into the educational process. However, further research should focus on empirically testing the claims made in the article.

References

Browne, M. N., & Keeley, S. M. (2007). *Asking the Right Questions: A Guide to Critical Thinking* (8th ed.). Pearson.

Bruer, J. T. (1993). *Schools for thought: A science of learning in the classroom*. MIT Press. https://doi.org/10.7551/mitpress/6052.001.0001

Butler, H. A., Pentoney, C., & Bong, M. P. (2017). Predicting real-world outcomes: Critical thinking ability is a better predictor of life decisions than intelligence. *Thinking Skills and Creativity, 25*, 38–46. https://doi.org/10.1016/j.tsc.2017.06.005

Chang, Z., Schwartz, M., Hinesley, V., & Dubinsky, J. (2021). Neuroscience concepts changed teachers' views of pedagogy and students. *Frontiers in Psychology, 12*, 685856. https://doi.org/10.3389/fpsyg.2021.685856

Cunnington, R. (2019, September 18). *Neuroplasticity: How the brain changes with learning.* IBE – Science of Learning Portal. https://solportal.ibe-unesco.org/articles/neuroplasticity-how-the-brain-changes-with-learning

Crawford, A., Saul, E. W., Mathews, S., & MaKinster, J. G. (2005). *Teaching and learning strategies for the thinking classroom*. International Debate Education Association.

Cubukcu, F. (2011). Critical thinking strategies in reading. *Porta Linguarum, 16*, 7–17.

da Silva Almeida, L., & Rodrigues Franco, A. H. (2011). Critical thinking: Its relevance for education in a shifting society. *Revista de Psicología*, 29(1), 175–195. Retrieved from https://www.scielo.org.pe/pdf/psico/v29n1/a07v29n1.pdf

Elder, L., & Paul, R. (1994). *Critical thinking development: A stage theory*. Foundation for Critical Thinking. http://www.criticalthinking.org/pages/critical-thinking-development-a-stagetheory/483

Ennis, R. H. (1987). A taxonomy of critical thinking dispositions and abilities. In J. B. Baron & R. J. Sternberg (Eds.), *Teaching thinking skills: Theory and practice* (pp. 9–26). W.H. Freeman. https://psycnet.apa.org/record/1986-98688-001

Ennis, R. H. (2011). *The nature of critical thinking: An outline of critical thinking dispositions and abilities*. University of Illinois https://education.illinois.edu/docs/default-source/faculty-documents/robert-ennis/thenatureofcriticalthinking_51711_000.pdf

Kasemsap, K. (2017). Promoting critical thinking in the modern learning environments. In I. Management Association (Ed.), *Research anthology on developing critical thinking skills in students* (pp. 36−59). IGI Global. https://doi.org/10.4018/978-1-7998-3022-1.ch003

Kazuša, I. (2020). Didactic model based on principles of critical thinking. In V. Lubkina & A. Indriksons (Eds.), *Society. Integration. Education: Proceedings of the International Scientific Conference* (Vol. 1, pp. 350–362). Rēzeknes Tehnoloģiju akadēmija. http://dx.doi.org/10.17770/sie2020vol1.4943

Ku, K. Y. L., Kong, Q., Song, Y., Deng, L., Kang, Y., & Hu, A. (2019). What predicts adolescents' critical thinking about real-life news? The roles of social media news consumption and news media literacy. *Thinking Skills and Creativity, 33*, Article 100570. https://doi.org/10.1016/j.tsc.2019.05.004

Lipman, M. (1988). *Critical thinking: What can it be?* Resource Publication, Series 1 No. 1. Montclair State College. Retrieved from https://files.eric.ed.gov/fulltext/ED352326.pdf

Lou, J. (2018). Improvement in university students' critical thinking following a strategic thinking training program. *NeuroQuantology, 16*(5), 91–96. Retrieved from https://www.semanticscholar.org/paper/Improvement-in-university-students%E2%80%99-critical-a-Lou/6880bb3bc6afdcc79494e6019ac18a6d0e96316e

Melnyk, O. H. (2009). Emotsiinyi intelekt i krytychne myslennia [Emotional intelligence and critical thinking]. *Naukovi zapysky Natsionalnoho universytetu "Ostrozka akademiia". Seriia: Psykholohiia i pedahohika [Scientific Notes of Ostroh Academy National University:*

Psychology and Pedagogy Series], 12, 122−131. Retrieved from http://nbuv.gov.ua/UJRN/Nznuoapp_2009_12_14

Moeller, M., Cutler, K., Fiedler, D., & Weier, L. (2013). Visual thinking strategies = creative and critical thinking. *Phi Delta Kappan, 95*(3), 56−60. https://doi.org/10.1177/003172171309500312

Ostendorf, A., & Thoma, M. (2022). Demands and design principles of a "heterodox" didactics for promoting critical thinking in higher education. *Higher Education, 84*, 33–50. https://doi.org/10.1007/s10734-021-00752-1

Panhelova, N., & Krutsevych, T. (2019). Neuropsychological principles of activating the speech of children of the senior preschool age in the course of motor activities. *Psycholinguistics. Series: Psychology, 25*(1), 232−255. https://doi.org/10.31470/2309-1797-2019-25-1-232-255

Pylypenko, N. M., & Pylypenko, V. V. (2021). Rozvytok krytychnoho myslennya studentiv pid chas vyvchennya mikro- ta makroekonomiky [Developing students' critical thinking in the study of micro- and macroeconomics]. *Ekonomichna teoriia ta istoriia ekonomichnoi dumky [Economic Theory and History of Economic Thought], 66*, 17−22. https://doi.org/10.32843/bses.66-3

Rusmin, L., Misrahayu, Y., Pongpalilu, F., Radiansyah, R. & Dwiyanto, R. (2024). Critical thinking and problem-solving skills in the 21st century. *Journal of Social Science, 1*(5), 144–162. https://doi.org/10.59613/svhy3576

Seo, J. H., Park, H. S., Park, S. S., Kim, C. J., Kim, D. H., & Kim, T. W. (2019). Physical exercise ameliorates psychiatric disorders and cognitive dysfunctions by hippocampal mitochondrial function and neuroplasticity in post-traumatic stress disorder. *Experimental Neurology, 322*, Article 113043. https://doi.org/10.1016/j.expneurol.2019.113043

Shcherbina, T. R. (2017). How neurolinguistic and psycholinguistic elements of brain activity affect the proficiency of higher education applicants in learning a second foreign language (Chinese). *Pedagogical Sciences, 2(LXXX)*, 78−82. Retrieved from https://journals.indexcopernicus.com/api/file/viewByFileId/575043.pdf

Sofii, N. Z., Onopriienko, O. V., Naida, Yu. M., Prystinska, M. S., & Bolshakova, I. O. (2017). *The New Ukrainian School: A guide for the teacher.* Pleiades Ltd. Retrieved from https://nus.org.ua/wp-content/uploads/2017/11/NUSH-poradnyk-dlya-vchytelya.pdf

Susanti, R. (2024). Effective strategies in developing critical thinking skills in elementary school-age children. *West Science Interdisciplinary Studies, 2*(4), 732–736. https://doi.org/10.58812/wsis.v2i04.785

Terno, S. O. (2011). *Teoriya rozvytku krytychnoho myslennia (na prykladi navchannya istoriyi) [Examining the development of critical thinking through teaching history]*. Zaporizhzhia National University. Retrieved from http://ppko-koippo.edukit.kr.ua/Files/downloads/Terno_CTDTheory-1.pdf

Terno, S. O. (2016). *Krytychne myslennia yak instrument provedennia pravoosvitnikh zakhodiv u zahalnoosvitnikh navchalnykh zakladakh [Applying critical thinking to the delivery of law-education activities in comprehensive schools]*. Organization for Security and Co-operation in Europe (OSCE). Retrieved from http://sites.znu.edu.ua/interactiv.edu.lab/Posibnyky/ReaderCT.pdf

Vidal-Sepúlveda, M., Olivares-Rodríguez, C., & Cárcamo-Ulloa, L. (2021). What kind of sources do I need? *Information Research, 26(4),* Article 913. https://doi.org/10.47989/irpaper913