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The Relationship Between Interpersonal Communication Skills and Student Problem-Solving Ability in Chemistry Learning

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Abstract: *Problem-solving in chemistry is a multifaceted process influenced by both cognitive and social factors, including students' interpersonal communication skills. This study aimed to examine the relationship between students' interpersonal communication skills and their problem-solving ability in chemistry learning. A quantitative correlational design was employed, involving 157 eleventh-grade students from SMA Labschool Jakarta, Cibubur, and Cirendeu. Students' problem-solving ability was measured using a multiple-choice multiple-answer (MCMA) test, while their interpersonal communication skills were assessed using the Interpersonal Communication Competence Scale (ICCS). The results showed a significant but weak positive correlation (r = 0.294) between the two variables, indicating that students with stronger interpersonal communication skills tend to perform better in solving chemistry problems. Although the contribution of interpersonal communication was relatively small, it suggests that social interaction and communicative engagement play a meaningful role in supporting cognitive performance. These findings underscore the importance of fostering interpersonal communication within chemistry education to enhance students' problem-solving outcomes.*

Keywords: *interpersonal communication; problem-solving; chemistry learning*

INTRODUCTION

The era of globalization and digitalization has brought significant transformations in the field of education. The orientation of learning is no longer limited to the mastery of academic content but has shifted toward the development of 21st-century skills (Turiman et al., 2012). The National Research Council (2013) categorizes these skills into three main dimensions: cognitive (critical thinking, problem-solving, creativity, and knowledge mastery), intrapersonal (self-regulation, motivation, and metacognition), and interpersonal (communication, collaboration, and leadership). This need is further reinforced by The Future of Jobs Report 2025, published by the World Economic Forum (WEF), which highlights critical thinking, communication, and problem-solving as essential competencies required for the future workforce (World Economic Forum, 2025).

In line with these demands, the mastery of twenty-first-century skills has become a crucial aspect of science education

(Turiman et al., 2012). As a branch of science, chemistry learning does not merely require conceptual understanding but also involves higher-order thinking skills, experimental activities, and scientific communication to articulate observations and reasoning (Crawford et al., 2019; Sevian & Talanquer, 2014). The inherently abstract, experiment-based, and interdisciplinary nature of chemistry, closely linked to physics, biology, environmental science, and technology, requires students to think critically and establish connections across disciplines (Al-thani et al., 2025; Gabel, 1999). Consequently, critical thinking and interpersonal communication skills constitute essential components of chemistry education, as they enable students to analyze data, explain phenomena logically, and collaborate effectively in the communication of ideas (Crawford et al., 2019; Malinda Wilson, 2015).

Interpersonal communication is understood as the ability to convey and comprehend information effectively through verbal and nonverbal interactions (DeVito, 2022). In education, this skill has a significant influence on the learning process. It facilitates rapport-building between teachers and students, enhances learning motivation, supports scientific discussions, promotes teamwork in laboratory settings, aids in the presentation of ideas through reports or presentations, and helps clarify understanding of subject matter. Effective interpersonal communication fosters a conducive and comfortable learning environment, thereby supporting both academic achievement and students' social development (Govindaraju & Seruji, 2022; Malinda Wilson, 2015). Within the framework of Deep Learning (Pembelajaran Mendalam), communication skills are positioned as one of the core dimensions of the graduate profile. Students equipped with strong communication abilities are expected to build positive relationships, bridge differences in perspectives, and establish mutual understanding in both social and professional contexts (Tim Kemendikdasmen, 2025).

In addition to interpersonal communication, chemistry learning also highlights the significance of developing problem-solving skills. Problem-solving is a process in which individuals utilize their knowledge, skills, and understanding to address unfamiliar situations. This process begins when an individual is confronted with a problem and continues until a solution is found and evaluated against the initial conditions. In practice, problem-solving requires students to connect and apply previously acquired knowledge in different contexts to arrive at appropriate solutions (Krulik & Rudnick, 1988). Mastery of problem-solving skills enables students to apply chemical concepts in everyday life, such as in industry, environmental issues, and health. However, many students continue to face difficulties in grasping abstract chemical concepts, analyzing experimental data, and linking various levels of chemical representation, which hinders their ability to solve problems effectively (Kurniawati et al., 2023; Safitri et al., 2019).

This condition is reflected in the PISA 2022 results, which reported that only 34% of Indonesian students reached the minimum proficiency level (Level 2) in science, while almost none achieved the top performer levels (Level 5–6), which indicates the ability to apply scientific knowledge independently and creatively (OECD, 2023). Similarly, in the domain of creative thinking, Indonesian students scored relatively low, particularly in scientific problem-solving, highlighting weaknesses in divergent thinking, the integration of scientific concepts, and scientific communication skills that are crucial in inquiry-based chemistry learning (OECD, 2024).

One of the key aspects that supports the development of problem-solving skills is interpersonal communication. Clear and effective communication is required not only to convey solutions but also to collaborate

with others, report and coordinate with different stakeholders, manage conflicts, address differences, articulate requests objectively, remain open to new ideas, and express perspectives on critical issues throughout the problem-solving process (Febriyanti & Ananda Ismail, 2022; Minarsi et al., 2018).

Research undertaken by Makiyah et al. (2021) explored how communication skills relate to problem-solving capacity among Physics Education students studying Quantum Mechanics, revealed a positive correlation of moderate strength, with communication contributing 25% to problem-solving performance. This finding suggests that the more proficient students are in communication, the better their problem-solving abilities. In the field of Mathematics Education, Ariawan and Nufus (2017) identified a significant but weak relationship between students' mathematical communication skills and their overall mathematical problem-solving abilities. Similarly, the study conducted by Minarsi, Nirwana, and Yarmis (2018) The effect of interpersonal communication on problem-solving found that interpersonal communication contributes positively, though modestly (1.8%), to students' problem-solving strategies. Although the contribution was relatively small, these findings reaffirm that interpersonal communication still plays a role in shaping how students develop strategies for solving problems.

Building on these previous studies, Most previous studies have been conducted in the context of physics and mathematics education, with very limited research exploring the link between interpersonal communication and problem-solving in chemistry learning. This gap highlights the need to examine how interpersonal communication skills relate to students' problem-solving abilities in chemistry contexts. Therefore, the present study aims to analyze the relationship between interpersonal communication skills and students' problem-solving ability in chemistry learning.

Based on the theoretical framework and previous findings, the hypothesis proposed in this study is that interpersonal communication skills are positively correlated with problem-solving ability, that is, students with higher interpersonal communication competence tend to demonstrate better problem-solving performance in chemistry.

LITERATURE REVIEW

Problem-solving ability

Problem-solving ability is a crucial competency as it enables individuals to face challenges, adapt to change, and generate innovative solutions (Ocak et al., 2022). The Programme for International Student Assessment (PISA) 2003 defines this skill as fundamental for lifelong learning, social participation, and personal activities (OECD, 2004). In the educational context, problem-solving contributes to students' adjustment, enhances learning motivation, and supports mental well-being (de la Fuente et al., 2023). Moreover, it is closely associated with cognitive development, creativity, and flexibility (Dostál, 2015).

In general, problem-solving is considered a complex activity involving cognitive, motivational, and behavioral components (Yuriev et al., 2017). This process encompasses conceptual understanding, problem representation, strategy selection, solution implementation, and reflective evaluation (OECD, 2004). Several models have been developed to guide this process. Polya's model (1973), one of the most frequently applied approaches, comprises four phases: problem comprehension, strategy formulation, execution of the strategy, and reflection on the solution. This model has been frequently applied in mathematics and science education (Akben, 2020). Another framework is the IDEAL model developed by Bransford and Stein (2016), which outlines five stages: identifying the problem, representing the problem, exploring strategies, applying solutions, and evaluating outcomes (Bransford & Stein, 1993). In addition, Krulik

and Rudnick (1988) introduced a heuristic model that highlights five stages: reading to understand the problem, exploring to collect ideas or information, selecting a strategy, solving, and finally, looking back and extending by reviewing results and considering further applications. (Ennis, 1985; Ma et al., 2023). This study measures problem-solving competence based on Polya's (1973) stages, which provide a framework for analyzing students' performance and identifying strengths and weaknesses at each stage of the problem-solving process (Scherer et al., 2014).

Table 1. Problem-solving processes

Polya (1973)	IDEAL (Bransford and Stein, 1984)	Krulik and Rudnick (1988)
1. Comprehend the problem 2. Formulate a solution strategy 3. Implement the chosen strategy 4. Reflect on the outcome	1. Identify problems and opportunities 2. Define the problem clearly 3. Explore alternative strategies 4. Apply the most appropriate strategy 5. Review and evaluate the results	1. Read to grasp the problem 2. Explore ideas or gather relevant information 3. Select an appropriate strategy 4. Solve the problem 5. Look back and extend the solution to broader applications

In chemistry education, problem-solving requires a systematic and reflective approach. Yuriev et al. (2017) developed a scaffolding strategy known as Goldilocks Help (GH), which guides students through five stages: understanding, analysis, planning, implementation, and evaluation. However, many students continue to face difficulties in solving chemistry problems due to challenges such as limited conceptual understanding, misconceptions, reliance on algorithmic procedures, and difficulties in linking mathematical representations with chemical contexts. Other contributing factors include cognitive overload, weak metacognitive skills, low self-confidence, and a tendency to prioritize final answers over the reasoning process itself (Yuriev et al., 2017). Beyond cognitive aspects, problem-solving skills are also significantly shaped by communication abilities, as effective communication enables students to articulate ideas clearly, consider alternative perspectives, and minimize potential conflicts (Han et al., 2019).

Thus, problem-solving represents an essential skill encompassing conceptual understanding, strategic planning, solution implementation, and reflective evaluation. Success in this skill is determined not only by knowledge mastery but also by communication competence, which enhances collaboration and the overall effectiveness of problem resolution, particularly in the context of chemistry learning.

Interpersonal Communication Skills

Interpersonal communication represents a fundamental form of human interaction, as it enables individuals to exchange information, build relationships, resolve conflicts, and strengthen social bonds. This type of communication occurs through both verbal and nonverbal channels, in which each participant simultaneously functions as both sender and receiver of messages. The process is shaped by contextual factors, the medium employed, and potential communication barriers (DeVito, 2022).

According to Gamble and Gamble (2014) and Adler and Proctor (2011), interpersonal communication can be understood from both quantitative and qualitative perspectives. From a quantitative standpoint, it is defined as a two-way interaction that ceases when one party withdraws. From a qualitative perspective, however, interpersonal communication emphasizes relational depth and uniqueness, where distinctive interaction patterns (relational culture) are formed. Effective communication is typically characterized by openness, trust, and supportive verbal and nonverbal expressions. Wood (2010) further argues that interpersonal communication is selective, systemic, unique, and dynamic,

highlighting that it extends beyond mere message exchange to include the co-construction of meaning and the development of emotional closeness within relationships.

Various models have been proposed to capture the dimensions of interpersonal communication. Martin and Rubin (1994) identify ten indicators, including self-disclosure, empathy, social relaxation, assertiveness, altercentrism, interaction management, expressiveness, supportiveness, immediacy, and environmental control. Another framework, developed by Bienvenu and Stewart (1976) outlines eleven dimensions, such as self-disclosure, awareness of self and others, evaluation and acceptance of others, emotional regulation, clarity of messages, avoidance tendencies, dominance, constructive management of differences, and perceived acceptance.

Taken together, these perspectives illustrate that interpersonal communication is a multidimensional skill encompassing cognitive, emotional, and social aspects. In the present study, this construct is operationalized using the indicators proposed by Martin and Rubin (1994).

METHODS

Research Design and Participants

This study employed a quantitative associative research design to investigate the relationship between interpersonal communication competence (independent variable) and problem-solving ability (dependent variable). The participants consisted of 157 eleventh-grade students enrolled in chemistry courses at Labschool Jakarta, Cibubur, and Cirendeu. The sampling technique applied was purposive sampling, ensuring that all participants had completed both the reaction rate and the chemical equilibrium topics.

Instruments

Two main instruments were used in this study: a Multiple-Choice Multiple-Answer (MCMA) test for problem-solving ability and the Interpersonal Communication Competence Scale (ICCS) for interpersonal communication.

Problem-Solving Ability Test

The MCMA instrument measured students' problem-solving ability in the context of reaction rate and chemical equilibrium. Unlike conventional multiple-choice tests, the MCMA format allows multiple correct answers in a single item, encouraging more analytical reasoning.

The test initially consisted of 21 items, of which 17 items were retained after psychometric evaluation. Validity and reliability analyses were conducted using Item Response Theory (IRT) with the Generalized Partial Credit Model (GPCM). The analysis also produced item discrimination and difficulty indices, confirming that the retained items met the recommended criteria. A sample item is presented in Appendix A.

Interpersonal Communication Ability Test

Students' interpersonal communication competence was measured using the Interpersonal Communication Competence Scale (ICCS), adapted from Rubin and Martin (1994). The original 30-item scale was refined to 28 valid items following validity and reliability testing using the Rasch Model with the Rating Scale Model (RSM) approach. The ICCS measures ten dimensions, namely self-disclosure, empathy, social relaxation, assertiveness, altercentrism, interaction management, expressiveness, supportiveness, immediacy, and environmental control. The full instrument blueprint and example items are provided in Appendix B.

Data Analysis

Data were analyzed using Pearson's product–moment correlation to determine the strength and direction of the relationship between interpersonal communication competence and problem-solving ability. The significance level was set at $p < 0.05$ (two-tailed). All statistical analyses were conducted

using SPSS version 25. Through this correlation test, it can be identified whether the relationship between the two variables is positive or negative, as well as the degree of their association. For ease of interpretation, the categories of correlation coefficients are presented in the following table.

Table 2. Correlation Coefficient Categories

Correlation Coefficient Value	Correlation Level
≥ 0.70	Very Strong
0.40 – 0.69	Strong
0.30 – 0.39	Moderate
0.20 – 0.29	Weak
0.01 – 0.19	Very Weak

RESULT AND DISCUSSION

1. Descriptive Statistical Analysis

The descriptive data in this study are presented to provide a general overview of the distribution of respondents' scores. The data were obtained from raw data processing using descriptive statistical techniques, including the mean and standard deviation. Referring to the number of variables examined, the data description is divided into two sections corresponding to the research variables, namely interpersonal communication skills and problem-solving ability, with the descriptive statistical results of each variable presented in the subsequent section.

a.) Problem-Solving Skills

A general description of students' problem-solving ability data is presented in Table 3.

Table 3. Results of problem-solving skills in general

Data	**Result**
Number of Students	157
Top Rated	18
Lowest Value	46
Mean	33.81
Standard Deviation	5.283

As shown in Table 3, students' problem-solving ability scores ranged from 18 to 46, with a mean of 33.81 and a standard deviation of 5.283. When compared to the maximum score, the average represents 73.50% (33.81 ÷ 46 × 100%), which indicates that students generally have moderately good problem-solving skills.

b.) Interpersonal Communication Skills

A general description of students' interpersonal communication skills data is presented in Table 4.

Table 4. Results of interpersonal communication skill in general

Data	Result
Number of Students	157
Top Rated	56
Lowest Value	113
Mean	94.38
Standard Deviation	8.131

As shown in Table 4, students' interpersonal communication scores ranged from 56 to 113, with a mean of 94.38 and a standard deviation of 8.131. When compared to the maximum score, the mean represents 83.54% (94.38 ÷ 113 × 100%), indicating that, overall, students demonstrate good interpersonal communication skills.

2. Inferential Statistical Analysis

a) Normality Test

The normality test was conducted to determine whether the research data followed a normal distribution. In this study, the Kolmogorov–Smirnov test was applied with a 5% significance level ($\alpha = 0.05$). The decision criterion was that if the significance value (p) was greater than 0.05, the data were considered normally distributed; otherwise, they were not.

Table 5. Result of the normality test

	Sig.	Conclusion
Data Normality Test	0.200	Normal

As shown in Table 5, the Kolmogorov–Smirnov test yielded a significance value (Asymp. Sig. 2-tailed) of 0.200, which is greater than the threshold of 0.05. This indicates that the data are normally distributed, thereby satisfying the assumption of normality. Consequently, the data were deemed appropriate for further analysis using parametric statistical techniques, specifically the Pearson correlation test employed in this study.

b) Linearity Test

The linearity test was conducted to determine whether the relationship between the variables followed a linear pattern. This analysis was performed using IBM SPSS Statistics 25. A relationship is considered linear if the significance value for the Deviation from Linearity exceeds 0.05.

Table 6. Result of the linearity test

Variable Relationship	F	Sig.	Conclusion
Interpersonal Communication Skills (X) and Problem-Solving Ability (Y)	0.685	0.847	Linear

As shown in Table 6, the linearity test between interpersonal communication skills (X) and problem-solving ability (Y) produced a significance value (Sig.) of 0.847. Since this value is greater than 0.05, it indicates no significant deviation from linearity. Therefore, the relationship between the two variables can be considered linear, satisfying one of the assumptions required for applying Pearson's product–moment correlation analysis in this study.

c) Test The Hypothesis

After confirming the assumptions of normality and linearity, the research hypothesis was tested using the Pearson product–moment correlation analysis. The results are summarized in Table 7.

Table 7. Correlation between Interpersonal Communication and Problem-Solving

Correlations

		Interpersonal Communication	Problem-Solving
Interpersonal Communication	Pearson Correlation	1	0.294
	Sig. (2-tailed)		0.000
	N	157	157
Problem-Solving	Pearson Correlation	0.294	1
	Sig. (2-tailed)	0.000	
	N	157	157

As shown in Table 7, the Pearson correlation coefficient between interpersonal communication skills and problem-solving ability was 0.294, with a significance value of 0.000 (< 0.05). These results indicate a significant positive correlation between the two variables. The correlation coefficient of 0.294 falls within the weak category (0.20–0.29), suggesting that the relationship between interpersonal communication skills and problem-solving ability is statistically significant, although the strength of the relationship is relatively low.

DISCUSSION

The primary objective of this study was to examine the relationship between interpersonal communication skills and problem-solving ability among students in the context of chemistry learning. The Pearson correlation analysis revealed a coefficient of 0.294 with a p-value of 0.000 (< 0.05), indicating a statistically significant positive relationship. This finding implies that students who demonstrate stronger interpersonal communication skills tend to achieve better performance in solving chemistry problems.

However, the correlation coefficient of 0.294 indicates that the strength of this

relationship is relatively weak. This suggests that while interpersonal communication contributes to students' problem-solving ability, its influence is limited. These results are consistent with Minarsi et al. (2018), who found that interpersonal communication had a positive yet modest contribution to problem-solving, reflected by a regression coefficient of 0.136 and a contribution value of only 1.8%. Despite its small effect size, interpersonal communication remains an essential component of effective learning interactions.

Minarsi et al. (2018) further noted that interpersonal communication supports students in determining appropriate problem-solving strategies. This view aligns with Lazarus and Folkman's (1987) theory, which highlights that social competence, including the ability to communicate and interact effectively, can facilitate collaborative problem-solving (Huang & Lajoie, 2023) enhance emotional regulation and promote adaptive coping. Within the context of chemistry learning, students who can express ideas clearly, negotiate meanings, and discuss alternative solutions are more likely to organize and plan their problem-solving strategies effectively.

Nevertheless, the weak correlation suggests that problem-solving ability in chemistry is influenced by multiple factors beyond interpersonal communication. Other determinants, such as critical thinking skills (Kaya, 2024; Paul & Elder, 2008; Prakong, 2024) conceptual understanding (Bodner & Herron, 2003), learning motivation ((Chen et al., 2020), metacognitive skills (Azizah et al., 2019; Güner & Erbay, 2021), and instructional strategies (Malangtupthong et al., 2022) also play significant roles. This finding supports Gurat (2018), who emphasized that effective problem solvers must integrate diverse cognitive and social skills to tackle complex chemistry problems successfully.

CONCLUSION

This study concludes that interpersonal communication skills have a positive and significant relationship with students' problem-solving ability, as indicated by a Pearson correlation coefficient of 0.293 and a significance value of 0.000 (< 0.05). Although the relationship is statistically significant, its weak strength suggests that interpersonal communication contributes only modestly to students' performance in solving problems. These findings are consistent with previous research indicating that interpersonal communication exerts a supportive but non-dominant influence on problem-solving.

It can be inferred that students' problem-solving ability in chemistry is more strongly influenced by other key factors, including critical thinking, conceptual understanding, learning motivation, and metacognitive competence. Therefore, the development of problem-solving skills should be approached holistically through learning designs that not only foster effective social interaction but also strengthen students' cognitive and metacognitive dimensions in an integrated manner.

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REFERENCE

Adler, R. B., & Proctur II, R. F. (2011). *Looking Out, Looking in* (13th ed.). Cengage Learning.

Akben, N. (2020). Effects of the Problem-Posing Approach on Students' Problem Solving Skills and Metacognitive Awareness in Science Education. *Research in Science Education*, *50*(3), 1143–1165. https://doi.org/10.1007/s11165-018-9726-7

Al-thani, N. J., Siby, N., Saad, A., Bhadra, J., Qahtani, N., Sellami, A., & Ahmad, Z. (2025). Meta-analysis of chemistry-based interdisciplinary informal research experience program for high school students. *Evaluation and Program Planning*, *108*. https://doi.org/10.1016/j.evalprogplan.2024.102517

Ariawan, R., & Nufus, H. (2017). Hubungan Kemampuan Pemecahan Masalah Matematis dengan kemampuan Komunikasi Matematis Siswa. *Jurnal THEOREMS (The Original Research of Mathematics)*, *1*(2), 82–91.

Azizah, U., Nasrudin, H., & Mitarlis. (2019). Metacognitive Skills: A Solution in Chemistry Problem Solving. *Journal of Physics: Conference Series*, *1417*(1). https://doi.org/10.1088/1742-6596/1417/1/012084

Bienvenu, M. J., & Stewart, D. W. (1976). Dimensions of interpersonal communication. *Journal of Psychology: Interdisciplinary and Applied*, *93*(1), 105–111. https://doi.org/10.1080/00223980.1976.9921380

Bodner, G. M., & Herron, J. D. (2003). Problem-Solving in Chemistry. In J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust, & J. H. Van Driel (Eds.), *Chemical Education: Towards Research-based Practice* (pp. 235–266). Springer Netherlands. https://doi.org/10.1007/0-306-47977-X_11

Bransford, J. D., & Stein, B. S. (1993). *The IDEAL Problem Solver: A Guide for Improving Thinking, Learning and Creativity.* W. H. Freeman and Company.

Chen, L., Inoue, K., Goda, Y., Okubo, F., Taniguchi, Y., Oi, M., Konomi, S., Ogata, H., & Yamada, M. (2020). Exploring Factors that Influence Collaborative Problem Solving Awareness in Science Education. *Technology, Knowledge and Learning*, *25*(2), 337–366. https://doi.org/10.1007/s10758-020-09436-8

Crawford, G. L., Kloepper, K. D., Meyers, J. J., & Singiser, R. H. (2019). Communicating Chemistry: An Introduction. In *ACS Symposium Series* (Vol. 1327, pp. 1–15). American Chemical Society. https://doi.org/10.1021/bk-2019-1327.ch001

de la Fuente, A., Cardeñoso, O., Chang, E. C., Lucas, A. G., Li, M., & Chang, O. D. (2023). The role of problem-solving ability, beyond academic motivation, in college students' psychological adjustment. *Current Psychology*, *42*(21), 17888–17897. https://doi.org/10.1007/s12144-022-02945-y

DeVito, J. A. . (2022). *The interpersonal communication book* (16th ed.). Pearson Education.

Dostál, J. (2015). Theory of Problem Solving. *Procedia - Social and Behavioral Sciences*, *174*, 2798–2805. https://doi.org/10.1016/j.sbspro.2015.01.970

Ennis, R. H. (1985). A Logical Basis for Measuring Critical Thinking Skills. Educational Leadership. *Educational Leadership*, *43*(2), 44–48.

Febriyanti, A., & Ananda Ismail, I. (2022). The Role of Interpersonal Communication Between Teachers and Students to Improve the Success of the Learning Process. *International Journal of Progressive Sciences and Technologies (IJPSAT*,

30(2), 37–41. https://doi.org/10.52155/ijpsat.v30.2.3974

Gabel, D. (1999). Improving Teaching and Learning through Chemistry Education Research: A Look to the Future*. In *Research: Science and Education 548 Journal of Chemical Education* • (Vol. 76, Issue 4).

Gamble, T. K., & Gamble, M. W. (2014). *Interpersonal Communication: Building Connections Together*. SAGE Publications, Inc.

Govindaraju, V., & Seruji, Z. (2022). Interpersonal Communication and Relationship: A Conceptual Review between Educators and Undergraduate Students. *Multicultural Education*, *8*(6), 30–37. https://doi.org/10.5281/zenodo.6618219

Güner, P., & Erbay, H. N. (2021). Metacognitive Skills and Problem-Solving. *International Journal of Research in Education and Science*, *7*(3), 715–734. https://doi.org/10.46328/ijres.1594

Gurat, M. G. (2018). Mathematical problem-solving strategies among student teachers. *Journal on Efficiency and Responsibility in Education and Science*, *11*(3), 53–64. https://doi.org/10.7160/eriesj.2018.110302

Han, J.-H., Ahn, E., & Hwang, J.-M. (2019). Effects of Critical Thinking and Communication Skills on the Problem-Solving Ability of Dental Hygiene Students. *Journal of Dental Hygiene Science*, *19*(1), 31–38. https://doi.org/10.17135/jdhs.2019.19.1.31

Huang, X., & Lajoie, S. P. (2023). Social emotional interaction in collaborative learning: Why it matters and how can we measure it? In *Social Sciences and Humanities Open* (Vol. 7, Issue 1). Elsevier Ltd. https://doi.org/10.1016/j.ssaho.2023.100447

Kaya, S. (2024). One intervention, several benefits: Deliberate computer-assisted argument mapping practices in an online teacher education course. *Journal of Computer Assisted Learning*, *40*(6), 3230–3248. https://doi.org/10.1111/jcal.13067

Krulik, Stephen., & Rudnick, J. A. . (1988). *Problem solving : a handbook for elementary school teachers*. Allyn and Bacon.

Kurniawati, Y., Mayshinta, I., & Yenti, E. (2023). *Identifikasi Kesulitan Materi Kimia Bagi Siswa SMA: Kajian Literatur*. 23–27. https://doi.org/10.36378/prosidinguniks.v0i0

Lazarus, R. S., & Folkman, S. (1987). Transactional theory and research on emotions and coping. In *European Journal of Personality* (Vol. 1).

Ma, X., Yin, Z., & and Luo, X. (2023). Students' and teachers' critical thinking in science education: are they related to each other and with physics achievement? *Research in Science & Technological Education*, *41*(2), 734–758. https://doi.org/10.1080/02635143.2021.1944078

Makiyah, Y. S., Mahmudah, I. R., Sulistyaningsih, D., & Susanti, E. (2021). Hubungan Keterampilan Komunikasi Abad 21 dan Keterampilan Pemecahan Masalah Mahasiswa Pendidikan Fisika. *Journal of Teaching and Learning Physics*, *6*(1), 1–10. https://doi.org/10.15575/jotalp.v6i1.9412

Malangtupthong, P., Nurittamont, W., & Phayaphrom, B. (2022). Factors

Influencing Mathematical Problem-Solving Competency: A Case Study On High School Student. *Article in PSAKU International Journal of Interdisciplinary Research*, *11*(2), 1–18. https://doi.org/10.14456/psakuijir.2022.6

Malinda Wilson, L. G. (2015). The Importance of Critical Thinking, Verbal Reasoning and Mathematics in Teaching Chemistry in the 21st Century. *Modern Chemistry & Applications*, *03*(03). https://doi.org/10.4172/2329-6798.1000e121

Martin, M., & Rubin, R. (1994). Development of a Measure of Interpersonal Communication Competence. *Communication Research Reports*, *11*(1), 33–44. https://doi.org/10.1080/08824099409359938

Minarsi, M., Nirwana, H., & Yarmis, Y. (2018). *Contribution of the interpersonal communication toward problem solving strategies of high school students*. 80–85. https://doi.org/10.29210/2018112

National Research Council. (2013). *Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. The National Academies Press. https://doi.org/https://doi.org/10.17226/13165

Ocak, G., Dogruel, A. B., & Tepe, M. E. (2022). An Analysis of the Relationship between Problem Solving Skills and Scientific Attitudes of Secondary School Students. *International Journal of Contemporary Educational Research*, *8*(1), 72–83. https://doi.org/10.33200/ijcer.780710

OECD. (2004). *The PISA 2003 Assesment Framework: Mathematics, Reading, Science and Problem Solving Knowledge and Skills*. https://doi.org/https://doi.org/10.1787/9789264101739-en.

OECD. (2023). *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*. https://oecdch.art/a40de1dbaf/C108.

OECD. (2024). *PISA 2022 Results Volume III: Creative Minds, Creative Schools*. https://doi.org/https://doi.org/10.1787/765ee8c2-en.

Paul, R., & Elder, L. (2008). *Paul, R., & Elder, L. (2008). The Miniature Guide to Critical Thinking: Concepts and Tools. Foundation for Critical Thinking.* www.criticalthinking.org

Polya, G. (1973). *How to solve it: A New Aspect of Mathematical Method* (2nd ed.). Princeton University Press.

PRAKONG, S. (2024). The Role of Critical Thinking in Enhancing Students' Problem-Solving Abilities in Higher Education. *Journal of Education, Humanities, and Social Research*, *1*(1), 10–16. https://doi.org/10.70088/scx8x622

Safitri, N. C., Nursaadah, E., & Wijayanti, I. E. (2019). Analisis Multipel Representasi Kimia Siswa pada Konsep Laju Reaksi. *EduChemia (Jurnal Kimia Dan Pendidikan)*, *4*(1), 1. https://doi.org/10.30870/educhemia.v4i1.5023

Scherer, R., Meßinger-Koppelt, J., & Tiemann, R. (2014). Developing a computer-based assessment of complex problem solving in Chemistry. *International Journal of STEM Education*, *1*(1).

https://doi.org/10.1186/2196-7822-1-2

Sevian, H., & Talanquer, V. (2014). Rethinking chemistry: A learning progression on chemical thinking. In *Chemistry Education Research and Practice* (Vol. 15, Issue 1, pp. 10–23). https://doi.org/10.1039/c3rp00111c

Turiman, P., Omar, J., Daud, A. M., & Osman, K. (2012). Fostering the 21st Century Skills through Scientific Literacy and Science Process Skills. *Procedia - Social and Behavioral Sciences*, *59*, 110–116. https://doi.org/10.1016/j.sbspro.2012.09.253

Venable, G. T., Shepherd, B. A., Loftis, C. M., McClatchy, S. G., Roberts, M. L., Fillinger, M. E., Tansey, J. B., & Klimo, P. (2016). Bradford's law: Identification of the core journals for neurosurgery and its subspecialties. In *Journal of Neurosurgery* (Vol. 124, Issue 2, pp. 569–579). American Association of Neurological Surgeons. https://doi.org/10.3171/2015.3.JNS15149

Wood, J. T. (2010). *Interpersonal Communication: Everyday Encounters*. Cengage Learning.

World Economic Forum. (2025). *The Future of Jobs Report 2025*. https://www.weforum.org/publications/the-future-of-jobs-report-2025/

Yuriev, E., Naidu, S., Schembri, L. S., & Short, J. L. (2017). Scaffolding the development of problem-solving skills in chemistry: Guiding novice students out of dead ends and false starts. *Chemistry Education Research and Practice*, *18*(3), 486–504. https://doi.org/10.1039/c7rp00009j