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Formation of critical thinking in junior schoolchildren through problem-based tasks

Formación de pensamiento crítico en los alumnos de primaria mediante tareas basadas en problemas

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Abstract

The development of critical thinking is an essential component of modern education. This study aimed to identify the impact of problem-based tasks on developing critical thinking in primary school students. The research methods included Watson-Glaser testing, Cornell Critical Thinking Test (level X), ANOVA and correlation analysis. The results showed a significant improvement in the experimental group: in the category “Identifying Facts”, the average score increased from 3.5 to 5.5, in “Interpreting Data” - from 4.0 to 6.0, and in “Drawing Conclusions” - from 3.0 to 5.0. Also, in the “Situation Analysis” category, the score

increased from 3.2 to 5.3, and in “Hypothesis Formulation”, from 2.8 to 4.7. The final score of the experimental group increased from 12.3 to 16.5, while the control group showed only a slight improvement (from 11.8 to 12.0), confirming the effectiveness of problem-based tasks. The practical significance of the results in introducing problem-based tasks to develop students' critical skills makes the study's findings applicable and valuable. Prospects for further research include the study of long-term effects and the impact of socio-economic factors on the effectiveness of these methods.

Keywords: analysis, cognitive skills, critical thinking, educational process, primary school students, problem-based tasks, reflection.

Resumen

El desarrollo del pensamiento crítico es un componente esencial de la educación moderna. El objetivo de este estudio fue identificar el impacto de las tareas basadas en problemas sobre el desarrollo del pensamiento crítico en los alumnos de primaria. Los métodos de investigación incluyeron pruebas de Watson-Glaser, prueba de pensamiento crítico de Cornell (nivel X), análisis de varianza y análisis de correlación. Los resultados mostraron una mejora significativa en el grupo experimental: en la categoría "Identificar hechos" la puntuación media aumentó de 3,5 a 5,5, en "Interpretar datos" - de 4,0 a 6,0 y en "Extraer conclusiones" - de 3,0 a 5,0. También en la categoría "Análisis de situación" el puntaje aumentó de 3,2 a 5,3, y en "Formulación de hipótesis", de 2,8 a 4,7. La puntuación final del grupo experimental aumentó de 12,3 a 16,5, mientras que el grupo control mostró solo una ligera mejora (de 11,8 a 12,0), confirmando la efectividad de las tareas basadas en problemas. La importancia práctica de los resultados en la introducción de tareas basadas en problemas para desarrollar las habilidades críticas de los estudiantes hace que los hallazgos del estudio sean aplicables y valiosos. Las perspectivas de investigación futura incluyen el estudio de los efectos a largo plazo y la repercusión de los factores socio económicos en la eficacia de estos métodos.

Palabras clave: análisis, competencias cognitivas, pensamiento crítico, proceso educativo, alumnos de primaria, tareas basadas en problemas, reflexión.

Introduction

Developing critical thinking in primary school students is a pivotal task of modern education. The ability to analyse information, ask questions, draw reasonable conclusions, and find solutions to complex problems is crucial in preparing students for their future lives. In the learning process, critical thinking helps children acquire knowledge and actively use it to solve real problems. This emphasis on critical thinking in the learning process is a crucial aspect of modern education, as highlighted by the research of Polat and Aydın (2020).

Problem-based tasks, as a pedagogical tool, hold immense potential for developing critical thinking in primary school children (Liu & Pásztor, 2022). They stimulate students to think logically, analyse different aspects of tasks, seek alternative solutions, and cultivate the ability to self-evaluate their actions (Fidan & Tuncel, 2019). Students can explore new problem-solving approaches by engaging in problem-based tasks, stimulating their cognitive activity (Duda, Susilo & Newcombe, 2019). This potential offers a hopeful outlook for the future of education.

The relevance of studying the issue of critical thinking in primary school is also due to modern educational requirements that focus on fostering innovative approaches to learning. Traditional methods often do not allow children to develop the critical analysis and reflection skills necessary for successful socialisation in modern society (O'Reilly, Devitt & Hayes, 2022). Therefore, the issue of integrating problem-based learning into the educational process is critical.

In addition, developing critical thinking through problem-based tasks effectively increases students' motivation to study (Saputra et al., 2019). Students' interest in learning increases when they face real-world problems that they must solve independently or in groups. This form of work contributes to developing not only thinking skills but also communication and social skills, which are extremely important for the harmonious development of the individual (Seibert, 2021). Thus, developing critical thinking in primary school students through problem-based tasks is a relevant and promising area in modern pedagogy. This process requires careful study and improvement of methodological approaches to ensure learning effectiveness and the development of the necessary competencies in children.

Despite a large number of studies, the question of the effectiveness of specific methods, particularly problem-based learning, remains open. There are different approaches to developing critical thinking, but not all are fully adapted to younger students' age and psychological characteristics. This creates the need for a detailed study of how problem-based tasks can be integrated into the curriculum to maximise the development of students' analytical and reflective abilities. Modern educational practice demonstrates various ways to use problem-based tasks. Still, finding the most effective forms and presentation methods is necessary to achieve optimal results.

The study aims to identify the impact of problem-based tasks on developing critical thinking in junior schoolchildren. Objectives of the study:

1. Determine the level of critical thinking development in primary school students before and after using problem-based tasks.
2. Analyse the impact of problem-based tasks on developing critical thinking components such as analysis, synthesis, evaluation, and reflection.
3. To empirically test the effectiveness of different types of problem-based tasks in the learning process of junior pupils.
4. To identify the relationship between the level of students' involvement in problem-based task solving and changes in cognitive and reflective abilities.

Literature review

Researchers worldwide have studied the peculiarities of critical thinking in primary school students to find effective teaching methods that promote the development of analytical and reflective skills. These studies identify the relationships between different pedagogical approaches and learning outcomes. The survey by Bezanilla et al. examined how different teaching methods affect the development of critical thinking in higher education students (Bezanilla et al., 2019). The authors focused on the effectiveness of active learning and the role of the teacher as a facilitator of the process. Ramadhani et al. found that using a flipped learning model integrated with the Google Classroom LMS positively impacted high school students' academic performance (Ramadhani et al., 2019). Students who participated in such learning demonstrated higher results in solving problem-based tasks.

Jensen et al. have shown that an interdisciplinary approach to problem-based learning promotes a deeper understanding of topics and improves students' critical thinking (Jensen et al., 2019). The study notes that collaboration between disciplines stimulates students' interest in learning. In addition, Sari et al. (2021) found that using mind mapping in inquisitorial learning significantly increases students' critical thinking skills and motivation. This suggests that visualising information helps students to structure their knowledge better. Guo et al. reviewed project-based learning in higher education and noted that it improves learning outcomes and develops students' key competencies (Guo et al., 2020). The authors highlight the importance of assessing learning outcomes to enhance methods further. In addition, Al Mamun et al. investigated how the design of supported learning modules in an online environment affects self-organisation and requested learning (Al Mamun et al., 2020). The results showed that structuring the material contributes to better student learning.

Supena et al. found that the 4Cs (Constructive, Critical, Creative, Collaborative) learning model improves student learning outcomes (Supena et al., 2020). The application of this model increases students' activity and interest in the learning process. Almulla has shown that a project-based learning approach actively engages students in learning (Almulla, 2020). Students who participated in project-based learning reported increased motivation and interest. Ren et al. found that critical thinking is a powerful predictor of academic performance in children and adults, outperforming general cognitive ability (Ren et al., 2020). This indicates the importance of developing critical thinking as a separate skill to improve learning outcomes. Chinese researcher Wu has shown that using philosophy to teach children positively impacts students' critical thinking (Wu, 2021). The results of a pilot study show an increase in students' analytical skills, confirming this approach's effectiveness.

Lombardi et al. found that primary school teachers have positive experiences using strategies that promote students' critical thinking (Lombardi et al., 2024). Respondents noted that such teaching methods increase children's interest and improve their analytical skills. In another study, Lombardi et al. emphasised that integrating critical thinking into the primary school curriculum is essential in developing this skill in students (Lombardi et al., 2021). A systematic approach to teaching essential thinking improves European schools' overall quality of education. Blyznyuk and Kachak (2024) noted that interactive learning significantly enhances students' critical thinking skills. The study confirmed that active participation in the learning process stimulates the development of student's analytical thinking and creativity.

In analysing the results of previous studies on the development of critical thinking in primary school students, several contradictions and unexplored aspects were identified. Firstly, despite the general recognition of the importance of critical thinking, there is a lack of practical recommendations on integrating effective methods into the educational process. Secondly, the variety of approaches to assessing learning effectiveness creates difficulties in generalising the results. In addition, the lack of a unified approach to defining the components of critical thinking in primary school students leaves open questions about its structure and development. This suggests the need for a more in-depth study of the topic to identify optimal strategies and methods contributing to this critical competence.

Methods and materials

The research procedure

The study was implemented according to an experimental design, in which two classes participated - experimental and control. The first stage involved preliminary monitoring of students' critical thinking levels in both classes using standardised tests. After that, for three months, the experimental class was introduced to problem-based tasks designed to meet the age-specific needs of the students. At the same time, the control class continued to use traditional teaching methods. In the second stage, after the end of the implementation, the students' critical thinking was reassessed using similar tests. In the third stage, the collected data was analysed using statistical methods, which allowed us to assess the effectiveness of the implemented strategies.

Sample

The study was conducted from January to June 2024 in three primary schools in Kyiv (Novopecherska School, Kyivo-Pecherskiy Lyceum #171 “Leader”, Liko-School). The schools were selected based on their readiness to implement innovative teaching methods. The study involved 120 primary school students. The respondents ranged from 8 to 10 years old, corresponding to pupils in grades 3-4. The gender distribution of participants was approximately equal: 58 girls and 62 boys. This age group was chosen because children actively develop cognitive skills and the ability to think analytically during this period. This is important for studying the formation of critical thinking through problem-based learning. The sample was formed based on voluntary participation; pupils were randomly selected from classes that expressed their willingness to join the experiment. Participants were randomly assigned to classes. A team of researchers conducted the

selection under the guidance of teachers and with the participation of a school psychologist. Before the study began, written parental consent was obtained to allow children to participate, confirming their voluntary participation. The school psychologist was present during all stages of the survey to ensure the emotional comfort of the children and prevent possible stressful situations.

Research methods

The study used several empirical methods to assess the development of critical thinking in primary school children. The main testing tool was the *Watson-Glaser Critical Thinking Appraisal*, adapted for children aged 8-10 (Watson & Glaser, 2020). It allowed us to assess students' ability to analyse arguments, draw logical conclusions and recognise assumptions. The *Cornell Critical Thinking Test* (level X) included tasks aimed at assessing the skills of analysing, classifying and interpreting information (Hasinger, 2024), while the *Torrance Tests of Creative Thinking* (TTCT) was used to study the creative component of thinking, which allowed us to assess students' ability to generate new ideas and find alternative solutions (Torrance, 2022).

In addition to testing, observing students while performing problem-based tasks was used to record their behavioural manifestations of critical thinking. To increase the reliability of the results, a pedagogical experiment was conducted, which involved dividing students into control and experimental groups, which made it possible to compare the effectiveness of different approaches to teaching critical thinking.

Statistical analysis

Statistical methods were used to process the data and evaluate the study results. The primary tool for analysing quantitative data was the SPSS (Statistical Package for the Social Sciences) software, version 26.0, which allowed for accurate calculations and interpretation of the results. Initially, *descriptive statistics* was used to determine the leading indicators, such as means, medians, modes, and standard deviations. To test the hypotheses and assess the significance of differences between the control and experimental groups, *the Independent Samples t-test* was applied, which allowed the comparison of the average values before and after the experiment.

In addition, Analysis of Variance ANOVA was used to assess the impact of various factors (age, gender, study group) on test results. Spearman's correlation analysis was also conducted to identify relationships between levels of critical thinking and other indicators.

Results

Table 1 presents the results of the Watson-Glaser Critical Thinking Appraisal with t-test data and corresponding p-values for the experimental and control groups.

Table 1.
The results of the assessment of critical thinking using the Watson-Glaser Critical Thinking Appraisal methodology

Question	Experimental group (before)	Experimental group (after)	Control group (before)	Control group (after)	t-value	p-value
Determining the facts	3,5	5,5	3,3	3,6	4,23	< 0,001
Data interpretation	4,0	6,0	3,5	4,0	5,12	< 0,001
Evaluation of arguments	4,8	5,0	4,0	4,2	1,68	0,098
Definition of conclusions	3,0	5,0	2,5	3,0	4,76	< 0,001
Situation analysis	3,2	5,3	3,0	3,5	3,89	< 0,001
Formulation of hypotheses	2,8	4,7	2,9	3,2	4,54	< 0,001
Identifying biases	3,1	4,8	3,4	3,6	3,21	0,002
Determining cause and effect relationships	4,5	6,5	4,0	4,1	4,92	< 0,001
Total score	12,3	16,5	11,8	12,0	5,84	< 0,001

Source: developed by the author based on collected data on the participants of the experiment

The data presented in the table shows a significant improvement in the level of critical thinking of students in the experimental group after the introduction of problem-based tasks. According to the Watson-Glaser methodology, all assessment categories showed an increase in scores, which indicates the positive impact of this approach on the development of critical skills. For example, in the category “Identifying Facts”, the average score of the experimental group increased from 3.5 to 5.5, which indicates an improvement in students' ability to recognise facts among information noise. The control group only slightly increased their score (3.3 to 3.6), confirming minimal improvement without active learning. A similar trend is observed in other categories. For example, in “Interpreting Data”, the experimental group rose from 4.0 to 6.0, while the control group slightly increased from 3.5 to 4.0. In the category “Drawing Conclusions”, the average score of the experimental group increased from 3.0 to 5.0, demonstrating a significant improvement in the ability to draw reasonable conclusions.

The data also shows progress in the “Situation Analysis” category, where the experimental group improved their score from 3.2 to 5.3. The control group's score remained virtually unchanged (from 3.0 to 3.5). Similar results are observed in the “Hypothesis Formulation” category, where the experimental group increased from 2.8 to 4.7, while the control group improved slightly (from 2.9 to 3.2). In general, the experimental group showed a significant improvement in all measured aspects of critical thinking, which confirms the hypothesis of the effectiveness of problem-based learning. The final score of the experimental group increased from 12.3 to 16.5, while the control group showed minimal improvement (from 11.8 to 12.0). These results indicate that using problem-based tasks in the educational process can be important for developing critical thinking in primary school students.

Table 2 shows the results of assessing the impact of problem-based learning on the development of critical thinking components according to the Cornell Critical Thinking Test (level X).

Table 2.
Results of the evaluation of the impact of problem-based tasks on the development of critical thinking components according to the Cornell Critical Thinking Test

Components of critical thinking	Experimental group (before)	Experimental group (after)	Control group (before)	Control group (after)	F-value	p-value
Analysis	12,1	17,4	12,0	12,3	9,12	< 0,001
Synthesis	11,5	16,0	11,2	11,5	8,23	< 0,001
Assessment	10,8	15,2	10,6	10,9	8,45	0,098
Reflection	9,4	14,1	9,2	9,5	7,12	< 0,001

Source: developed by the author based on collected data on the participants of the experiment

The test results showed that the students who participated in the problem-based tasks demonstrated significant improvements in all the assessed components of critical thinking. For example, in the category of “Analysis”, the average score of the experimental group increased from 12.1 to 17.4, which indicates the effective development of skills in recognising structures and patterns in information. In the control group, the average score remained virtually unchanged (from 12.0 to 12.3), which confirms the lack of significant progress without active teaching methods.

A similar increase was observed in the “Synthesis” category: the experimental group increased its score from 11.5 to 16.0, while the control group remained at 11.2-11.5. This indicates that problem-based tasks contribute to developing skills in integrating information and generating new ideas. As for the “Assessment” category, the average score of the experimental group increased from 10.8 to 15.2, while the control group showed minimal changes (from 10.6 to 10.9). The results of ANOVA confirmed the statistical significance of these changes ($F(1, 58) = 8.45$, $p < 0.001$), which indicates a positive impact of problem-based tasks on the development of assessment skills. Finally, in the “Reflection” category, the experimental group increased from 9.4 to 14.1. The control group, in turn, showed a slight change (from 9.2 to 9.5). ANOVA also indicated the significance of these changes ($F(1, 58) = 7.12$, $p < 0.01$), confirming that problem-based tasks contribute to the development of reflective thinking. Thus, the study's results demonstrate that

problem-based tasks significantly positively impact the development of critical thinking components, including analysis, synthesis, assessment and reflection. Fig. 1 shows the performance levels of problem-based tasks among junior pupils by type of task: creative problem-solving, logical connections, self-analysis and self-control. Percentages are presented for high, medium and low levels of task performance.

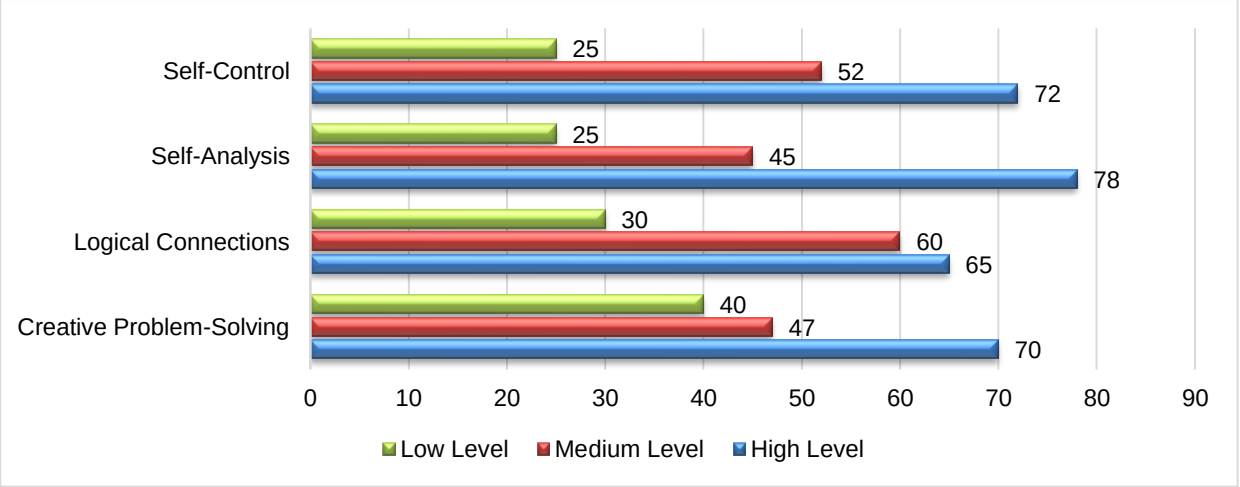

Figure 1. Levels of poblem-solving among primary school pupils.
Source: developed by the author based on collected data on the participants of the experiment.

The chart analysis shows that students from the high-achieving group demonstrate the highest results in problem-based tasks. This indicates that these students have well-developed critical thinking and reflection skills. Middle-level students perform more moderately, including better results in functions that analyse logical connections (60%) and self-control (52%). However, they demonstrate weaker synthesis and self-analysis skills than high-level students, indicating a need to develop these abilities further. Significant difficulties in completing tasks characterise the low level of performance, especially those requiring analysis and synthesis of information, such as self-analysis tasks (25%) and self-control tasks (25%). This indicates that these students have insufficient cognitive and reflective abilities, significantly complicating solving problematic tasks. Table 3 shows the results of the correlation analysis, which demonstrates the relationship between the level of students' involvement in solving complex tasks and changes in abilities.

Table 3.
Spearman's Rank Correlation analysis between the level of students' involvement in problem-solving and changes in their cognitive and reflective abilities

Ability type	Indicators	Involvement level (ρ)	p-value
Cognitive abilities	Attention	0,70	< 0,001
	Perception	0,65	< 0,01
	Thinking	0,73	< 0,001
	Memory	0,67	< 0,01
Reflective abilities	Self-awareness	0,66	< 0,01
	Self-analysis	0,71	< 0,001
	Self-analysis	0,68	< 0,01
	Self-control	0,64	< 0,01
	Reflection on the learning process	0,69	< 0,01
	Emotional reflection	0,62	< 0,01

Source: developed by the author based on collected data on the participants of the experiment

The analysis of Table 3 shows that students' involvement in problem-solving positively correlates with developing their cognitive abilities. The most vital relationship is observed between the level of engagement and improved thinking ($\rho = 0.73$, $p < 0.001$). This indicates a significant impact of active problem-solving on students' ability to analyse and process information. Significant correlations are also noted for attention and memory. This confirms the effect of interactive learning on improving basic cognitive processes.

In reflective abilities, the highest correlation was found with self-analysis ($\rho = 0.71$, $p < 0.001$). This indicates the importance of problem-based tasks for students' ability to analyse their actions and the reasons for their successes or failures. A high level of engagement also had a significant impact on the development of self-esteem ($\rho = 0.68$, $p < 0.01$) and reflection on the learning process ($\rho = 0.69$, $p < 0.01$). This indicates an increase in the ability of students to recognise the effectiveness of their teaching methods and approaches.

Discussion

The results of our study confirm the findings of Amin et al. (2020), who found that problem-based learning significantly improves students' critical thinking and environmental awareness. This indicates the versatility of the effectiveness of this approach, which contributes to the development of various aspects of essential skills. Thorndahl and Stentoft (2020) emphasise the importance of critical thinking in the context of higher education. This aligns with our results, as problem-based tasks stimulate deeper thinking and analysis of information. This parallel confirms that problem-based learning is an effective means of preparing students for complex tasks.

Ahdhianto et al. (2020) demonstrated that problem-based learning improves fifth graders' mathematical problem-solving and critical thinking. This aligns with our results, where students in the experimental group also showed significant improvements in critical skills through problem-based learning. In their systematic review, Anggraeni et al. (2023) emphasise that problem-based learning promotes critical thinking in students of all ages. Our findings support this view, showing that primary school students engaged in problem-based learning significantly improved their skills.

Razak et al. (2022) also found that introducing problem-based learning into the educational process improves critical thinking. This reflects the results of our study, where the experimental group demonstrated significant improvements in necessary skills. The survey by Manuaba et al. (2022) explains the effectiveness of problem-based learning in medical education, emphasising its role in developing independent learning and critical thinking. Similarly, our study shows that younger students can benefit from an active learning approach. Yusuf et al. (2020) showed that problem-based learning based on LBK increases critical thinking and learning outcomes. Our findings confirm that similar methods can be successfully adapted for younger students, contributing to their development of essential skills. The practical application of the results is integrating problem-based tasks into the learning process to develop critical thinking in primary school students. This will improve their learning outcomes and contribute to the formation of critical cognitive skills necessary for further learning and personal development.

Limitations of the study

The study's limitations include its conduct within a single city, which limits the generalisability of the results, and using only one type of test to assess critical thinking. In addition, the short implementation of the problem-based learning tasks limits the ability to identify long-term effects, and the lack of control over external factors such as social conditions may have influenced the results.

Recommendations

Introducing problem-based tasks into the learning process is recommended as an effective tool for developing students' critical thinking. It is essential to train teachers on how to use such tasks. In addition,

the effectiveness of the implemented methods should be regularly evaluated to adapt the curriculum to the needs of students.

Conclusions

The development of critical thinking in primary school students is an essential aspect of modern education, as it contributes to the successful learning process. The study's results indicate a significant positive impact of problem-based learning on developing critical thinking in primary school students. The study showed that the experimental group demonstrated significant improvement in all measured aspects of critical thinking, confirming this approach's effectiveness. In particular, students in the experimental group made substantial gains in the categories assessed by the Watson-Glaser methodology, including “Identifying Facts”, “Interpreting Data”, “Drawing Conclusions”, and “Analysing Situations”. The average score of the experimental group increased from 12.3 to 16.5, indicating a significant improvement in their critical skills, while the control group showed slight improvement. This result suggests that without active learning, students' progress remains minimal. The results also confirm that students who were actively involved in solving problematic tasks improved their skills in the categories of “Analysis”, “Synthesis”, “Assessment”, and “Reflection”. Statistical analysis showed that these changes are significant, which emphasises the importance of problem-based learning in the educational process. In addition, the correlation analysis revealed that a high level of students' involvement in problem-based learning is positively correlated with developing their cognitive and reflective abilities. This confirms that active learning improves basic mental processes such as attention, memory and self-analysis. Thus, the study results emphasise the importance of problem-based learning as an essential tool for developing critical thinking in younger students. Introducing such tasks into the learning process can significantly improve the quality of education and encourage students to analyse and reflect more deeply, which will help to develop their critical skills. Areas for future research could include studying the long-term effects of introducing problem-based learning on the development of student's critical thinking in different age groups and educational contexts. It is also essential to study the impact of socioeconomic factors on the effectiveness of such teaching methods.

Bibliographic references

Ahdhianto, E., Marsigit, H., & Nurfauzi, Y. (2020). Improving fifth-grade students’ mathematical problem-solving and critical thinking skills using problem-based learning. *Universal Journal of Educational Research, 8*(5), 2012-2021. https://doi.org/10.13189/ujer.2020.080539

Al Mamun, M. A., Lawrie, G., & Wright, T. (2020). Instructional design of scaffolded online learning modules for self-directed and inquiry-based learning environments. *Computers & Education*, *144*, 103695. https://doi.org/10.1016/j.compedu.2019.103695

Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *Sage Open, 10*(3), 1-15. https://doi.org/10.1177/2158244020938702

Amin, S., Utaya, S., Bachri, S., Sumarmi, S., & Susilo, S. (2020). Effect of problem based learning on critical thinking skill and enviromental attitude. *Journal for the Education of Gifted Young Scientists, 8*(2), 743-755. https://doi.org/10.17478/jegys.650344

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. https://doi.org/10.1016/j.tsc.2023.101334

Bezanilla, M. J., Fernández-Nogueira, D., Poblete, M., & Galindo-Domínguez, H. (2019). Methodologies for teaching-learning critical thinking in higher education: The teacher’s view. *Thinking skills and creativity*, *33*, 100584. https://doi.org/10.1016/j.tsc.2019.100584

Blyznyuk, T., & Kachak, T. (2024). Benefits of interactive learning for students' critical thinking skills improvement. *Journal of Vasyl Stefanyk Precarpathian National University, 11*(1), 94-102.

Chashechnikova, O., Odintsova, O., Hordiienko, I., Danylchuk, O., & Popova, L. (2024). Innovative technologies for the development of critical thinking in students. *Amazonia Investiga*, *13*(81), 197–213. https://doi.org/10.34069/AI/2024.81.09.16

Duda, H. J., Susilo, H., & Newcombe, P. (2019). Enhancing different ethnicity science process skills: Problem-based learning through practicum and authentic assessment. *International Journal of Instruction, 12*(1), 1207-1222. https://files.eric.ed.gov/fulltext/EJ1201323.pdf

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem-based learning: The effects on learning achievement and attitude in physics education. *Computers & Education*, *142*, 103635. https://doi.org/10.1016/j.compedu.2019.103635

Folomieieva, N., Koriakin, O., Matsenko, L., Siaska I., & Fed, I. (2024). Problem-based learning in higher education: a path towards training innovative and competent specialists. *Amazonia Investiga*, *13*(77), 201–217. https://doi.org/10.34069/AI/2024.77.05.15

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, *102*, 101586. https://doi.org/10.1016/j.ijer.2020.101586

Hasinger, E. (2024). *Cornell Critical Thinking Test Guid*. Tests.com. Retrived from https://acortar.link/V6cdoP

Jensen, A. A., Stentoft, D., & Ravn, O. (2019). *Interdisciplinarity and problem-based learning in higher education*. Cham: Springer. https://doi.org/10.1007/978-3-030-18842-9

Liu, Y., & Pásztor, A. (2022). Effects of problem-based learning instructional intervention on critical thinking in higher education: A meta-analysis. *Thinking Skills and Creativity*, *45*, 101069. https://doi.org/10.1016/j.tsc.2022.101069

Lombardi, L., Thomas, V., Rodeyns, J., Mednick, F. J., De Backer, F., & Lombaerts, K. (2024). Primary school teachers' experiences of teaching strategies that promote pupils' critical thinking. *Educational Studies, 50*(5), 683-701. https://doi.org/10.1080/03055698.2021.1990017

Lombardi, L., Mednick, F. J., De Backer, F., & Lombaerts, K. (2021). Fostering critical thinking across the primary school's curriculum in the European schools system. *Education Sciences, 11*(9), 505. https://doi.org/10.3390/educsci11090505

Manuaba, I. B. A. P., -No, Y., & Wu, C. C. (2022). The effectiveness of problem based learning in improving critical thinking, problem-solving and self-directed learning in first-year medical students: A meta-analysis. *PloS One, 17*(11), 0277339. https://doi.org/10.1371/journal.pone.0277339

O'Reilly, C., Devitt, A., & Hayes, N. (2022). Critical thinking in the preschool classroom – A systematic literature review. *Thinking skills and creativity*, *46*, 101110. https://doi.org/10.1016/j.tsc.2022.101110

Polat, Ö., & Aydın, E. (2020). The effect of mind mapping on young children's critical thinking skills. *Thinking Skills and Creativity*, *38*, 100743. https://doi.org/10.1016/j.tsc.2020.100743

Ramadhani, R., Umam, R., Abdurrahman, A., & Syazali, M. (2019). The effect of flipped-problem based learning model integrated with LMS-google classroom for senior high school students. *Journal for the Education of Gifted Young Scientists, 7*(2), 137-158. https://doi.org/10.17478/jegys.548350

Razak, A. A., Ramdan, M. R., Mahjom, N., Zabit, M. N. M., Muhammad, F., Hussin, M. Y. M., & Abdullah, N. L. (2022). Improving critical thinking skills in teaching through problem-based learning for students: A scoping review. *International Journal of Learning, Teaching and Educational Research, 21*(2), 342-362. https://doi.org/10.26803/ijlter.21.2.19

Ren, X., Tong, Y., Peng, P., & Wang, T. (2020). Critical thinking predicts academic performance beyond general cognitive ability: Evidence from adults and children. *Intelligence*, *82*, 101487. https://doi.org/10.1016/j.intell.2020.101487

Saputra, M. D., Joyoatmojo, S., Wardani, D. K., & Sangka, K. B. (2019). Developing critical-thinking skills through the collaboration of a jigsaw model with a problem-based learning model. *International Journal of Instruction, 12*(1), 1077-1094. https://files.eric.ed.gov/fulltext/EJ1201249.pdf

Sari, R., Sumarmi, S., Astina, I., Utomo, D., & Ridhwan, R. (2021). Increasing students' critical thinking skills and learning motivation using inquiry mind map. *International Journal of Emerging Technologies in Learning (iJET), 16*(03), 4-19. https://doi.org/10.3991/ijet.v16i03.16515

Seibert, S. A. (2021). Problem-based learning: A strategy to foster Generation Z's critical thinking and perseverance. *Teaching and Learning in Nursing, 16*(1), 85-88. https://doi.org/10.1016/j.teln.2020.09.002

Supena, I., Darmuki, A., & Hariyadi, A. (2020). The influence of 4C (constructive, critical, creativity, collaborative) learning model on students' learning outcomes. *International Journal of Instruction, 14*(3), 873-892. https://doi.org/10.29333/iji.2021.14351a

Thorndahl, K. L., & Stentoft, D. (2020). Thinking critically about critical thinking and problem-based learning in higher education: A scoping review. *Interdisciplinary Journal of Problem-Based Learning, 14*(1). https://doi.org/10.14434/ijpbl.v14i1.28773

Torrance, E. P. (2022). *Torrance Tests of Creative Thinking (TTCT)*. Testingmom. Retrived from https://www.testingmom.com/tests/torrance-test/

Watson, G., & Glaser, E. (2020). *Watson-Glaser Critical Thinking Appraisal*. Pearson. Retrived from https://www.talentlens.com/content/dam/school/global/Global-Talentlens/uk/manuals/W-G-III-Technical-Manual.pdf

Wu, C. (2021). Training teachers in China to use the philosophy for children approach and its impact on critical thinking skills: A pilot study. *Education Sciences, 11*(5), 206. https://doi.org/10.3390/educsci11050206

Yusuf, R., Sanusi, R., Maimun, B. A., & Putra, I. (2020). Critical thinking and learning outcomes through problem based learning model based on LBK application. *International Journal of Innovation, Creativity and Change, 12*(12), 907-918. https://www.ijicc.net/images/vol12/iss12/121285_Yusuf_2020_E_R.pdf