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ENHANCING MATHEMATICAL CONCEPTUAL UNDERSTANDING, CRITICAL THINKING, AND PROBLEM-SOLVING THROUGH COLLABORATIVE INQUIRY-BASED LEARNING: A QUASI-EXPERIMENTAL STUDY OF PRESERVICE ELEMENTARY TEACHERS

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ABSTRACT

Mathematics learning is fundamental to developing students' analytical, critical, and problem-solving skills and thus requires collaborative, discovery-based learning. This study aims to examine the influence of Collaborative Inquiry-Based Learning on students' conceptual understanding, critical thinking, and mathematical problem-solving. The research design used was a quasi-experimental study with a posttest-only control group. The study sample consisted of 64 first-semester students enrolled in the Elementary School Teacher Education Study Program at a university in West Java, Indonesia. The sample was divided into an experimental and a control group. Data were collected using tests. The instruments used included tests of conceptual understanding, critical thinking, and problem-solving. Data were calculated for validity and reliability tests. Data were analyzed by calculating prerequisite and hypothesis tests. The independent t-test indicated a significant difference between the two groups ($p < 0.05$), with the experimental group scoring higher on all three variables than the control group. The t-test scores for the conceptual understanding, critical thinking, and problem-solving aspects were 13.569, 14.636, and 14.037, respectively. These results indicate that Collaborative Inquiry-Based Learning is potent in improving conceptual understanding, critical thinking, and problem-solving skills in elementary school teacher education students. This model is recommended for implementation in basic mathematics courses to develop reflective and adaptive prospective teachers.

KEYWORDS: Conceptual Understanding, Critical Thinking, Problem Solving, Collaborative Inquiry-Based Learning

1. INTRODUCTION

Mathematics learning in elementary school plays a fundamental role in developing students' logical, systematic, and critical thinking skills (Nurtamam & Jannah, 2025; Oljayevna & Shavkatovna, 2020). The teacher's conceptual understanding greatly influences the quality of mathematics instruction in delivering meaningful—not merely procedural—teaching (Aguilar & Telese, 2018; Eisenhart et al., 1993; Hurrell, 2021; Rittle-Johnson et al., 2016). In the context of teacher education, conceptual understanding is not only crucial for preservice teachers' own comprehension but also essential for effectively representing and transforming mathematical concepts for students. Kilpatrick (2001) identified five levels of mathematical proficiency: conceptual understanding, stage fluency, tactical competence, flexible reasoning, and constructive disposition. Among these aspects, conceptual understanding serves as the foundation that supports the development of the other proficiencies. Conceptual understanding enables students to understand why a particular procedure is used and when it is appropriate. Conversely, without a strong understanding, students merely memorize meaningless algorithms, making them vulnerable to misconceptions (Şenyiğit, 2021). Several studies indicate that preservice elementary school teachers still struggle to deeply understand basic mathematical concepts (Prediger et al., 2023; Stoehr & Olson, 2023). Many of them can only solve problems procedurally, yet fail to explain the underlying concepts verbally or visually. This condition may affect the quality of mathematics education at the elementary level, for which they will eventually be responsible.

This limitation is largely due to the lack of integration of learning activities that stimulate critical thinking and mathematical problem-solving in teacher education programs. Orhan (2022) emphasizes that the infrequent use of critical thinking practices during college leads to weak decision-making and limited problem-solving flexibility. Other studies show a significant positive correlation between critical thinking skills and conceptual understanding among preservice elementary school teachers (Mafarja & Zulnaidi, 2022; Wulandari, 2018). Furthermore, data from the Program for International Student Assessment 2020 reveal that Indonesian students' mathematics skills remain below the Organization for Economic Co-operation and Development average, particularly in reasoning and problem-solving (OECD, 2023). This reinforces the vital role of future teachers in building a strong foundation of numeracy from early education, which can only be achieved if they themselves possess a solid conceptual understanding. To address issues in mathematics instruction, there is a need for innovative learning approaches that center on students' critical thinking and mathematical problem-solving skills. Such learning can be directed by implementing Collaborative Inquiry-Based Learning (CIBL). This model combines two approaches: collaborative learning and inquiry-based learning. Both emphasize collective problem-solving through discussion and investigation. CIBL aims to enhance conceptual understanding, scientific skills, critical thinking, collaborative thinking, and working like a scientist (Nankhantee, 2025). This objective is supported by previous findings that show a significant increase in students' critical thinking skills after implementing CIBL (Linsih et al., 2025). Similarly, another study found that CIBL is a highly influential factor in the development of higher-order thinking skills, whether spontaneous or not (Lu et al., 2021). The effectiveness of CIBL has also been proven by other researchers, who found that it facilitates effective learning processes that lead to long-term student learning success (Korkman & Metin, 2021). Furthermore, previous literature explains that collaborative learning has a strong impact on students' achievement, attitudes, motivation, and problem-solving skills (Aktaş, 2013; Gök & Sılay, 2009; Güngör & Özkan, 2012). In this regard, the integration of inquiry and collaboration provides a meaningful learning environment that encourages active knowledge construction. Other studies indicate that learning groups implementing collaborative inquiry-based approaches tend to develop environmental awareness and reading comprehension (Gülin, 2010; Yılmaz & Top, 2015). Although many studies have discussed misconceptions or the lack of mastery in mathematical concepts among preservice elementary school teachers, studies that directly explore the interrelation between conceptual understanding, critical thinking skills, and problem-solving skills simultaneously are still limited, especially in the Indonesian context and in fundamental topics such as fractions, proportions, and geometry. Additionally, there is still limited research on the impact of CIBL on students' mathematical conceptual understanding. Some studies examine this approach in relation to overall learning outcomes (Gülin, 2010; Yılmaz & Top, 2015). Furthermore, previous studies have not fully explained the holistic influence of CIBL on students' understanding.

This study is conducted in the context of mathematics education, which is still rarely implemented in such models. Previous findings tend to focus more on science education than mathematics. This study guides future researchers who aim to use a similar method in mathematics learning. In general, this research aims to determine the effectiveness of CIBL on the level of mathematical conceptual understanding among preservice elementary school teachers, as well as its connection with critical thinking and mathematical problem-solving skills. The main focus is on conceptual representation, the ability to explain the logical reasoning behind a procedure, and proficiency in solving non-routine problems. The findings of this research are expected to serve as a foundation for developing more contextually grounded, reflective, and transformative teacher education curricula, while also promoting mathematics learning that is understanding-oriented rather than merely procedural.

RESEARCH METHOD

This study used a quantitative approach. Quasi-experimental design is a research method that measures the effect of a particular treatment on variables without full randomization (Creswell & Creswell, 2022). The research focuses on quasi-experiments with a posttest-only control

group design. This design involves treatment and control groups that are not randomly selected. The difference between the groups is measured before and after the intervention. This research was conducted on students in the Elementary School Teacher Education program, who were freshmen at a university in West Java, Indonesia. The selected subjects were students enrolled in the Basic Mathematics Concepts course. A total of 64 students participated, split into two groups: 32 students in the experimental class (n = 32) and 32 in the control class (n = 32). The experimental class received treatment through CIBL exercises, while the control class continued with traditional learning models. This research used testing techniques for data collection (Pandey & Pandey, 2021).

The research instruments consisted of three types of essay-based tests. These tests were designed to assess conceptual understanding, critical thinking using Ennis' indicators, and mathematical problem-solving using Polya's stages. Experts validated the instruments to ensure validity and reliability. The instruments were validated and pilot-tested to ensure validity ($r > 0.30$) and reliability ($\alpha > 0.78$). Validity was tested using product-moment correlation, while reliability was measured using Cronbach's alpha formula. Ethical considerations were strictly upheld throughout the research. Participants provided informed consent, and their anonymity and confidentiality were maintained throughout. This comprehensive protocol ensured the quality and reliability of the collected data, forming a strong foundation for analysis. The data were analyzed both descriptively and inferentially using prerequisite and hypothesis testing (Creswell & Creswell, 2022). Prerequisite testing involved normality and homogeneity tests. The Kolmogorov-Smirnov test was used to assess normality, and the Scheffé test was used to assess homogeneity. Hypothesis testing employed the independent t-test. The independent t-test was applied to examine differences between the groups. All data were analyzed using Statistical Product and Service Solutions (SPSS) version 26.

RESULTS AND DISCUSSION

3.1 Results

The conceptual understanding test includes several types of questions: interpreting, giving examples, classifying, comparing, explaining, and concluding. Meanwhile, the problem-solving skills test is analyzed based on the stages of understanding the problem, designing, and interpreting. For the critical thinking indicators, six criteria are implemented: focus, reasoning, drawing conclusions, situation, clarity, and review. The study's findings show that the experimental and control groups differed significantly in their conceptual understanding, critical thinking, and mathematical problem-solving.

Table 1: Descriptive Statistics.

Group	Variable	N	Mean	Std. Deviation	Minimum	Maximum
Experimental	Conceptual Understanding	32	84.41	3.38	78	91
Experimental	Critical Thinking	32	81.09	3.32	74	88
Experimental	Problem Solving	32	79.25	3.33	73	88
Control	Conceptual Understanding	32	73.16	2.97	68	78
Control	Critical Thinking	32	68.75	3.24	62	74
Control	Problem Solving	32	67.16	2.99	61	72

Based on Table 1, the experimental group receiving conceptual understanding-based learning through the application of the CIBL model achieved an average score of 84.41, which is significantly higher than the control group's average of 73.16. Similarly, students' critical thinking and mathematical problem-solving skills in the experimental group showed average scores of 81.09 and 79.25, respectively, whereas the control group achieved averages of 68.75 and 67.16, respectively. To ensure there was no discernible difference between the two groups, the variables of conceptual comprehension, critical thinking, and problem-solving were further examined using an independent-samples t-test. Normal distribution and homogeneous data are the primary requirements for performing the independent-samples t-test.

For both the control and experimental classes, normality tests were performed before and after the test. With significance values greater than 0.05, the normality test for the experimental and control groups met the criteria, indicating that the data were normally distributed. The homogeneity test was then used to determine whether the samples were drawn from populations with homogeneous variables at both the pre-test and post-test phases. The homogeneity test results indicated that the data were homogeneous, as the p-values for students' conceptual knowledge, critical thinking, and problem-solving skills during the pre-test and post-test phases were above 0.05. After fulfilling the requirements of normality and homogeneity, the results were further analyzed using the t-test. Table 2 presents the results of the independent samples t-test comparing the experimental and control groups across the measured variables.

Table 2: Independent Samples T-Test.

Variable	t	df	Sig. (2-tailed)	Mean Difference
Conceptual Understanding	13.569	62	0.000	11.25
Critical Thinking	14.636	62	0.000	12.34
Problem Solving	14.037	62	0.000	12.09

The results of the independent t-test shown in Table 2 indicate that the differences between the two groups across the three variables were significant (Sig. 2-tailed < 0.05). The t-scores for each variable (conceptual understanding = 13.569; critical thinking = 14.636; problem-solving = 14.037) reinforce that there were meaningful differences between the treatments given to the experimental and control groups. Therefore, compared to traditional learning, the CIBL model significantly improves primary school teacher education students' conceptual understanding, critical thinking, and problem-solving skills.

DISCUSSION

This study shows that elementary teacher education students who participated in a learning intervention that strengthened critical thinking and problem-solving (experimental group) had significantly higher levels of conceptual understanding than those in the control group who experienced conventional learning. The skills of aspiring primary school teachers in using project-based, reflective, and active problem-solving techniques have a significant impact on their conceptual understanding (Han et al., 2015; Rahmawati & B, 2023; Syamsuddin et al., 2020). According to Wardyaningrum and Suyanto (2019), one way to improve students' conceptual understanding is by assigning tasks in groups and conducting discussions in accordance with the topic being studied. In the experimental group's learning process, students actively participated in the learning activities. They were actively involved in developing concepts aligned with the material they were about to learn. This condition made the learning meaningful for students (Kosasi, 2015). Meaningful learning helps students better understand concepts. In addition, a significant improvement was also observed in critical thinking and problem-solving skills. These findings reinforce previous studies indicating that critical thinking skills are closely related to the skills to solve non-routine mathematical problems (Marzuki et al., 2021; Suryawan et al., 2023). The results revealed that critical thinking skills greatly contribute to students' conceptual understanding (Hasnunidah et al., 2019). Students' comprehension of biological ideas is also improved when their critical thinking skills are strengthened. Because critical thinking entails problem-solving, inference formulation, probability calculation, and decision-making, it is intentional, rational, and goal-directed. When people think critically, they assess the results of their reasoning and the effectiveness of solutions to issues or decisions. Other studies also found a positive correlation between critical thinking and problem-solving, supporting the argument that these two skills reinforce each other and are inseparable in meaningful mathematics learning (Susilowati et al., 2020; Üredi & Kösece, 2020).

Analytical skills are also directly enhanced by critical thinking, which helps pupils map issues and locate data that serve as the basis for problem-solving (Chijioke & Offiah, 2013; Cullen et al., 2018). This statement aligns with Taleb and Chadwick (2016), who argued that analytical skills can be enhanced through critical thinking. Better critical thinking not only helps students become more analytical, but it also makes it easier for them to reach conclusions (Cañongo et al., 2020). Students' skills to conclude are particularly useful when they are choosing how to approach difficulties (Soto et al., 2019). Students' problem-solving skills have probably improved as a result of the teacher's constant efforts to make learning engaging and fun. Students are constantly allowed to ask questions about the course material and connect it to their personal experiences in a student-centered learning environment. As a result, the educational process might encourage students to improve their problem-solving skills. According to Ültay (2017), this thesis is supported by the premise that students' problem-solving skills are enhanced by issues that provide opportunities to examine, synthesize, and evaluate. Similar to the findings of Susanti and Hartono (2019), the problem-solving and critical thinking skills indicate that students' levels are good, but still need to be optimized in the mathematics learning process. Students who are intentionally exposed to this type of learning will undoubtedly develop higher-order mathematics skills, such as problem-solving and critical thinking (Susanti & Hartono, 2019). Researchers think that students' proficiency has influenced the development of these two primary cognitive skills in mathematics. Students who are gifted are more likely to excel in both of these areas. For students to perform at their best, teachers are therefore obligated to make every effort to maximize their potential. The findings of this study are also consistent with several earlier investigations. According to Sidiq et al. (2021), mastery of critical thinking skills can provide significant benefits for learners, particularly in science-related problem-solving. Sukaesih and Sutrisno (2017) claimed that, for pupils to grasp the subject matter, critical thinking requires contextual learning experiences, high levels of engagement and participation, and support. The features of the conceptual comprehension procedures learning model align with this assertion. All students can benefit from better comprehension and involvement when the conceptual comprehension procedures model is used in conjunction with cooperative learning and simple assignments. In this study, the experimental group guided by the CIBL approach showed higher achievement in the three measured aspects than the control group that received conventional learning.

CIBL provides students the opportunity to work together to solve and answer inquiry questions in ways that may not be possible for individual students (Yu et al., 2024). The effectiveness of learning that emphasizes students' active involvement in thinking and collaborative discussion can be explained through the CIBL (Korkman & Metin, 2021; Lu et al., 2021). This model combines the principles of collaborative and inquiry-based learning, in which students work in small groups to investigate concepts, formulate questions, explore solutions, and reflect on their learning process. The theory of cognitive apprenticeship underpins this model by emphasizing scaffolding, modeling, and coaching within an authentic social context (Collins et al., 1991; Bruin, 2019). In this study, students in the experimental group engaged in learning that stimulated

metacognition and conceptual reflection through group discussions, solving non-routine problems, and verbally explaining the mathematical procedures they used. It has been demonstrated that CIBL helps students develop their critical thinking skills (Agbi & Yuangsoi, 2022). Collaborative learning allows students to learn not only from instructors but also from their peers through the exchange of ideas, argumentation, and concept clarification. This process aligns with the stages in Polya's model, which emphasizes understanding the problem, planning strategies, implementing solutions, and evaluating results as key steps in constructing holistic conceptual understanding.

According to another research, CIBL not only improves students' academic achievement but also fortifies higher-order cognitive capabilities (Kolloffel et al., 2011; Lämsä et al., 2018; Pifarré & Staarman, 2011), such as reasoning and analysis, to help them better adapt to society (Lu et al., 2021). The CIBL model has incorporated several learning recommendations that serve as the basis for its development. These recommendations include fostering inquiry-oriented experimental activities, fostering open discussion, and training critical thinking through the presentation of contextual or real-life cases in learning (Fine & Desmond, 2015; Miri et al., 2007; Samarapungavan et al., 2008). According to Prayogi et al. (2018), the CIBL model can help aspiring physics teachers develop their critical thinking skills. As such, it is a useful tool for educators or instructors of aspiring teachers to meet learning needs and develop critical thinking skills. To conceptually examine its potential to enhance the analytical and reasoning skills of primary teacher education students, this learning model was developed solely based on current research and ideas. Based on these findings, it is recommended that Teacher Education Institutions begin integrating the CIBL model into the curriculum of fundamental mathematics courses. By using this technique, the Elementary School Teacher Education students will be able to improve their conceptual comprehension by concurrently developing their critical thinking and problem-solving skills. Thus, this approach not only addresses the issue of weak conceptual mastery among prospective teachers but also builds a more reflective, adaptive, and contextual pedagogical foundation for teaching mathematics in elementary schools.

CONCLUSION

The results of this study indicate that the CIBL model is effective in improving conceptual understanding, critical thinking, and problem-solving skills of elementary teacher education students. The experimental group guided using the CIBL approach achieved higher outcomes across the three measured aspects than the control group, which received conventional learning. These findings affirm that active student involvement in inquiry, collaborative discussion, and reflection on problem-solving strategies can strengthen the meaningful construction of mathematical knowledge. Therefore, the CIBL model is highly recommended for implementation in teacher education courses, especially in conceptual and applicative subjects such as basic mathematics. The application of this model not only affects cognitive learning outcomes but also cultivates the critical and reflective thinking necessary for prospective teachers to guide student learning in elementary schools.

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REFERENCES

Agbi, A., & Yuangsoi, P. (2022). Enhancement of critical thinking skills in students using mobile-blended learning with a collaborative inquiry-based approach. Humanities, Arts and Social Sciences Studies, 22(1), 9–20.

Aguilar, J. J., & Telese, J. A. (2018). Mathematics understanding of elementary preservice teachers: The analysis of their procedural-fluency, conceptual-understanding, and problem-solving strategies. Mathematics Teaching Research Journal, 10(3–4), 24–37.

Aktaş, M. (2013). 5E öğrenme modeli ve işbirlikli öğrenme yönteminin biyoloji dersi başarısına etkisi. Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi, 14(3), 37–58.

Antonio Cañongo, A., Acle Tomasini, G., & Reyes López, N. G. (2020). Habilidades de nivel inferencial y crítico en alumnos de primaria. Revista Electrónica de Investigación Educativa, 22, 1–12.

Bruin, L. R. D. (2019). The use of cognitive apprenticeship in the learning and teaching of improvisation: Teacher and student perspectives. Research Studies in Music Education, 41(3), 261–279.

Chijioke, U. C., & Offiah, P. F. C. (2013). The relationship between senior secondary school students analytical skill and their achievement in chemistry in Anambra State. International Journal of Engineering Science Invention, 2(7), 44–57.

Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship making thinking visible. American Educator, 1–18.

Creswell, J. W., & Creswell, J. D. (2022). Research design: Qualitative, quantitative, and mixed methods approaches, 5th edition. Journal of Electronic Resources in Medical Libraries, 19(1–2), 54–55.

Cullen, S., Fan, J., van der Brugge, E., & Elga, A. (2018). Improving analytical reasoning and argument

understanding: a quasi-experimental field study of argument visualization. Npj Science of Learning, 3(1), 1–6.
Eisenhart, M., Borko, H., Underhill, R., Brown, C., Jones, D., & Agard, P. (1993). Conceptual knowledge falls through the cracks: Complexities of learning to teach mathematics for understanding. Journal for Research in Mathematics Education, 24(1), 8–40.
Fine, M., & Desmond, L. (2015). Inquiry-based learning: Preparing young learners for the demands of the 21st Century. Journal of Best Practices in Education, 8(1), 2–11.
Gök, T., & Sılay, İ. (2009). İşbirlikli öğrenme gruplarında problem çözme stratejileri öğretiminin öğrencilerin başarı güdüsü üzerindeki etkileri. Kastamonu Eğitim Dergisi, 17(3), 821–834.
Gülin, C. (2010). Fen bilgisi öğretmen adaylarının alan gezileri ve işbirlikçi sorgulama ortamında çevre bilgisini yapılandırma ve kavramalarını araştırma, Yayınlanmamış yüksek lisans tezi. Ortadoğu Teknik Üniversitesi, Ankara.
Güngör, S. N., & Özkan, M. (2012). İlköğretim 7. sınıf fen ve teknoloji dersindeki insan ve çevre ünitesinin işbirlikli öğrenme yöntemiyle işlenmesinin öğrenci başarısı üzerine etkisi. Uludağ Üniversitesi Eğitim Fakültesi Dergisi, 25(1), 249–258.
Han, S., Yalvac, B., Capraro, M. M., & Capraro, R. M. (2015). In-service teachers' implementation and understanding of STEM project based learning. Eurasia Journal of Mathematics, Science and Technology Education, 11(1), 63–76.
Hasnunidah, N., Susilo, H., Irawati, M., & Suwono, H. (2019). The contribution of argumentation and critical thinking skills on students' concept understanding in different learning models. Journal of University Teaching and Learning Practice, 17(1), 1–15.
Hurrell, D. (2021). Conceptual knowledge or procedural knowledge or conceptual knowledge and procedural knowledge: Why the conjunction is important to teachers. Australian Journal of Teacher Education (Online), 46(2), 57–71.
Kilpatrick, J. (2001). Understanding mathematical literacy: The contribution of research. Educational Studies in Mathematics, 47(1), 101–116.
Kolloffel, B., Eysink, T. H. S., & de Jong, T. (2011). Comparing the effects of representational tools in collaborative and individual inquiry learning. International Journal of Computer-Supported Collaborative Learning, 6(2), 223–251.
Korkman, N., & Metin, M. (2021). The effect of inquiry-based collaborative learning and inquiry-based online collaborative learning on success and permanent learning of students. J.Sci.Learn, 2021(2), 151–159.
Kosasi, S. (2015). Perancangan E-learning untuk Meningkatkan Motivasi Belajar Guru dan Siswa. Prosiding Seminar Nasional Pendidikan Teknik Informatika (SENAPATI 2015), 1(1), 82–88.
Lämsä, J., Hämäläinen, R., Koskinen, P., & Viiri, J. (2018). Visualising the temporal aspects of collaborative inquiry-based learning processes in technology-enhanced physics learning. International Journal of Science Education, 40(14), 1697–1717.
Linsih, R. A., Soepriyanto, Y., & Praherdhiono, H. (2025). The effect of collaborative inquiry-based learning model and learning motivation on critical thinking skills of elementary school. Jurnal Kajian Teknologi Pendidikan, 8(2), 118–127.
Lu, K., Pang, F., & Shadiev, R. (2021). Understanding the mediating effect of learning approach between learning factors and higher order thinking skills in collaborative inquiry-based learning. Educational Technology Research and Development, 69(5), 2475–2492.
Mafarja, N., & Zulnaidi, H. (2022). Relationship between Critical thinking and academic self-concept: An experimental study of reciprocal teaching strategy. Thinking Skills and Creativity, 45, 101113.
Marzuki, M., Wahyudin, W., Cahya, E., & Juandi, D. (2021). Students' critical thinking skills in solving mathematical problems; a systematic procedure of grounded theory study. International Journal of Instruction, 14(4), 529–548.
Miri, B., David, B. C., & Uri, Z. (2007). Purposely teaching for the promotion of higher-order thinking skills: A case of critical thinking. Research in Science Education, 37(4), 353–369.
Nankhantee, A. (2025). Combining inquiry-based learning and collaborative learning: a new model for improving students' teamwork and problem-solving skills. Journal of Education and Educational Development, 12(1), 13–38.
Nurtamam, M. E., & Jannah, A. N. (2025). A systematic qualitative review of teachers' strategies in enhancing mathematical reasoning in elementary schools. Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini, 9(2),

553–562.
OECD. (2023). PISA 2022 Assessment and analytical framework. OECD Publishing.
Oljayevna, O., & Shavkatovna, S. (2020). The development of logical thinking of primary school students in mathematics. European Journal of Research and Reflection in Educational Sciences, 8(2), 235–239.
Orhan, A. (2022). Critical thinking dispositions and decision making as predictors of high school students' perceived problem solving skills. The Journal of Educational Research, 115(4), 235–245.
Pandey, P., & Pandey, M. M. (2021). Research methodology tools and techniques. Kogaion Publishing Center.
Pifarré, M., & Staarman, J. K. (2011). Wiki-supported collaborative learning in primary education: How a dialogic space is created for thinking together. International Journal of Computer-Supported Collaborative Learning, 6(2), 187–205.
Prayogi, S., Yuanita, L., & Wasis, L. (2018). Critical inquiry based learning: A model of learning to promote critical thinking among prospective teachers of physics. Journal of Turkish Science Education, 15(1), 43–56.
Prediger, S., Dröse, J., Stahnke, R., & Ademmer, C. (2023). Teacher expertise for fostering at-risk students' understanding of basic concepts: conceptual model and evidence for growth. Journal of Mathematics Teacher Education, 26(4), 481–508.
Rahmawati, R. D., & Atmojo, S. E. (2023). Improving the problem-solving ability of prospective elementary school teacher candidates through blended project-based learning. Proceedings of the 1st UPY International Conference on Education and Social Science (UPINCESS 2022), 2(1), 1–8.
Rittle-Johnson, B., Fyfe, E. R., & Loehr, A. M. (2016). Improving conceptual and procedural knowledge: The impact of instructional content within a mathematics lesson. British Journal of Educational Psychology, 86(4), 576–591.
Samarapungavan, A., Mantzicopoulos, P., & Patrick, H. (2008). Learning science through inquiry in kindergarten. Science Education, 92(5), 868–908.
Şenyiğit, Ç. (2021). The effect of problem-based learning on preservice primary school teachers' conceptual understanding and misconceptions. International Online Journal of Primary Education, 10(1), 50–72.
Sidiq, Y., Ishartono, N., Desstya, A., Prayitno, H. J., Anif, S., & Hidayat, M. L. (2021). Improving elementary school students' critical thinking skill in science through hots-based science questions: A quasi-experimental study. Jurnal Pendidikan IPA Indonesia, 10(3), 378–386.
Soto, C., Gutiérrez de Blume, A. P., Jacovina, M., McNamara, D., Benson, N., Riffo, B., & Kruk, R. (2019). Reading comprehension and metacognition: The importance of inferential skills. Cogent Education, 6(1). 1–20.
Stoehr, K. J., & Olson, A. M. (2023). Elementary prospective teachers' visions of moving beyond mathematics anxiety. Mathematics Education Research Journal, 35(1), 133–152.
Sukaesih, S., & Sutrisno, S. (2017). The Effects of conceptual understanding procedures (cups) towards critical thinking skills of senior high school students. Journal of Physics: Conference Series, 824(1). 1–8.
Suryawan, I. P. P., Sudiarta, I. G. P., & Suharta, I. G. P. (2023). Students' critical thinking skills in solving mathematical problems: systematic literature review. Indonesian Journal of Educational Research and Review, 6(1), 120–133.
Susanti, E., & Hartono. (2019). An analysis mathematical problem solving and mathematical critical thinking skills of junior high school students. Journal of Physics: Conference Series, 1320(1). 1–7.
Susilowati, E., Hartini, S., Suyidno, S., Mayasari, T., & Winarno, N. (2020). Hubungan antara kemampuan pemecahan masalah terhadap keterampilan berpikir kritis pada materi deret. Prosiding Seminar Nasional Lingkungan Lahan Basah, 5(1), 119–125.
Syamsuddin, A., Juniati, D., & Siswono, T. Y. E. (2020). Understanding the problem solving strategy based on cognitive style as a tool to investigate reflective thinking process of prospective teacher. Universal Journal of Educational Research, 8(6), 2614–2620.
Taleb, A. M. H., & Chadwick, C. (2016). Enhancing student critical and analytical thinking skills at a higher education level in developing countries: Case study of the British University in Dubai. Journal of Educational and Instructional Studies in the World, 6(1), 67–77.
Ültay, E. (2017). Examination of context-based problem-solving abilities of preservice physics teachers. Journal of Baltic Science Education, 16(1), 113–122.
Üredi, L., & Kösece, P. (2020). Investigating the relationship between critical thinking skills and mathematical problem solving achievements of secondary education students. The European Journal of Educational Sciences, 7(2), 186–202.

Wardyaningrum, A. R., & Suyanto, S. (2019). Improving students' conceptual understanding of biology through Quipper School. IOP Conference Series: Journal of Physics, 1233(1), 1–8.

Wulandari, A. Y. R. (2018). Correlation between critical thinking and conceptual understanding of student's learning outcome in mechanics concept. AIP Conference Proceedings, 2024(1), 1–7.

Yılmaz, M., & Top, M. B. (2015). İşbirlikli tartışma sorgulama (İTS) stratejisinin ilkokul 4. sınıf öğrencilerinin okuduğunu anlama başarılarına etkisi. Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 12(30), 78–97.

Yu, S., Jantharajit, N., & Srikhao, S. (2024). Collaborative inquiry-based instructional model to enhance mathematical analytical thinking and reasoning skills for fourth-grade students. Asian Journal of Education and Training, 10(1), 10–17.