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Are Argumentation Skills Can Describe Understanding Concepts?

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ABSTRACT

Objective: Based on the several aspects, one aspect is quite important in the process of learning science, namely communicating. Argumentation is one of communication skills. Are argumentation can describe understanding concepts? **Method:** This study uses a literature review method from thirteen articles. **Results:** Argumentation skills can describe understanding concepts. Interpretation of the correlation coefficient shows that argumentation skills strongly correlate with understanding concepts. It is because argumentation skills positively correlate with critical thinking and logic skills. Argumentation skills can improve students' critical thinking level and logical skills in the thinking process. Everyone has good argumentation skills if has good critical thinking and good logic skills. **Novelty:** Argumentation skills are one of the communication skills that improve understanding of concepts. Argumentation skills are moderators for high-order thinking skills. It can occur because the components of argumentation skills are claim, evidence, and reasoning. Someone can meet all the argumentation skills components with good thinking.

INTRODUCTION

Science is defined as three main pillars, namely, science as an attitude, science as a process, and science as a product. Concepts are the product of science. The concept is a collection of stimuli with the same attributes for organizing knowledge and experience into categories. Understanding concepts in science learning is an important aspect. Every student must have an understanding of concepts, namely scientific concepts. The Southeast Asian Ministers of Education Organization (SEAMEO) webinar in September 2022 explained that six skills are needed in 21st-century education: character, citizenship, critical thinking, creativity, collaboration, and communication. Three of the six skills critical, creative, and communication are higher-order thinking skills (Baguma et al., 2019; Kwangmuang et al., 2021; Lu et al., 2021; Nahar et al., 2022; Suherman et al., 2020; Supena et al., 2021). Higher-order thinking skills are the ability to think strategically to use information in solving problems, analyzing arguments, negotiating issues, or making predictions (Al-Husban, 2020; Alsaleh, 2020; Lu et al., 2021; Munawati, 2019; Quinn et al., 2020).

Learning is directed at creating an active, critical, analytical, and creative atmosphere in problem-solving through developing thinking skills. This thought process includes several aspects such as observing, classifying, measuring, looking for relationships, conducting experiments, and communicating (Alsaleh, 2020; Dökmecioğlu et al., 2022; Eslami et al., 2019; Henriksen et al., 2020; Lacerda et al., 2020; Lu et al., 2021; Munawati, 2019; Quinn et al., 2020; Radianti et al., 2020; Setiadi & Elmawati, 2019; Taques et al., 2021;

Yaniawati et al., 2020). Based on the several aspects that have been mentioned, there is one aspect that is quite important in the process of learning science, namely, communication. One of communication skill is argumentation. Argumentation is defined as a language skill to influence the attitudes and opinions of others to match what the writer or speaker wants. Argumentation skills are needed to respond some scientific issues that occur in today's society, make decisions, assess a claim that arises both through mass media and other media based on valid and reliable evidence (Bencze et al., 2020; Bodé et al., 2019; Fjelland, 2020; Gericke et al., 2022; Ke et al., 2021; Maass et al., 2019; Noroozi, 2022; Priemer et al., 2020).

Argumentation skills are critical to be applied in learning to improve the skills demanded in 21st-century learning in order to prepare students to face the Industrial Revolution 5.0 (Anita et al., 2019). Argumentation is usually in the science learning process based on data and evidence to support explanations of scientific concepts (Bayram-Jacobs et al., 2019; Manz et al., 2020; Panadero & Jonsson, 2020; Zhai et al., 2020; Zhu et al., 2020). Argumentation skills are growing slowly, but argumentation skills must be learned carefully. In this case, we will discuss scientific argumentation. The use of scientific argumentation in teaching is of great importance as it makes the students' engagement more effective in the teaching and learning process, as it helps develop their ideas because they come to know themselves rather than presenting them in ready-made templates. Teaching individuals how to engage in discussions and use scientific evidence in these discussions is essential for future decision-making, especially when students are faced with controversial issues. Therefore, science should play a critical role in developing future citizens with such skills (Coy et al., 2021; García-Feijoo et al., 2020; Nguyen et al., 2020; Nugroho et al., 2019; Orgill et al., 2019). Uncertainty in argument created productive moments for students to collaborate in dialogue and direct their understanding of natural phenomena toward more coherent scientific explanations. Based on this explanation, the author has two research questions: 1) Can argumentation skills describe understanding concepts? 2) How can argumentation skills describe understanding concepts?

RESEARCH METHOD

This study uses the literature review method. A literature review is a written summary of journal articles, books, and other documents that describe the past and current state of information on the topic of research study. This data was collected from thirteen articles. The author uses the document analysis method to analyze data. Detail of research method in Figure 1.

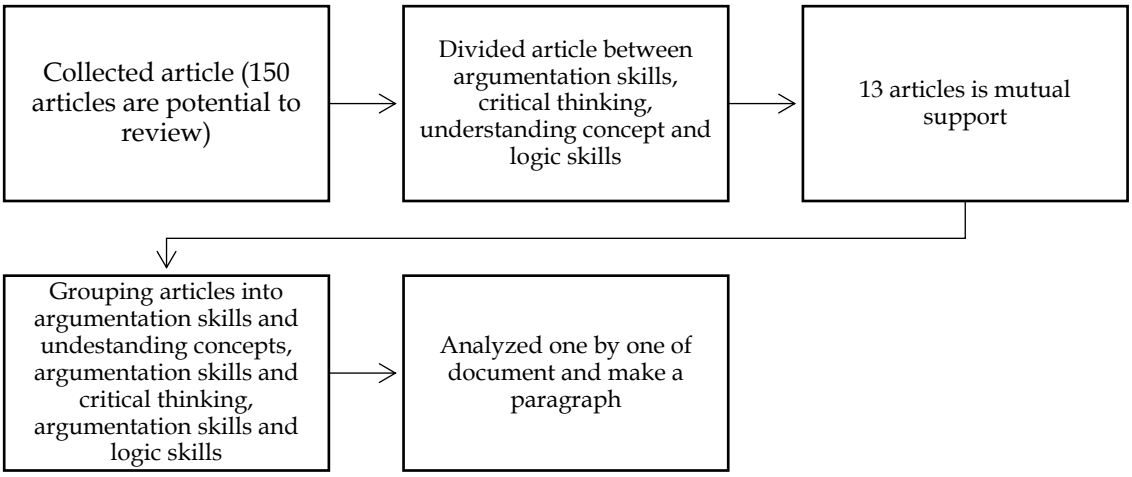

Figure 1. Research method.

Document analysis is a systematic procedure for reviewing or evaluating printed and electronic documents (computer-based and Internet-transmitted) documents. Document analysis is a technique that enables researchers to study human behavior through an analysis of their communications. The first author collected 150 articles from some search engines. The article is divided into four topics: argumentation skills, critical thinking, understanding concepts, and logic skills. Then, the author collected some articles with mutual support and found 13. The articles are grouped into three topics: argumentation skills and understanding concepts, argumentation skills and critical thinking, and argumentation skills and logic skills. The articles are analyzed and synthesized into a make-sense paragraph.

RESULTS AND DISCUSSION

Results

Some research in Table 1 shows the correlation between argumentation skills and understanding concepts. Table 2 shows argumentation skills can improve critical thinking. Table 3 shows the argumentation process includes logic skills.

Table 1. Some research shows a correlation between argumentation skills and understanding concepts.

Author	Method	Results
Apriliani et al., (2019)	Correlational	The correlation between conceptual knowledge and argumentation skills obtained a Pearson correlation coefficient of 0.419 and a sig value of 0.007
Sarira et al., (2019)	Correlational	There is a significant correlation between argumentation skills and cognitive learning outcomes (significant value 0.000<0.050) with a correlation coefficient (r) 0.786
Pratiwi et al., (2019)	Descriptive qualitative	Problem-based learning that implements argumentation skills can improve conceptual understanding of the relationship between buoyant force and sinking volume. The correlation coefficient obtained a value of 0,639. This indicates a high correlation between the argumentation

Author	Method	Results
		skills taught using the Problem-Based Learning students' model.
Paramita et al., (2020)	Quasi Experiment post only	The experiment class better understands concept and argumentation skills than the control class.
Amin et al., (2022).	Correlational	The regression equation derived from the data analysis is y = 0.608x + 39.05 with a reliability value of 0.179, indicating that conceptual knowledge accounts for 82.100% of argumentation skills and other factors account for 17.900% of argumentation skills.

Table 2. Argumentation skills can improve critical thinking.

Author	Method	Results
Suraya et al., (2019).	Descriptive	Students' argumentation abilities are at levels 2, 3, and 4, and students' critical thinking skills are at the Unacceptable and strong levels, where both argumentation skills and critical thinking are equivalent.
Hasnunidah et al., (2020).	Correlational Study	The correlation between students' understanding of basic biology concepts and their argumentation and critical thinking skills is very high (R ADI = 0.886; R Conventional= 0.817). Moreover, the contribution of students' argumentation skills to their understanding of basic biology concepts (ADI = 0.600%; Conventional = 0.800%) was lower than the contribution of their critical-thinking skills (ADI = 88.000%; Conventional = 80.900%.
Haruna & Nahadi, (2021).	Quantitative research	argumentation ability is closely related to critical thinking ability. Students with low argumentation level (level 1) have low critical thinking skills (level 1). Students with a high argumentation level (level 4) have high critical thinking skills (level 4).
Winarti et al., (2021).	Correlation	There is a correlation between critical thinking and writing argumentative text. It shows that argumentation skills can describe critical thinking and writing skills.
Ristanto et al., (2022).	Quasi-experiment, pretest-postest control group design	The Guided Discovery Learning Argument Mapping implementation was proven capable of influencing critical thinking skills on environmental changes, and it was better than the control class. The GDL and argument mapping had characteristics that enabled students to develop a way of thinking, thus training their critical thinking skills.

Author	Method	Results
Demircioglu et al., (2023).	Qualitative research	Students' frequency of using critical thinking skills varies according to the use of the argumentation method.

Table 3. The argumentation process includes logic skills.

Author	Method	Results
Ekanara et al., (2018)	Correlational research	The value of reasoning ability and argumentation skills obtained in this study show a strong and positive relationship. This is shown by the results of this study, which obtained a correlation coefficient (r) of 0.760. The r value means that reasoning ability and argumentation skills have a strong positive relationship.
Al-Ajmi & Ambusaidi. (2021).	Survey approach	There is a correlation between argumentation skills and logical skills.

Discussion

Argumentation is gathering the various components needed to build an argument. Argumentation is a discursive process for making claims, providing evidence to support claims, and criticizing. In education, argumentation skills can encourage students to provide facts, data, and theories that are appropriate to support claims against a problem and can be accounted for (Rahayu et al., 2020; Hardini & Alberida, 2022). In another definition, it is explained that argumentation skills are a form of thinking skills possessed by a person in compiling knowledge claims that are supported by evidence and strengthened by reason when assessing a phenomenon (Allchin & Zemplén, 2020; Kaeppel, 2021; Kim et al., 2022; Maknun, 2020; Nussbaum, 2021; Ping et al., 2020; Rapanta, 2021).

Argumentation skills can be in the form of a student's ability to understand the issues being debated, find and understand relevant information, assess the strengths and weaknesses of arguments, build strong and consistent arguments, present arguments clearly and effectively, accept and respond to criticism well so that they can make appropriate and logical conclusions (Ekanara et al., 2018). According to Roviati & Widodo (2019), indicators of argumentation skills include the ability to identify, evaluate, and make arguments. Based on the Toulmin Argumentation Pattern (TAP) argumentation model, the quality of the argument consists of six components, including claims, data, warrants, backing, rebuttals, and qualifiers (Toulmin, 1958). The argumentation component consisted of claims, evidence, and reasoning. Specifically, argumentation skills are divided into four components, namely (1) compiling claims, (2) showing evidence, (3) compiling reasons, and (4) compiling counterarguments (Chin & Osborne, 2010).

Argumentation skills correlate with student understanding. This statement is supported by several studies by Apriliani et al. (2019) which state that the correlation between conceptual knowledge and argumentation skills obtained Pearson correlation coefficient 0.419 and sig value 0.007; Sarira et al (2019) correlational there are significant correlation between argumentation skills and cognitive learning outcomes (significant

value 0.000<0.050) with correlation coefficient (r) 0.786; Pratiwi et al (2019) Problem based learning that implements argumentation skills can improve students' conceptual understanding of the relationship between buoyant force and sinking volume; Paramita et al (2020) Experiment class has a better understanding of concepts and argumentation skills than control class; Amin et al (2022) The regression equation derived from the data analysis is y = 0.608x + 39.050 with a reliability value of 0.179, indicating that conceptual knowledge accounts for 82.10% of argumentation skills and that other factors account for 17.900% of argumentation skills. Interpretation of the correlation between the two variables is shown in Table 4.

Table 4. Interpretation of correlation coefficient.

Correlation Coefficient	Interpretation
0.000	There is no correlation between the two variables
>0.000-0.250	Very weak correlation
>0.250-0.500	Medium Correlation
>0.500-0.750	Strong correlation
>0.750-0.990	Solid correlation
1.000	Correlation of perfect positive relationship
-1.000	Correlation of perfect negative relationship

Table 5. Interpretation of correlation coefficient obtained from several studies.

Author	Correlation Coefficient	Interpretation
Apriliani	0.419	Medium correlation
Pratiwi	0.639	Strong correlation
Amin	0.608	Strong correlation
sarira	0.786	Solid correlation

The correlation coefficient between arguments obtained from several studies is summarized in Table 5. Argumentation skills strongly correlate with conceptual understanding. This is supported by Chin & Osborne (2010), who interpret that arguments are obtained from thought processes that play an essential role in developing students' understanding. The results of other studies that strengthen the correlation between argumentation skills and understanding of concepts are as follows.

Argumentation Skills Are Related to Critical Thinking

Critical thinking is a component of higher-order thinking skills (HOTS). As critical thinking, HOTS is defined as the skill of giving wise judgments and criticizing something using logical and scientific reasons. Critical thinking is deciding what to do or believe (Saphira & Prahani, 2022). Someone who has good critical thinking skills will also have a good understanding. Indicators of critical thinking skills based on Ennis' opinion are:

a. Give a simple explanation.
   - Focus problem
   - Analyze arguments
   - Ask and answer clarifying questions or challenging questions
b. Build basic skills
   - Consider the source
   - Observe and consider the results of observations
c. Making inferences

- Make a deduction and consider the results of the deduction, or make an induction and consider the results.
- Make decisions and weigh the results.

d. Provide further explanation
- Define terms and consider definitions
- Identify assumptions

e. Set strategy and tactics
- Formulate and decide on an action
- Present arguments orally or in writing

From the indicators sparked by Ennis, it can be stated that critical thinking is related to argumentation skills. This statement is supported by research conducted by Suraya et al. (2019) that students' argumentation abilities are at levels 2, 3, and 4 and students' critical thinking skills are at the Unacceptable and strong levels, where both levels of argumentation skills and critical thinking are at equivalent levels; Hasnunidah et al (2020) said that the correlation between students' understanding of basic biology concepts and both their argumentation and critical thinking skills is very high (R ADI = 0.886; R Conventional = 0.817). Moreover, the contribution of students' argumentation skills to their understanding of basic biology concepts (ADI = 0.600%; Conventional = 0.800%) was lower than the contribution of their critical-thinking skills (ADI = 88%; Conventional = 80.900%); Haruna & Nahadi (2021) said that argumentation skills are closely related to critical thinking skills. Students with low argumentation level (level 1) have low critical thinking skills (level 1). Students with a high level of argumentation (level 4) have high critical thinking skills (level 4; Winarti et al. (2021) said that There is a correlation between critical thinking and writing argumentative text. It shows that argumentation skills can describe critical thinking and writing skills. The Guided Discovery Learning Argument Mapping implementation was proven capable of influencing critical thinking skills on environmental changes, and it was better than the control class. The GDL and argument mapping had characteristics that enabled students to develop ways of thinking, thus training their critical thinking skills. Demircioglu et al. (2023) said that the frequency of using critical thinking skills by students varies according to the use of the argumentation method. The mapping of argumentation skills with indicators of critical thinking is explained in Table 6.

Table 6. Mapping indicators of argumentation skills and critical thinking.

Code	Critical Thinking Indicators	Component of Argumentation
K1	Distinguish relevant and irrelevant information	Claim
K2	Detect error and correct conceptual errors	Rebuttal and backing
K3	Test the problem openly	Data
K4	Analyze the problem	Warrant
K5	Understanding the characteristics of a particular, even if it is changed in form	Warrant
K6	Conclude all the facts have been gathered and considered	Claim, Data + Warrant

Argumentation Skills Correlate With Logic or Reasoning Skills

Logic is a branch of science that seeks to derive conclusions through valid formal rules. Logic is a thinking process that is systematic and bound to specific rules. Logic is the knowledge and skills to think straight and precisely. The ability to think logically has been identified as essential to support the development of learning science and mathematics (Arytunova & Gykasyan, 2021; Rizaldi et al., 2020). The ability to think logically includes five types of reasoning, namely proportional, controlling variables, probability, correlational, and combinatorial (Fitria & Malik, 2022; Nopriana et al., 2021; Rohaeti et al., 2019; Sanjayanti et al., 2019 2020). Proportional reasoning is essential in the quantitative aspects of chemistry, especially for understanding the derivation and use of many functional relationships in chemistry, such as the development and interpretation of tabular and graphical data. Correlational reasoning plays a role in formulating hypotheses and interpreting data that needs to consider the relationship between variables—control of essential variables in planning, implementation, and interpretation. Interpreting data from findings, observations, or experiments often requires probabilistic reasoning. Combinatorial reasoning occurs in formulating alternative hypotheses to test the effect of the selected variables.

A learner is considered to have good argumentation skills if he can compile claims, show evidence for the claims made, and provide appropriate explanations for the evidence shown (Chin & Osborne, 2010). The explanation built must be per the evidence shown. Evidence can be in the form of phenomena in everyday life, practicum results, and data that support claims (Ginanjar & Utari, 2015). Evidence is explained by appropriate theories, concepts, and laws so that the arguments presented are accurate, reasonable, and acceptable. Therefore, a student must have good logical skills and conceptual understanding in building compatibility between evidence and explanation.

Logic skills are essential to fulfill the reasoning component in argumentation skills. This statement is supported by research conducted by Ekanara et al. (2018), who said that the value of reasoning ability and argumentation skills obtained in this study show a strong and positive relationship. This is shown by the results of this study, which obtained a correlation coefficient (r) of 0.760. The r value means that reasoning ability and argumentation skills have a strong positive relationship. Research conducted by Ajmi et al. (2021) said there is a correlation between argumentation and logical skills.

CONCLUSION

Fundamental finding: Argumentation skills can describe understanding concepts. Interpretation of the correlation coefficient shows that argumentation skills strongly correlate with understanding concepts. It is because argumentation skills positively correlate with critical thinking and logic skills. Argumentation skills can improve students' critical thinking level and logical skills in the thinking process. Everyone has good argumentation skills if has good critical thinking and good logic skills. **Implication:** This research can be a reference for argumentation skills, understanding concepts, critical thinking, and logic skills. **Limitation:** This study is limited to analyzed from some literature. There have yet to be experiments in this study. **Future research:** Teachers must often apply argumentation skills in the learning process because argumentation skills can explain understanding concepts of student

REFERENCES

Al-Ajmi, B., & Ambusaidi, A. (2019). The level of scientific argumentation skills in chemistry. *Science Education International, 33*(1), 66–74. https://doi.org/https://doi.org/10.33828/sei.v33.i1.7

Al-Husban, N. A. (2020). Critical thinking skills in asynchronous discussion forums: A case study. *International Journal of Technology in Education*, *3*(2), 82-90. https://doi.org/10.46328/ijte.v3i2.22

Allchin, D., & Zemplén, G. (2020). Finding the place of argumentation in science education: Epistemics and whole science. *Science Education*, *104*(5), 907–933. https://doi.org/10.1002/sce.21589

Alsaleh, N. J. (2020). Teaching critical thinking skills: Literature review. *Turkish Online Journal of Educational Technology-TOJET*, *19*(1), 21–39.

Amin, A. M. ., Majid, I. ., Hujjatusnaini, N., & Adiansyah, R. (2023). The correlation between the character and self-efficacy of pre-service biology teachers. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 5157–5162. https://doi.org/10.29303/jppipa.v9i7.2999

Anita, A., Afandi, A., & Tenriawaru, A. B. (2019). Pentingnya keterampilan argumentasi di era ledakan informasi digital. *Prosiding Seminar Nasional,* 1-10.

Apriliani, N., Suharsono, S., & Diella, D. (2019). Hubungan penguasaan konsep dengan kemampuan argumentasi ilmiah peserta didik pada sub konsep kelainan respirasi manusia. *Seminar Nasional Biologi, Saintek, dan Pembelajarannya (SN-Biosper) Tahun 2019,* 326-331.

Arytunova, A., & Gykasyan, S. (2021). Development of logical thinking in primary school students in mathematics lessons. *European Journal of Research and Reflection in Educational Sciences*, *8*(2), 56–60. https://doi.org/10.52376/978-5-907419-23-0_056

Baguma, R., Bagarukayo, E., Namubiru, P., Brown, C., & Mayisela, T. (2019). Using whatsapp in teaching to develop higher order thinking skills-a literature review using the activity theory lens. *International Journal of Education and Development Using Information and Communication Technology (IJEDICT)*, *15*(2), 98–116.

Bayram-Jacobs, D., Henze, I., Evagorou, M., Shwartz, Y., Aschim, E. L., Alcaraz-Dominguez, S., Barajas, M., & Dagan, E. (2019). Science teachers' pedagogical content knowledge development during enactment of socioscientific curriculum materials. *Journal of Research in Science Teaching*, *56*(9), 1207–1233. https://doi.org/10.1002/tea.21550

Bencze, L., Pouliot, C., Pedretti, E., Simonneaux, L., Simonneaux, J., & Zeidler, D. (2020). SAQ, SSI and STSE education: Defending and extending "science-in-context." *Cultural Studies of Science Education*, *15*(3), 825–851. https://doi.org/10.1007/s11422-019-09962-7

Bodé, N. E., Deng, J. M., & Flynn, A. B. (2019). Getting past the rules and to the WHY: Causal mechanistic arguments when judging the plausibility of organic reaction mechanisms. *Journal of Chemical Education,* 1-15. https://doi.org/10.1021/acs.jchemed.8b00719

Chin, M., & Osborne, J. (2010). Supporting argumentation through student's question in science classroom. *Journal of The Learning Science*, *19*(2), 1-17. https://doi.org/10.1080/10508400903530036

Coy, D., Malekpour, S., Saeri, A. K., & Dargaville, R. (2021). Rethinking community empowerment in the energy transformation: A critical review of the definitions, drivers and outcomes. *Energy Research and Social Science*, *72*, 1-13. https://doi.org/10.1016/j.erss.2020.101871

Demircioglu, T., Karakus, M., & Ucar, S. (2022). *Developing students' critical thinking skills and argumentation abilities through augmented reality–based argumentation activities in science classes*. Springer Netherlands.

Dewantari, T., Hasnunidah, N., & Maulina, D. (2022). Kajian kemampuan argumentasi siswa pada materi pokok animalia melalui pendekatan saintifik di SMA dengan peringkat akreditasi yang berbeda. *BIOEDUSAINS:Jurnal Pendidikan Biologi Dan Sains*, *5*(1), 267–278. https://doi.org/10.31539/bioedusains.v5i1.3285

Dökmecioğlu, B., Tas, Y., & Yerdelen, S. (2022). Predicting students' critical thinking dispositions in science through their perceptions of constructivist learning environments and metacognitive self-regulation strategies: a mediation analysis. *Educational Studies*, *48*(6), 809–826. https://doi.org/10.1080/03055698.2020.1833838

Ekanara, B., Adisendjaja, Y. H., & Hamdiyati, Y. (2018). Hubungan kemampuan penalaran dengan keterampilan argumentasi siswa pada konsep sistem pencernaan melalui PBL (problem based learning). *Biodidaktika, Jurnal Biologi Dan Pembelajarannya*, *13*(2), 1-10. https://doi.org/10.30870/biodidaktika.v13i2.3677

Eslami, T., Mirjalili, V., Fong, A., Laird, A. R., & Saeed, F. (2019). ASD-DiagNet: A hybrid learning approach for detection of autism spectrum disorder using fMRI Data. *Frontiers in Neuroinformatics*, *13,* 1-11. https://doi.org/10.3389/fninf.2019.00070

Fitria, Y., & Malik, A. (2022). Analysis of difficulties in logical thinking ability in learning natural science faced by students of elementary education. *Jurnal Penelitian Pendidikan IPA*, *8*(2), 515–520. https://doi.org/10.29303/jppipa.v8i2.1295

Fjelland, R. (2020). Why general artificial intelligence will not be realized. *Humanities and Social Sciences Communications*, *7*(1), 1–9. https://doi.org/10.1057/s41599-020-0494-4

García-Feijoo, M., Eizaguirre, A., & Rica-Aspiunza, A. (2020). Systematic review of sustainable-development-goal deployment in business schools. *Sustainability (Switzerland)*, *12*(1), 1–19. https://doi.org/10.3390/SU12010440

Gericke, N., Högström, P., & Wallin, J. (2022). A systematic review of research on laboratory work in secondary school. *Studies in Science Education*, *59*(2), 245–286. https://doi.org/10.1080/03057267.2022.2090125

Ginanjar, W. S., & Utari, S. (2015). Penerapan model argument-driven inquiry dalam pembelajaran ipa untuk meningkatkan kemampuan argumentasi ilmiah siswa SMP. *Jurnal Pengajaran MIPA, 20*(1), 32-38. http://dx.doi.org/10.18269/jpmipa.v20i1.559

Hardini, S. D., & Alberida, H. (2022). Analisis kemampuan argumentasi peserta didik. *Biodidaktika: Jurnal Biologi dan Pembelajarannya,* 17(1), 1-10. http://dx.doi.org/10.30870/biodidaktika.v17i1.16108

Haruna, A., & Nahadi. (2021). Menjelajahi hubungan level argumentasi dengan kemampuan berfikir kritis siswa dalam menyelesaikan soal ikatan kimia. *Jurnal Inovasi Pendidikan Kimia*, *15*(1), 2686–2694. https://doi.org/10.15294/jipk.v15i1.24156

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. https://doi.org/10.53761/1.17.1.6

Henriksen, D., Richardson, C., & Shack, K. (2020). Mindfulness and creativity: Implications for thinking and learning. *Thinking Skills and Creativity*, *37*, 1–10. https://doi.org/10.1016/j.tsc.2020.100689

Kaeppel, K. (2021). The influence of collaborative argument mapping on college students' critical thinking about contentious arguments. *Thinking Skills and Creativity*, *40*, 1-9. https://doi.org/10.1016/j.tsc.2021.100809

Ke, L., Sadler, T. D., Zangori, L., & Friedrichsen, P. J. (2021). Developing and using multiple models to promote scientific literacy in the context of socio-scientific issues. *Science and Education*, *30*(3), 589–607. https://doi.org/10.1007/s11191-021-00206-1

Kim, N. J., Vicentini, C. R., & Belland, B. R. (2022). Influence of scaffolding on information literacy and argumentation skills in virtual field trips and problem-based learning for scientific problem solving. *International Journal of Science and Mathematics Education*, *20*(2), 215–236. https://doi.org/10.1007/s10763-020-10145-y

Kwangmuang, P., Jarutkamolpong, S., Sangboonraung, W., & Daungtod, S. (2021). The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools. *Heliyon*, *7*(6), 1-13. https://doi.org/10.1016/j.heliyon.2021.e07309

Lacerda, G., Petrillo, F., Pimenta, M., & Guéhéneuc, Y. G. (2020). Code smells and refactoring: A tertiary systematic review of challenges and observations. *Journal of Systems and Software*, *167*, 1-48. https://doi.org/10.1016/j.jss.2020.110610

Lu, K., Yang, H. H., Shi, Y., & Wang, X. (2021). Examining the key influencing factors on college students' higher-order thinking skills in the smart classroom environment. *International Journal of Educational Technology in Higher Education*, *18*(1), 1–13. https://doi.org/10.1186/s41239-020-00238-7

Maass, K., Geiger, V., Ariza, M. R., & Goos, M. (2019). The role of mathematics in interdisciplinary STEM education. *ZDM - Mathematics Education*, *51*(6), 869–884. https://doi.org/10.1007/s11858-019-01100-5

Maknun, J. (2020). Implementation of guided inquiry learning model to improve understanding physics concepts and critical thinking skill of vocational high school students. *International Education Studies*, *13*(6), 117-131. https://doi.org/10.5539/ies.v13n6p117

Manz, E., Lehrer, R., & Schauble, L. (2020). Rethinking the classroom science investigation. *Journal of Research in Science Teaching*, *57*(7), 1148–1174. https://doi.org/10.1002/tea.21625

Munawati, A. (2019). The effectiveness of HOTS (Higher Order Thinking Skill) in teaching reading comprehension. *Education of English as a Foreign Language*, *2*(1), 32–43. https://doi.org/10.21776/ub.educafl.2019.002.1.5

Nahar, S., Suhendri, Zailani, & Hardivizon. (2022). Improving students' collaboration thinking skill under the implementation of the quantum teaching model. *International Journal of Instruction*, *15*(3), 451–464. https://doi.org/10.29333/iji.2022.15325a

Nguyen, T. P. L., Nguyen, T. H., & Tran, T. K. (2020). STEM education in secondary schools: Teachers' perspective towards sustainable development. *Sustainability (Switzerland)*, *12*(21), 1–16. https://doi.org/10.3390/su12218865

Nopriana, T., Firmasari, S., & Martadiputra, B. A. P. (2021). Profile of hard skills and soft skills of mathematics education students. *Eduma : Mathematics Education Learning and Teaching*, *10*(1), 1-13. https://doi.org/10.24235/eduma.v10i1.6460

Noroozi, O. (2022). The role of students' epistemic beliefs for their argumentation performance in higher education. *Innovations in Education and Teaching International*, *60*(4), 501–512. https://doi.org/10.1080/14703297.2022.2092188

Nugroho, O. F., Permanasari, A., & Firman, H. (2019). The movement of stem education in Indonesia: Science teachers' perspectives. *Jurnal Pendidikan IPA Indonesia*, *8*(3), 417–425. https://doi.org/10.15294/jpii.v8i3.19252

Nussbaum, E. M. (2021). Critical integrative argumentation: Toward complexity in students' thinking. *Educational Psychologist*, *56*(1), 1–17. https://doi.org/10.1080/00461520.2020.1845173

Orgill, M. K., York, S., & Mackellar, J. (2019). Introduction to systems thinking for the chemistry education community. *Journal of Chemical Education*, *96*(12), 2720–2729. https://doi.org/10.1021/acs.jchemed.9b00169

Panadero, E., & Jonsson, A. (2020). A critical review of the arguments against the use of rubrics. *Educational Research Review*, *30*, 1-65. https://doi.org/10.1016/j.edurev.2020.100329

Paramita, A. K., Yahmin, Y., & Dasna, I. W. (2021). Pembelajaran inkuiri terbimbing dengan pendekatan stem (science, technology, engineering, mathematics) untuk pemahaman konsep dan keterampilan argumentasi siswa SMA pada materi laju reaksi. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *5*(11), 1652-1665. https://doi.org/10.17977/jptpp.v5i11.14189

Ping, I. L. L., Halim, L., & Osman, K. (2020). Explicit teaching of scientific argumentation as an approach in developing argumentation skills, science process skills and biology understanding. *Journal of Baltic Science Education*, *19*(2), 276–288. https://doi.org/10.33225/jbse/20.19.276

Pratiwi, S. N., Cari, C., & Aminah, N. S. (2019). Pembelajaran IPA abad 21 dengan literasi sains siswa. *Jurnal Materi dan Pembelajaran Fisika*, *9*, 34–42. https://doi.org/10.20961/jmpf.v9i1.31612

Priemer, B., Eilerts, K., Filler, A., Pinkwart, N., Rösken-Winter, B., Tiemann, R., & Zu Belzen, A. U. (2020). A framework to foster problem-solving in STEM and computing education. *Research in Science and Technological Education*, *38*(1), 105–130. https://doi.org/10.1080/02635143.2019.1600490

Quinn, S., Hogan, M., Dwyer, C., Finn, P., & Fogarty, E. (2020). Development and validation of the student-educator negotiated critical thinking dispositions scale (SENCTDS). *Thinking Skills and Creativity*, *38*, 1-17. https://doi.org/10.1016/j.tsc.2020.100710

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers and Education*, *147*, 1-29. https://doi.org/10.1016/j.compedu.2019.103778

Rahayu, S., & Purwanto, J. (2013). Identifikasi model mental siswa SMA kelas X pada materi hukum newton tentang gerak. *Kaunia: Integration and Interconnection Islam and Science Journal*, *9*(2), 12–20. https://doi.org/10.14421/kaunia.1051

Rahayu, Y., Suhendar, S., & Ratnasari, J. . (2020). Keterampilan argumentasi siswa pada materi sistem gerak SMA negeri kabupaten sukabumi-indonesia. *Biodik : Jurnal Ilmiah Pendidikan Biologi*, *6*(3), 312-318. https://doi.org/10.22437/bio.v6i3.9802

Rapanta, C. (2021). Can teachers implement a student-centered dialogical argumentation method across the curriculum? *Teaching and Teacher Education*, *105*, 1-14. https://doi.org/10.1016/j.tate.2021.103404

Ristanto, R. H., Ahmad, A. S., & Komala, R. (2022). Critical thinking skills of environmental changes: A biological instruction using guided discovery learning-argument mapping (GDL-AM). *Participatory Educational Research*, *9*(1), 173–191. https://doi.org/10.17275/per.22.10.9.1

Rizaldi, D. R., Nurhayati, E., & Fatimah, Z. (2020). The correlation of digital literation and STEM integration to improve indonesian students' skills in 21st century. *International Journal of Asian Education*, *1*(2), 73–80. https://doi.org/10.46966/ijae.v1i2.36

Rohaeti, E. E., Hindun, S., & Fitriani, N. (2019). Correlation of self-efficacy and mathematical critical thinking skills based on student's cognitive stage. *Journal of Physics: Conference Series*, *1315*(1), 1-10. https://doi.org/10.1088/1742-6596/1315/1/012034

Sanjayanti, A., Rustaman, N. Y., & Hidayat, T. (2019). 6E learning by design in facilitating logical thinking and identifying algae. *AIP Conference Proceedings*, *2194*, 1-8. https://doi.org/10.1063/1.5139841

Sanjayanti, A., Rustaman, N., & Hidayat, T. (2020). Equipping students' research skills and logical thinking through practical work on algae topic. *Journal of Physics: Conference Series*, *1521*(4), 1-7. https://doi.org/10.1088/1742-6596/1521/4/042035

Saphira, H. V., & Prahani, B. K. (2022). Profile of senior high school students' critical thinking skills and the need of implementation PBL model assisted by augmented reality book. *Jurnal Pendidikan Sains Indonesia*, *10*(3), 579–591. https://doi.org/10.24815/jpsi.v10i3.25031

Sarira, P. M., Priyayi, D. F., & Astuti, S. P. (2019). Hubungan argumentasi ilmiah dan hasil belajar kognitif pada penerapan model problem based learning (PBL). *Edu Sains Jurnal Pendidikan Sains & Matematika*, *7*(2), 1–10. https://doi.org/10.23971/eds.v7i2.1258

Setiadi, I., & Elmawati, D. (2019). Discovery learning method for training critical thinking skills of students. *European Journal of Education Studies*, *6*(3), 342–351. https://doi.org/10.5281/zenodo.3345924

Suherman, S., Prananda, M. R., Proboningrum, D. I., Pratama, E. R., Laksono, P., & Amiruddin. (2020). Improving higher order thinking skills (HOTS) with project based learning (PjBL) Model Assisted by Geogebra. *Journal of Physics: Conference Series*, *1467*(1), 1-9. https://doi.org/10.1088/1742-6596/1467/1/012027

Supena, I., Darmuki, A., & Hariyadi, A. (2021). The influence of 4C (constructive, critical, creativity, collaborative) learning model on students' learning outcomes. *International Journal of Instruction*, *14*(3), 873–892. https://doi.org/10.29333/iji.2021.14351a

Suraya, S., Setiadi, A. E., & Muldayanti, N. D. (2019). Argumentasi ilmiah dan keterampilan berpikir kritis melalui metode debat. *Edusains*, *11*(2), 233–241. https://doi.org/10.15408/es.v11i2.10479

Taques, F. H., López, M. G., Basso, L. F., & Areal, N. (2021). Indicators used to measure service innovation and manufacturing innovation. *Journal of Innovation and Knowledge*, *6*(1), 11–26. https://doi.org/10.1016/j.jik.2019.12.001

Toulmin, S. E. (2003). *The uses of argument: Updated edition*. Cambridge Publishing.

Winarti, N., & Yundayani, A. (2021). Korelasi antara keterampilan berpikir kritis dengan keterampilan menulis teks argumentatif. *Prosiding Seminar Nasional Pendidikan STKIP Kusuma Negara III*, 144–152.

Yaniawati, P., Kariadinata, R., Sari, N. M., Pramiarsih, E. E., & Mariani, M. (2020). Integration of e-learning for mathematics on resource-based learning: Increasing mathematical creative thinking and self-confidence. *International Journal of Emerging Technologies in Learning*, *15*(6), 60–78. https://doi.org/10.3991/ijet.v15i06.11915

Zhai, X., Yin, Y., Pellegrino, J. W., Haudek, K. C., & Shi, L. (2020). Applying machine learning in science assessment: a systematic review. *Studies in Science Education*, *56*(1), 111–151. https://doi.org/10.1080/03057267.2020.1735757

Zhu, M., Liu, O. L., & Lee, H. S. (2020). The effect of automated feedback on revision behavior and learning gains in formative assessment of scientific argument writing. *Computers and Education*, *143*, 103668. https://doi.org/10.1016/j.compedu.2019.103668

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