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Unveiling the Correlation between Metacognitive Skills, Argumentation Skills, and Problem-Solving Ability in the Realm of Biology Education

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ABSTRACT

Metacognition refers to the capacity for supervising, arranging, and directing the process of learning, while argumentation skills encompass the aptitude to construct and validate logical points. Proficiency in problem-solving holds a crucial role within the realm of scientific education. This research aims to explore the interconnection between metacognitive skills, argumentation skills, and problem-solving abilities in the domain of biology education. Employing a correlational research design, the investigation encompassed 118 students engaged in biology studies within the University of Jember's Biology Education Study Program during the academic term of 2022/2023, specifically within the Introduction to Education Science course. The research instrument utilized was a survey featuring 10 queries for each category—metacognitive skills, argumentation skills, and problem-solving abilities. Statistical analysis involved inferential methods, particularly multiple linear regression correlation. The findings unveiled a positive correlation between students' metacognitive skills and argumentation skills and their adeptness in problem-solving within the context of biology learning, signified by a noteworthy p-value of 0.000 ($p < 0.05$). This finding shows the importance of developing metacognitive skills and argumentation skills in improving students' problem solving abilities in learning. The implication of this finding can be used to design more effective learning strategies in improving metacognitive skills, argumentation skills and students' problem solving in biology subjects.

Introduction

Education has a central role in developing students' skills to understand complex concepts and face challenges in the modern knowledge-based world (Darling-Hammond et al., 2020). In the context of biology learning, students are challenged to not only understand scientific facts, but also to develop thinking skills such as critical thinking, creative thinking, argumentation skills, and problem solving (Keiler, 2018; Tasquier et al., 2022). Metacognitive skills, argumentation skills, and problem-solving abilities are considered as three key aspects in the learning process that encourage students to become independent learners and think reflectively (Markula & Aksela, 2022).

Metacognitive skills refer to students' awareness of their own thinking processes, as well as skills to plan, monitor, and organize learning strategies (Marantika, 2021). In the context of biology learning,

metacognitive skills allow students to identify their lack of understanding and take steps to improve it (Dye & Stanton, 2017). Metacognitive skills have a good impact on students during learning and in their daily lives (Hartman, 2001).

Metacognitive skills help students recognize the most suitable learning methods for themselves. They can identify effective learning strategies to deal with difficult material and maximize their understanding (Saleh et al., 2023). With metacognitive skills, students can plan their study time more effectively (Abdelrahman, 2020). They can identify the best time to understand certain material, avoid procrastination, and avoid stress caused by tasks that must be completed at the last minute (Innovation, 2016). Students who have good metacognitive skills tend to have stronger problem-solving abilities. They are able to solve problems more efficiently because they are able to plan solution steps, monitor progress, and evaluate the results (Lodge et al., 2018).

In addition, metacognitive skills allow students to look into themselves more deeply. They can recognize their strengths and weaknesses in learning, so they can work on aspects that need to be improved (Hartman, 2001). Students with good metacognitive skills are more likely to be independent learners. They are able to manage their own learning without relying on external instructions, because they can plan and organize the learning process effectively (Marantika, 2021). Thus, metacognitive skills are directly related to academic achievement. Students who are able to understand the most effective ways to study, manage time well, and have strong problem-solving abilities tend to achieve better results in exams and assignments (Azis, 2019).

In addition to metacognitive skills, one's skills in argumentation are also considered important. This relates to a person's ability to express an opinion. Argumentation skills encompass the aptitude to construct and substantiate arguments by utilizing pertinent substantiation and coherent rationale (Widodo et al., 2016). Within a scientific framework, the proficiency in argumentation is of great import since students must be capable of articulating their viewpoints appropriately and persuasively within scientific discourse settings (Rahayu et al., 2022).

These competencies prompt students to engage in critical contemplation of incoming information. To erect robust arguments, they must possess the capacity to scrutinize evidence, pinpoint vulnerabilities in counterarguments, and forge robust logical frameworks. For the construction of compelling arguments, students must command an in-depth grasp of the subject matter under consideration. This, in turn, spurs them to conduct more comprehensive explorations of concepts and to establish superior interconnections between data fragments. Students adept in argumentation can lucidly and convincingly convey their perspectives—a skill of significance in presentations, classroom dialogues, and general communication.

Comprising elements of eloquent speech and adept writing, argumentation proficiencies require cultivation. Verbal skills are honed through active involvement in classroom dialogues and presentations (Majidi et al., 2021). Similarly, writing proficiencies are enriched as students systematically arrange arguments within written compositions (Songsil et al., 2019). Engagement in argumentation exercises acquaints students with a diverse array of viewpoints and contentions from peers. This, in turn, can foster a more profound comprehension of differing stances and expand their receptivity to a myriad of perspectives (Songsil et al., 2019; Songsil & Faikhamta, 2017). The utility of argumentation skills extends to the professional realm, wherein adept arguers possess an edge in workplaces that mandate eloquent speech and public speaking talents (Bathgate et al., 2015; Hasnunidah et al., 2023).

One of the proficiencies imperative for success within the professional sphere is the ability to navigate challenges through problem-solving. Problem-solving abilities encompasses the skills required to discern issues, formulate strategies for resolution, and assess the viability of suggested remedies (Md, 2019). In the context of biology education, this capability facilitates the bridging of theoretical abstractions with

real-world scenarios (Hoskinson et al., 2013).

In educational settings, students routinely encounter assorted tasks and obstacles necessitating the application of problem-solving abilities. This dexterity empowers them to surmount problems, grasp intricate concepts, and surmount obstacles to learning (Lodge et al., 2018). Problem-solving often necessitates the application of imaginative thinking to devise innovative solutions. Those well-versed in problem-solving tend to exhibit greater creativity in identifying unorthodox remedies (Series, 2021). Problem solving ability is a skill that can be applied in various aspects of life. From solving everyday problems to making complex decisions, students with strong problem solving skills can face various situations with more confidence (Ismet et al., 2021). Students with good problem-solving abilities are able to identify obstacles in their learning process and formulate strategies to overcome these difficulties. This can improve their overall learning efficiency (Haleem et al., 2022; Juandi & Review, 2023).

Although these three skills are considered important, in-depth research on the relationship between metacognitive skills, argumentation skills, and problem-solving ability in the context of biology learning is limited. Some studies related to metacognitive skills with problem solving for example by (Budayasa, 2018; Erbay, 2021; Fazilla, 2022; Güner & Metacognitive, 2021; Lestari et al., 2018) and argumentation skills with problem solving for example by (Alberida et al., 2022; Cho & Jonassen, 2002; Fatmawati et al., 2019; Jumadi et al., 2021; Kundariati et al., 2022; Kurniawan & Triani, 2022; Mcghee, 2015). Therefore, this study aims to explore the relationship between these three aspects with a focus on biology learning in higher education. By understanding this relationship, we can identify how the development of metacognitive skills can support the development of argumentation and problem-solving abilities, and inform the design of more effective learning strategies to be implemented in the classroom.

This study aims to offer enhanced comprehension regarding the significance of nurturing these three proficiencies within the framework of biology education. Additionally, it seeks to furnish educators with pragmatic recommendations for crafting pedagogical approaches that foster comprehensive growth among students within the realm of science

Method

This research employed a correlational methodology to examine the interconnection among metacognitive skills, argumentation skills, and problem-solving abilities within the domain of biology education. The utilization of the correlational approach aims to ascertain whether a noteworthy connection exists between the variables under scrutiny, devoid of any external manipulation by the researcher. The study encompasses three distinct variables, namely metacognitive skills (X1) and argumentation skills (X2) as independent factors, while problem-solving (Y2) serves as the dependent element. The visual representation of the research framework is depicted in Figure 1.

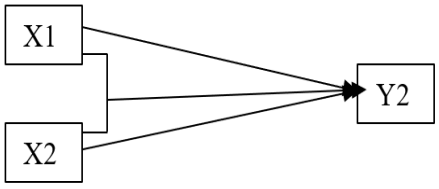

Figure 1. Correlational Research Design

The entire student body enrolled in the Biology Education program at FKIP UNEJ constituted the target population for this research. The selected subset of participants consisted of 4th Semester Biology Education students who were enrolled in the Biology Learning Media course during the academic period of 2022/2023.

To assess students' metacognitive skills, argumentation skills, and problem-solving abilities, this study employed open-ended essay inquiries. Each essay question, totaling 10 in number, correspondingly encapsulated distinct indicators pertaining to the variables under assessment. The essay test for Metacognitive Skills was developed to measure students' awareness of their thinking process and is measured by the way they answer questions.

The Argumentation skills test is a written test designed to measure students' skills in constructing logical arguments, presenting relevant evidence, and using appropriate reasoning. The Problem solving abilities test was developed to measure students' skills in identifying complex problems, formulating solution steps, and evaluating alternative solutions. The questions were arranged in the form of essay tests classified in the level of Blooms taxonomy which levels critical thinking skills, namely groups C4 to C6. Before the research instrument was used, validity and reliability tests were carried out first using the level of 0.05 and reliability testing using Cronbach's Alpha and content validation of questions validated by material experts.

Data analysis was carried out with the help of SPSS version 23.0. Data obtained from questionnaires and essay tests were processed using multiple linear regression correlation statistical analysis to reveal the relationship between metacognitive skills and argumentation skills with students' problem solving ability. a multiple regression correlation test was conducted with alpha = 0.05, and the correlation test used Pearson Product Moment ($\alpha = 0.05$) to determine the correlation level.

Results and Discussion

This study aims to reveal the relationship between metacognitive skills, and argumentation skills with problem solving abilities in biology learning. The results of Pearson correlation analysis showed a significant positive correlation between metacognitive skills, argumentation skills and problem solving abilities in biology learning. The correlation between metacognitive skills, argumentation skills and problem solving ability is 0.00 ($p < 0.05$), indicating that students who have better metacognitive skills and argumentation skills tend to have better problem solving abilities as well. In order to gauge the predictive capacity of metacognitive skills and argumentation skills in relation to problem-solving abilities, a regression analysis was carried out. The findings stemming from this analysis indicate a meaningful predictive relationship between metacognitive skills and argumentation skills concerning problem-solving ability ($\beta = 0.00$, $p < 0.05$). Further analysis results are presented in Table 1 - Table 4.

Table 1. Correlation of metacognitive skills, argumentation skills with problem solving ability

Correlations

		Problem-Solving	Metacognitive	Argumentation
Pearson Correlation	Problem-Solving	1.000	.716	.090
	Metacognitive	.716	1.000	.307
	Argumentation	.090	.307	1.000
Sig. (1-tailed)	Problem-Solving	.	.000	.167
	Metacognitive	.000	.	.000
	Argumentation	.167	.000	.
N	Problem-Solving	118	118	118
	Metacognitive	118	118	118
	Argumentation	118	118	118

Table 1 shows the results of a Pearson correlation analysis to identify the relationship between metacognitive skills, argumentation skills, and problem-solving ability. These results provide important insights into how these skills are interconnected. Below is a detailed analysis of the research findings: The strong positive correlation ($r = 0.716$) indicates that metacognitive skills play an important role in supporting problem-solving ability. This finding is consistent with previous studies stating that metacognitive abilities, such as planning, monitoring, and evaluation, help individuals effectively overcome challenges (Flavell, 1979; Schraw & Dennison, 1994).

The significance value (p = 0.000) shows that this relationship is statistically significant. Additionally, recent research by Damayanti et al. (2021) and Santoso et al. (2021) emphasized the importance of developing metacognitive skills in problem-solving contexts, particularly in the learning environment.

The correlation value (r = 0.090) indicates a very weak positive relationship between problem-solving ability and argumentation skills. This result is not statistically significant (p = 0.167), suggesting that argumentation skills do not directly influence problem-solving ability. This may be due to the lack of integration between argumentation practice and complex problem-solving situations (Kuhn, 1991). The findings of Damayanti et al. (2021) further support the idea that while metacognitive abilities are crucial for problem-solving, argumentation skills alone may not directly influence this process.

A weak positive correlation (r = 0.307) with statistical significance (p = 0.000) suggests that metacognitive skills have a significant relationship with argumentation skills. Individuals who are able to reflect on and regulate their thinking processes tend to be more skilled in constructing logical and coherent arguments. This aligns with research emphasizing the importance of metacognitive awareness in developing critical thinking and argumentation skills (Chinn & Anderson, 1998). Moreover, Santoso et al. (2021) highlighted that enhancing metacognitive awareness is essential in fostering effective argumentation skills in students. The analysis involved 118 participants, which is a sufficient sample size to produce reliable results in social research. The findings of this study emphasize the importance of metacognitive skills in supporting problem-solving ability and argumentation skills. However, argumentation skills did not show a significant relationship with problem-solving ability in this context. Future research could explore other factors that may mediate this relationship, such as the learning context or teaching strategies used.

Table 2. Coefficient of Determination of metacognitive skills, argumentation skills with problem solving ability

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.729a	.532	.524	5.94499

a. Predictors: (Constant), Argumentation, Metacognitive

Based on Table 2. The Coefficient of Determination (R-Square) on Metacognitive and Argumentation variables is 0.532, this shows that all independent variables simultaneously have a contribution of 53.2% to Problem-Solving (dependent variable). While the remaining 46.8% is influenced by other variables not tested in this study.

Table 3. Relationship between metacognitive skills, argumentation skills with problem solving ability

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4616.525	2	2308.262	65.311	.000b
	Residual	4064.433	115	35.343		
	Total	8680.958	117			

a. Dependent Variable: Problem-Solving

b. Predictors: (Constant), Argumentation, Metacognitive

Based on Table 3. the probability value (p-value) is 0.000, thus the value is <0.05, it can be said that there is a significant relationship between metacognitive skills, argumentation skills and problem solving ability.

Table 4. Multiple Linear Regression Test Results between Metacognitive skills, argumentation skills with problem solving ability

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	37.620	5.341		7.044	.000
	Metacognitive	.654	.058	.760	11.342	.000
	Argumentation	-.125	.058	-.144	-2.146	.034

a. Dependent Variable: problem-solving

The multiple linear regression equation of the variables measured in this study is Y = 0.654X1 - 0.125X2 + 37.620. From the results of this analysis it can be concluded that the effective contribution of each predictor variable is 53.2% with an effective contribution of metacognitive skills of 51.91% and a contribution of argumentation skills of 1.29% to problem solving ability. For the relative contribution of each predictor variable is 97.6% for metacognitive skills and 2.4% for argumentation skills to student problem solving skills. A summary of each contribution can be seen in Table 5.

Table 5. Contribution of each research variable

No	Variable	Effective Contribution (%)	Relative Contribution (%)
1	Metacognitive Skills	51,91	97,6
2	Argumentation Skills	1,29	2,4
Total		53,2	100

The main finding of this study is that there is a positive and significant relationship between metacognitive skills and argumentation skills with students' problem solving ability. The correlation analysis results show that students who have better metacognitive skills and high argumentation skills will tend to have better problem solving abilities as well. This correlation suggests that students' awareness of their learning processes, such as planning learning strategies and organizing understanding, can influence the extent to which they are able to construct coherent and effective arguments and solve scientific problems.

The results of the regression correlation analysis also support these findings by showing that metacognitive skills and argumentation skills and can be used as significant predictors for problem-solving ability. That is, the higher one's metacognitive skills and argumentation skills, the better they are at forming logical arguments and solving problems in the context of biology learning. This is in line with the research of Mcghee, 2015; Lestari et al., 2018; Budayasa, 2018; Fatmawati et al., 2019; Erbay, 2021; Güner & Metacognitive, 2021; Jumadi et al., 2021; Alberida et al., 2022; Kundariati et al., 2022; Kurniawan & Triani, 2022; and Fazilla, 2022; .

In this study, it was conducted in the Introduction to Education Science course. The Introduction to Education Science course is suitable for use in improving metacognitive skills and argumentation skills because this course specifically discusses the basics of education, including how humans learn, teach, and think about the teaching-learning process. The Introduction to Education Science course uses a problem-based learning approach. It prompts students to formulate and address issues pertinent to their learning environment. This procedure entails employing argumentation skills to express their thought processes and substantiate their chosen learning approaches (Alberida et al., 2022).

These findings carry significant implications within the sphere of biology education. Educators can leverage the outcomes of this study to formulate more efficacious pedagogical strategies for implementation during learning endeavors. By nurturing and cultivating students' metacognitive skills, educators can aid them in evolving into more autonomous and introspective learners. This heightened understanding of their learning methods and the adeptness to devise effective learning methodologies enhances their capacity to foster problem-solving abilities (Marantika, 2021). Metacognitive proficiencies encompass comprehending how one assimilates information and concepts. By discerning their own cognitive inclinations, individuals can identify their cognitive preferences, whether inclined toward visualizing, drawing analogies, or

other strategies (Susilo, 2022). This can substantively contribute to problem-solving by permitting individuals to adopt the most fitting approach for comprehending and tackling the issue at hand (Karlen et al., 2023). Metacognitive capabilities enable individuals to acknowledge the confines of their knowledge. This implies a greater willingness to seek additional information or counsel from external sources when their own knowledge appears inadequate for addressing a specific problem (Darling-Hammond et al., 2020).

Similar principles extend to argumentation skills. Proficiency in argumentation streamlines the process of presenting ideas and fostering innovative problem-solving abilities. Competent argumentation skills encompass the aptitude to delineate arguments meticulously, identify premises and conclusions, and critically assess the merits and shortcomings of each argument (Putri et al., 2021). Transferring these competencies to problem-solving entails encouraging individuals to undertake more comprehensive problem analyses, identifying constituent factors, and elaborating on relevant aspects to identify effective solutions (Purwati & Prasetyanti, 2019). In the realm of argumentation, individuals must locate pertinent information to underpin their arguments (Hasnunidah et al., 2015). This ability also extends to problem-solving, where individuals must possess the facility to seek requisite information to fathom the core issue and evaluate available solution avenues.

The Introduction to Education Science course frequently encompasses classroom dialogues and deliberative exercises on educational themes. These activities offer students opportunities to refine their argumentation skills, pose probing inquiries, and buttress their viewpoints with substantiation and analysis. Proficiency in argumentation not only refines communication and negotiation abilities but also bolsters teamwork aptitudes, facilitating collaborative problem-solving and fostering agreements that yield mutual benefits (Shinta, 2020). This course often acquaints students with diverse educational theories and methodologies, fostering an inclination to comprehend and scrutinize multiple perspectives—integral to adept argumentation skills (John Butterworth & Thwaites, 2013).

Furthermore, the findings from this study underscore the necessity for a more robust integration of learning facets. In the realm of biology, educators can design activities that stimulate students to cultivate metacognitive and argumentation skills, fostering their problem-solving abilities within the context of biology education. This approach illuminates the interconnectedness and mutually reinforcing nature of these three dimensions within the learning process, potentially elevating the efficacy of their educational endeavors.

Conclusion

Within the context of biology education, particularly within introductory courses in educational science, this study offers significant insights into the relevance of metacognitive and argumentation skills in relation to students' problem-solving proficiencies. The outcomes underscore the necessity for educators to craft pedagogical strategies that foster a comprehensive growth in students, encompassing the development of metacognitive and argumentation skills, which hold pivotal roles within skill-oriented learning environments. In subsequent research endeavors, it would be worthwhile to explore the evolution of metacognitive, argumentation, and problem-solving skills across a temporal continuum. Additionally, further investigations could delve into other variables that potentially impact the interplay among these three skills, such as students' motivational factors, the learning milieu, or their preferred learning approaches.

References

Abdelrahman, R. M. (2020). Metacognitive awareness and academic motivation and their impact on academic achievement of Ajman University students. *Heliyon*, *6*(9), e04192. https://doi.org/10.1016/j.heliyon.2020.e04192

Alberida, H., Sari, M., Razak, A., & Rahmi, Y. L. (2022). *Problem Solving : A Learning Model to Foster Argumentation and Critical Thinking Ability for Students with Different Academic Abilities*. *8*(3). https://doi.org/10.29303/jppipa.v8i3.1208

Alkandrie, R. P., & Mirza, A. (2017). Faktor-faktor yang Mempengaruhi Level Metakognisi dalam Pemecahan Masalah Pentidaksamaan Kuadrat di SMA. *Jurnal Pendidikan dan Pembelajaran Khatulistiwa, 4*(12). https://doi.org/10.26418/jpk.v4i12.30004

Azis, N. I. (2019). *the Implementation of Metacognitive Strategies in Teaching Speaking in Indonesian Efl Classroom*. 1–18.

Bensley, D.A., & Spero, R.A. (2014). Improving critical thinking skills and metacognitive monitoring through direct infusion. *Thinking Skills and Creativity, 12*, 55-68. https://doi.org/10.1016/j.tsc.2013.10.001

Bathgate, M., Crowell, A., Schunn, C., Cannady, M., & Dorph, R. (2015). The Learning Benefits of Being Willing and Able to Engage in Scientific Argumentation. *International Journal of Science Education*, *37*(10), 1590–1612. https://doi.org/10.1080/09500693.2015.1045958

Budayasa, I. K. (2018). *The influence of metacognition in mathematical problem solving The influence of metacognition in mathematical problem solving*.

Chinn, C. A., & Anderson, R. C. (1998). The structure of discussions that promote reasoning. *Teachers College Record, 100*(2), 315-368. https://doi.org/10.1177/016146819810000204

Cho, K., & Jonassen, D. H. (2002). *The Effects of Argumentation Scaffolds on Argumentation and Problem Solving*. *50*(3), 5–22.

Damayanti, B. P., Nur'Aini, A., Wulandari, K. F. N., & Primandiri, P. R. (2021). The Importance of Developing Students' Metacognitive Ability in Class XI MIPA during Biology Learning at SMAN 1 Sidoarjo. *Jurnal Pendidikan Biologi, 12*(1), 45-56. https://doi.org/10.12928/jpb.v12i1.10425

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Dye, K. M., & Stanton, J. D. (2017). Metacognition in upper-division biology students: Awareness does not always lead to control. *CBE Life Sciences Education*, *16*(2), 1–14. https://doi.org/10.1187/cbe.16-09-0286

Erbay, H. N. (2021). *Metacognitive Skills and Problem-Solving Metacognitive Skills and Problem- Solving To cite this article : May*. https://doi.org/10.46328/ijres.1594

Fatmawati, Z. A., Mulyani, S., Susilowati, E., & Iswari, R. S. (2019). *Journal of Innovative Science Education Effect of Argument Driven Inquiry (ADI) with Problem Solving Method for Student ' s Argumentation and Critical Thinking Skills*. *8*(3), 255–263.

Fazilla, S. (2022). *The Impact of Metacognition on Elementary School Students ' Problem-Solving Skills in Science Learning*. *6*(2), 278–286.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist, 34*(10), 906-911. https://doi.org/10.1037/0003-066X.34.10.906

Güner, P., & Metacognitive, H. N. (2021). *Metacognitive Skills and Problem-Solving To cite this article : Metacognitive Skills and Problem-Solving*.

Haleem, A., Javaid, M., Asim, M., & Suman, R. (2022). Understanding the role of digital technologies in education : A review. *Sustainable Operations and Computers*, *3*(February), 275–285. https://doi.org/10.1016/j.susoc.2022.05.004

Hartman, H. J. (2001). *Developing Students'*

Metacognitive Knowledge and Skills (Issue April). https://doi.org/10.1007/978-94-017-2243-8_3

Hasnunidah, N., Susilo, H., Henie, M. I., & Sutomo, H. (2015). Argument-driven inquiry with scaffolding as the development strategies of argumentation and critical thinking skills of students in Lampung, Indonesia. *American Journal of Educational Research*, *3*(9), 1195–1192. https://doi.org/10.12691/education-3-9-20

Hasnunidah, N., Susilo, H., Irawati, M., & Suwono, H. (2023). *6059 Words Journal of University Teaching & Learning Practice*.

Hoskinson, A. M., Caballero, M. D., & Knight, J. K. (2013). How canwe improve problem solving in undergraduate biology? applying lessons from 30 years of physics education research. *CBE Life Sciences Education*, *12*(2), 153–161. https://doi.org/10.1187/cbe.12-09-0149

Innovation, E. (2016). *Innovating Education and Educating for Innovation*. https://doi.org/10.1787/9789264265097-en

Ismet, Aisyah, N., Nawawi, E., Yusuf, M., & Meilinda. (2021). Problem Solving Skill: What is the Difference between Practitioners and Experts? *4th Sriwijaya University Learning and Education International Conference (SULE-IC 2020)*, *513*, 775–780.

John Butterworth, & Thwaites, G. (2013). Critical Thinking and Problem Solving Thinking Skills Thinking Skills Critical Thinking and Problem Solving Second edition. In *Critical Thinking Skills for Education Students* (Vol. 13, Issue August).

Juandi, D., & Review, S. L. (2023). *PROBLEM SOLVING ABILITY ANALYSIS : SYSTEMATIC*. *13*(1), 33–43.

Jumadi, J., Perdana, R., & Rosana, D. (2021). *The impact of problem-based learning with argument mapping and online laboratory on scientific argumentation skill*. *10*(1), 16–23. https://doi.org/10.11591/ijere.v10i1.20593

Karlen, Y., Hirt, C. N., Jud, J., Rosenthal, A., & Eberli, T. D. (2023). Teachers as learners and agents of self-regulated learning : The importance of different teachers competence aspects for promoting metacognition. *Teaching and Teacher Education*, *125*, 104055. https://doi.org/10.1016/j.tate.2023.104055

Keiler, L. S. (2018). Teachers' roles and identities in student-centered classrooms. *International Journal of STEM Education*, *5*(1). https://doi.org/10.1186/s40594-018-0131-6

Kuhn, D. (1991). *The Skills of Argument*. Cambridge University Press.

Kundariati, M., Maghfiroh, L., & Endah, S. (2022). *Revealing the effect of local-based teaching materials toward scientific reasoning , argumentation , and problem-solving in biology classroom*. *8*(3), 287–295.

Kurniawan, D. A., & Triani, E. (2022). *The effect of science process skills of students argumentation skills*. *8*(1), 78–88.

Lestari, W., Pratama, L. D., Matematika, T., Studi, P., Matematika, P., & Yogyakarta, U. N. (2018). *Metacognitive skills in mathematics problem solving*. *6*(3), 286–295.

Lodge, J. M., Kennedy, G., Lockyer, L., Arguel, A., & Pachman, M. (2018). Understanding Difficulties and Resulting Confusion in Learning: An Integrative Review. *Frontiers in Education*, *3*(June), 1–10. https://doi.org/10.3389/feduc.2018.00049

Majidi, A. el, Janssen, D., & de Graaff, R. (2021). The effects of in-class debates on argumentation skills in second language education. *System*, *101*(July), 102576. https://doi.org/10.1016/j.system.2021.102576

Marantika, J. E. R. (2021). Metacognitive ability and autonomous learning strategy in improving learning outcomes. *Journal of Education and Learning (EduLearn)*, *15*(1), 88–96. https://doi.org/10.11591/edulearn.v15i1.17392

Markula, A., & Aksela, M. (2022). The key

characteristics of project-based learning: how teachers implement projects in K-12 science education. *Disciplinary and Interdisciplinary Science Education Research*, *4*(1). https://doi.org/10.1186/s43031-021-00042-x

Mcghee, M. (2015). *Florida State University Libraries The Effects of Argumentation Scaffolding in a Problem-Based Learning Course on Problem-Solving Outcomes and Learner Motivation*.

Md, M. R. (2019). 21st Century Skill "Problem Solving": Defining the Concept. *Asian Journal of Interdisciplinary Research*, *April*, 64–74. https://doi.org/10.34256/ajir1917

Naqia, D., & Suaidi, A. (2023). *Students ' Critical Thinking Skills Perform in Debate Activities*. *6*(1), 55–64.

Purwati, R., & Prasetyanti, N. M. (2019). *Analysis of Argumentation Skills in Biology Learning at*. https://doi.org/10.4108/eai.23-3-2019.2284903

Putri, W. E., Sunarno, W., & Marzuki, A. (2021). *Analysis of The Students ' Argumentative Skills of Senior High School in Covid-19 Pandemic using Problem Based Learning in Static Fluid*. *7*(3). https://doi.org/10.29303/jppipa.v7i3.735

Rahayu, F., Putri, D. M., Apriansyah, Y., & Walid, A. (2022). The Quality Of Student Argumentation is Determined By An Analysis Of Student Statements Viewed From Science Literature. *Wahana Didaktika : Jurnal Ilmu Kependidikan*, *20*(3), 471–479. https://doi.org/10.31851/wahanadidaktika.v20i3.10617

Saleh, R., Zubaidah, S., & Mahanal, S. (2023). The Correlation between Critical Thinking and Metacognitive Skills on Student Retention Across Genders in Senior High School. *Uniciencia*, *37*(1), 1–20. https://doi.org/10.15359/ru.37-1.7

Santoso, H., Abdurrahman, A., & Wahyudi, I. (2021). The Application of the ASICC Learning Model to Improve Students' Metacognitive and Argumentation Skills in Biology Learning. *Jurnal Pendidikan Biologi, 12*(2), 123-134. https://doi.org/10.12928/jpb.v12i2.10743

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19*(4), 460-475. https://doi.org/10.1006/ceps.1994.1033

Series, C. (2021). *Learning barriers and student creativity in solving math problems*. https://doi.org/10.1088/1742-6596/1918/4/042088

Shinta, D. K. (2020). *Improving students ' arguments through collaborative learning*. *10*(2), 349–358.

Songsil, W., & Faikhamta, C. (2017). *Grade 10 Students ' Scientific Argumentation in Socio-Scientific Issues*. *11*(3).

Songsil, W., Pongsophon, P., Boonsoong, B., & Clarke, A. (2019). Developing scientific argumentation strategies using revised argument-driven inquiry (rADI) in science classrooms in Thailand. *Asia-Pacific Science Education*, *5*(1), 1–22. https://doi.org/10.1186/s41029-019-0035-x

Susilo, H. (2022). *EAQD-PC : Learning Model to Train Students ' Metacognitive Skills to Overcome Difficulties in Learning Biology*. *December*. https://doi.org/10.20944/preprints202212.0430.v1

Tasquier, G., Knain, E., & Jornet, A. (2022). Scientific Literacies for Change Making: Equipping the Young to Tackle Current Societal Challenges. *Frontiers in Education*, *7*(April), 1–20. https://doi.org/10.3389/feduc.2022.689329

Widodo, A., Waldrip, B., & Herawati, D. (2016). Students argumentation in science lessons: A story of two research projects. *Jurnal Pendidikan IPA Indonesia*, *5*(2), 199–208. https://doi.org/10.15294/jpii.v5i2.5949