JIPF (JURNAL ILMU PENDIDIKAN FISIKA)
p-ISSN: 2477-5959 | e-ISSN: 2477-8451 *Vol. 10 No. 1, January 2025, Page 125-135*

Argumentation Skills in Physisc Implementation: A Systematic Literature Review

Lucy Triananda [1*)], Heru Kuswanto [2], Jumadi [3]
Yogyakarta State University, Indonesia[1,2,3]
[*)]Corresponding E-mail: lucy.triananda0918@gmail.com

Received: September 18th, 2024. Revised: September 26th, 2024. Accepted: September 30th, 2024

Keywords :
Argumentation; Physics; Systematic Literature Review

ABSTRACT
The aim of this study are to analyze and describe the reasoning skills of students from primary school until college in understanding the learning concept and application of physics. This research focuses on the factors that influence students' concept understanding and argumentation skills in physics. The research method used was systematic literature review (SLR), a literature study in which data was collected through various published articles relevant to reasoning skills in physics from 2019 to 2023. The implementation of this research was done by collecting data through scientific articles published and indexed in the Scopus database. The data analysis technique used is the PRISMA flowchart with different levels and the VOSviewer application. The results showed that the factors effecting argumentation ability in learning physics are influenced by the learning model used, the learning approach, the way the teacher guides the learning activities, as well as environmental factors and community life.

INTRODUCTION

Education in the 21st century requires the curricula that the process of learning activities must be learner-centered, using the scientific method in every lesson so that students can be accustomed to or trained in critical thinking and be communicative or communicate well [1]. The development of science and technology requires people to improve the quality of education, where education aims at the learning process and the development of an individual into a creative, innovative, responsible and noble person [2]. Attitudes of learners are creative, innovative, responsible, and noble in education provide innovation in learning so that these activities are well prepared in schools [3]. Students' skills can be adapted based on the framework created by PISA. In the survey conducted in 2018, it was found that there are several scientific competencies, namely giving answers with scientific evidence, being able to explain existing phenomena with an appropriate application of science learning and using scientific evidence to draw conclusions and communicate assumptions, scientific evidence and appropriate reasons for conclusions [4].

The framework described by PISA clearly states that the reasoning framework plays an important role in classroom learning activities [5]. Based on this statement, reasoning is very important for the development of thinking skills, knowledge and effective communication skills in both written and oral forms among students [6]. Reasoning ability is one of the skills needed in today's world, where reasoning ability is the ability to argue with relevant information, engage in problem solving, make a statement, and make decisions supported by data and evidence when making statements [7].

Scientists use arguments to explain existing phenomena by incorporating data and scientific evidence that can support or refute a theory [8]. The development of argumentation skills is important for learning and its application, which is explained by several experts. Learners are given the opportunity to participate in learning activities that require the use of language and scientific reasoning with their classmates and teachers in order to understand the structure and evaluation of scientific reasoning. Keraf argues that argumentation is an attempt to influence the attitudes and opinions of others so that they believe and ultimately act in the author's or speaker's favor [9]. Therefore, argumentation skills need to be practiced in learning so that students can argue logically, hold clear views, and provide rational explanations to everyday events [10].

Physics is a science that deals with natural phenomena and then associated with learning materials. Physics education systematically investigates and studies every event that occurs in nature and finds existing laws and principles in accordance with facts and discoveries in daily life, for example, cognitive material, namely motion, energy, magnetism and all elements in nature. The ability to understand concepts becomes the basic of reasoning when solving problems in argumentation. Students can understand concepts when they are able to construct meaning from oral and written learning content that reasoning skills are among important to learning outcomes especially in physics learning [11]. Therefore, it is necessary to improve the quality of physics education in schools and in the environment in order to form individuals who are able to reason, be creative and communicative to solve problems based on scientific knowledge [12].

Lazarou states that students' argumentation skills increase at the elementary level when the argumentation pattern is applied, so that students learn more purposefully and understand the learning activities more easily [13]. This is consistent with what Stephen Toulmin states in his book “The Uses of Argument”, where he states that the argument pattern can have a significant impact on the way education defines and uses arguments when studying scientific material. Toulmin's argumentation shows that argument structure consists of six important components, namely reasoning, assertion, justification, support, qualification, and refutation [14].

Toulmin's argumentation pattern consists of data that supports the statement so that it can be proved but also disproved with a justification based on support. There is a relationship between data, claim, justification, support and counterargument [15]. Learners are expected to use this pattern of reasoning to arrive at 6 components, namely reasons, claims, justifications, substantiations, qualifications and refutations, so that the quality of each learner's reasoning can be measured [14]. The quality of argumentation depends on learners' conceptual understanding. Supported by some of Toulmin's components, learners can construct these components in such a way that they can convince and be understood by other learners [16].

Based on the above statement, the researchers are interested in conducting a research by analyzing several articles related to reasoning skills in learning and applying physics in everyday life. The findings are based on a literature review of a last 5 years so that the research problems to be solved are still relevant to the condition of the latest articles referenced The focus is on analyzing adapted articles published from 2019 to 2023, the purpose of the research, the research methods used in each article, the topics of the research, and the research results to determine the level of reasoning skills of a person. The aim of this research is to explain the level of a person's reasoning skills in understanding and applying physics concepts based on articles in online databases such as Scopus that have been reviewed.

METHOD

Research Design

This study uses the systematic literature review (SLR) research method in which several scholarly articles were collected to describe, review, and analyze reasoning skills, concept understanding, and the influence of reasoning in learning physics. This review applies the Item Reporting Technique for Systematic Reviews and Meta-Analyses (PRISMA) for identification, screening, eligibility checking, data entry, analysis, and presentation in narrative form. The process is carried out by identifying, screening, eligibility checking, and inclusion objectively according to the results of the reviewed data in recent articles related to the topic specified in this study. Based on the existing method, research data were collected in the form of scientific articles published in the Scopus database. This research data is a secondary source where the author didn't make any direct observations.

Inclusion and Exclusion Criteria for Publication Selection

There are six things that are done in the inclusion and exclusion stages, namely the first article indexed in the Scopus database, the second article searched based on the topic of argumentation skills in learning Physics, the third literature reviewed in the form of indexed scientific articles, the fourth article uses English and the publication of articles is limited to 2019-2023 so the research problems to be solved are still relevant to the condition.

Screening and Eligibility Test for Data Analysis

The literature search in Scopus was conducted since November 2023, and the titles, abstracts and keywords were specific to the topic and not too general. The search results yielded a total of 434 articles from Scopus with various keywords related to reasoning skills in learning and applying physics; the following data are shown in Table 1.

Table 1. Article findings from Scopus database

No	Keyword	Number of Article
1	Argumentation	50
2	Argumentation Physics	33
3	Argumentation Physisc Learning	11
4	Argumnetation Skill	340
	Total	**434**

Of the 434 articles found, the same articles were sorted out and 52 articles remained. In addition, the 52 selected articles were entered and saved in Excel format, then converted to CSV format, and then entered into the VOSviewer application version 1.6.19 to perform an initial network mapping of thematic relevance.

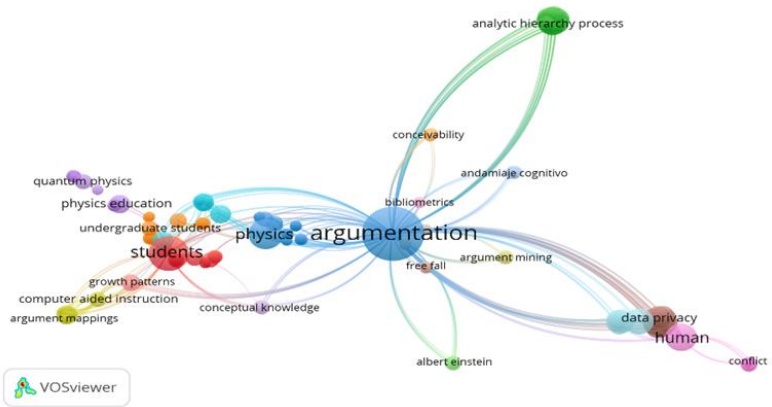

Fig 1. *Initial Network Visualization*

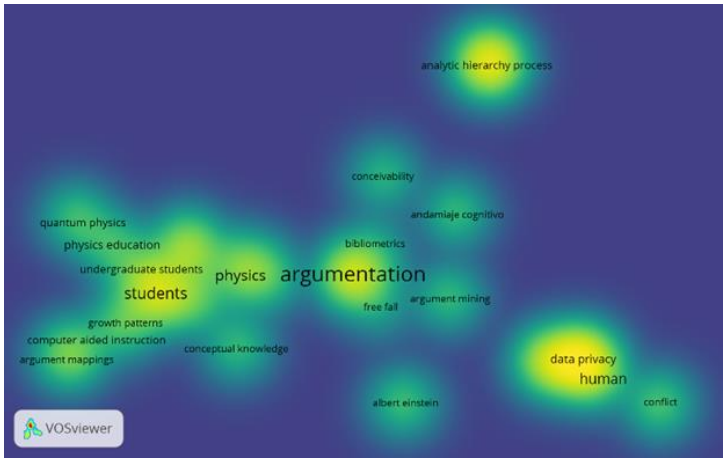

Fig 2. *Visualization of Article Distribution by Keyword*

Based on the results of the initial thematic association analysis, the topic of argumentation skills in learning physics shows a very complex association pattern in Figure 1 and the visualization of the distribution of articles based on keywords in VOSviewer in Figure 2. Figure 1 and Figure 2 show that the study on argumentation skills in learning physics is very closely related to several other study topics, such as argumentation, argumentation skills, concept knowledge, physics education, science education, learners, argumentation mapping, dialogic argumentation. Some keywords that are closely related to the topic of this study are mining argumentation, e-learning, quantum physics, artificial intelligence, and analytic hierarchy process.

Prism Flow Chart

In this study, the PRISM technique is applied to the search for articles in four stages. These stages are identification, filtering, suitability and inclusion. A total of 434 articles were found in the Scopus database. The articles were then checked for similarity using keywords, leaving 281 articles, while 153 similar articles were discarded. The article search only referred to the Scopus database, so the similarity was seen in the keywords used. Of the 281 articles, 191 irrelevant reports were screened out, leaving 60 articles. Subsequently, 60 full-text articles were selected and the remaining 52 articles were suitable for the research question in terms of title, abstract, keywords and comprehensive article content. The results are presented in line with this research, which deals with argumentation skills in physics education.

Fig 3. *Prism Flowchart*

RESULTS AND DISCUSSIONS

Based on the data obtained on articles on argumentation skills, each aspect will then be analyzed by looking at the number of article publications from 2019 to 2023, the methods and topics, and the results of each research paper on argumentation. Using some of these analyses, the researchers will lead discussions on the implementation of argumentation in physics education, the quality of argumentation skills in physics education, student engagement in argumentation skills, and the importance of mastering argumentation in explaining physics science concepts. The research findings, based on the year of publication of articles on argumentation skills in learning physics, are presented in Figure 4 as follows.

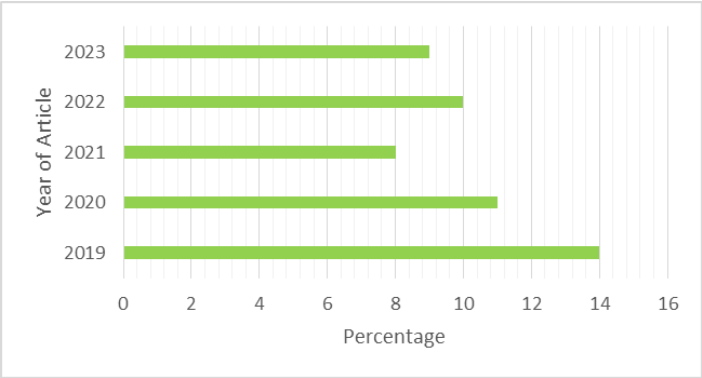

Fig 4. *Article Distribution 2019-2023*

Based on the total number of peer-reviewed articles, namely 52 articles on the topic of argumentation skills in physics education, Figure 4 shows that the publication of these articles is spread over several years with different numbers. In 2019, 14 articles were reviewed, in 2020 11, in 2021 8, in 2022 10 and in 2023 9. From the available data, it appears that only marginally more articles on argumentation have been published in the last 5 years, meaning that each year has seen a jump or decline.

The type of research method used in some of the articles reviewed can be seen in Diagram 5, which shows that many studies used qualitative methods. One example is collaborative hybrid learning based on physical reasoning with computer support to improve concept acquisition and reasoning skills, where the research referred to the development and implementation of a computer-based hybrid learning model with a physical reasoning approach [17].

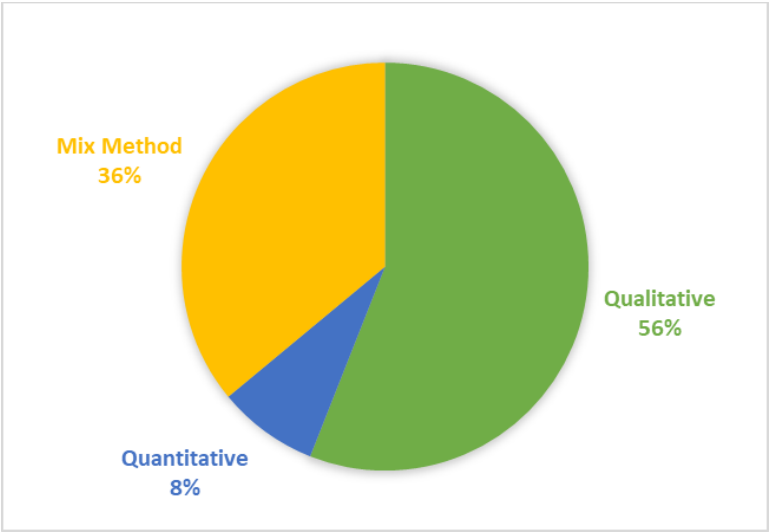

Fig 5. *Distribution of Articles by Research Method*

The results of the figure show that the 52 articles examined are divided into different research methods, namely articles using qualitative, quantitative and mix methods. The researchers used qualitative methods in 56%, namely 28 articles, quantitative methods in 8%, namely 4 articles, and qualitative methods in 36%, namely 18 articles. Following the analysis of the distribution of research methods, the distribution of articles is now analyzed according to the subject of the research conducted.

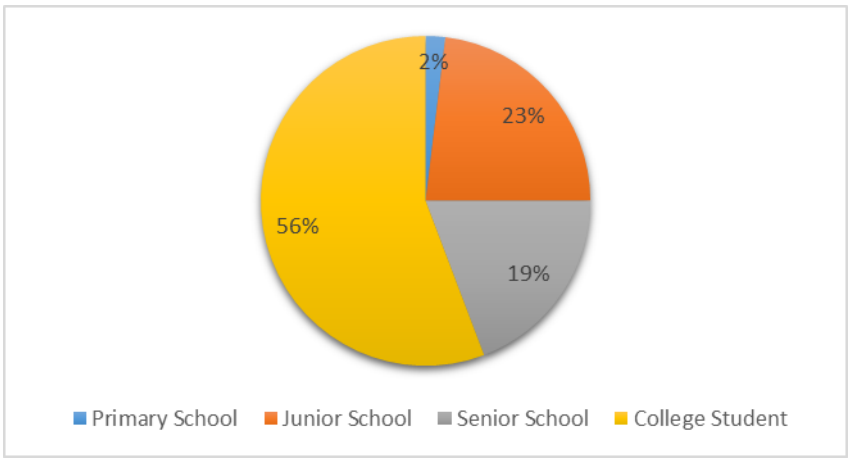

Fig 6. *Distribution of Articles by Research Subject*

Figure 6 shows data on the research topics used in the 52 articles studied. From the data obtained, it can be seen that college students are used as research topics in 29 articles, junior students are used as research topics in 12 articles, senior student are used as research topics in 10 articles, and primary school is used as research topics in 1 articles. Based on the present data, it can be concluded that the implementation of research related to reasoning skills in learning and applying physics is widespread in schools by including students as research subjects.

This research, which examined articles on argumentation skills, also found that the application of argumentation skills was not performed optimally, so the ability to argue is still at a low level [18]. Low reasoning ability can be influenced by various factors, such as the learning model applied, the way the teacher guides the learning activities, the learning model approach applied, and other factors such as the influence of the environment [4]. Obtaining articles from several researchers revealed analyses consistent with this literature review as follows.

Implementation of Argumentation in Physics Learning
Argumentation in Physics learning is still not effectively applied in learning. Although argumentation has been a focus in Physics learning for some time, it is still rarely found in Physics learning. In addition, there is also a link between language skills and argumentation, where the use of language in a generative way can improve the quality of argumentation and Physics learning. It is common to find that students in explaining Physics concepts often provide arguments without data and evidence to support their statements [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32].

Quality of Argumentation Skills in Physics Learning
Research conducted by Suliyanah in 2020 show that the results is the quality of the students' reasoning in one of the grammar schools is in the middle category [33]. There are several factors that can determine the quality of students' reasoning ability in the context of physics education, namely 1) accuracy of concept, 2) adequacy of evidence and reasoning, 3) logic and consistency, 4) use of clear language, 5) ability to distinguish fact from opinion, 6) consideration of experiments and observations, 7) consideration of practical context, 8) ability to receive feedback. The low quality of reasoning skills can also be influenced by other aspects outside the learning activities [17] [34] [35] [36] [37] [38].

Learner Involvement in Argumentation Skills

Learner involvement in argumentation is an important aspect of developing critical thinking and communication skills. Several articles suggest that there are several ways to improve learner engagement in argumentation in learning, particularly the collaborative approach where group discussions provide opportunities for learners to work together to compose arguments. In addition, learner discussion provides open-ended questions that encourage learners to think more deeply and develop stronger arguments with appropriate scientific evidence. In addition, project-based activities can influence learners' reasoning when learners are asked to write presentations or argumentative articles on a physics topic, one of which has to do with motion. By integrating different approaches, a learning environment can be created that appropriately supports the development of learners' argumentation skills [39] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50] [51].

The Importance of Argumentation in Explaining Scientific Concepts in Physics

The studies carried out have shown that reasoning skills are still at a low level. The mastery of reasoning in explaining scientific concepts in physics plays a very important role in learning physics. Reasoning skills are considered important for the following reasons: 1) Develop a deep understanding of physics concepts. 2) Reasoning skills can enhance critical thinking skills by explaining physics concepts. 3) Reasoning skills involve effective communication skills. 4) Developing confidence in the process of argument formation can help learners. 5) Encouraging creativity: argumentation is not just about communicating facts. 6) Shaping learners' scientific thinking in argumentation. 7) Preparation for theory development. Therefore, mastering reasoning in explaining scientific concepts in physics is not only an academic skill, but also a skill that promotes learners' intellectual and professional development in the long term [52] [53] [54] [55] [56] [57] [58] [59] [60] [61] [61] [63] [64] [65].

CONCLUSION AND SUGGESTION

Based on the review in this study with a systematic method of literature review of several articles from 2019 to 2023. Application of existing methods Many articles examine the argumentation skills of students with qualitative methods where in their activities by examining students' arguments and interviews which then each argument is adjusted to the Toulmin argumentation pattern. It can conclude that the articles reviewed obtained that the argumentation skills of students in learning Physics are at a low level. Previous research has shown that the quality of learners' argumentation is mostly rated low, which means that limited information or limited competence in reasoning limits the ability of each individual. This can influence by several factors such as the application of learning models, learning approaches used, teachers guiding learning activities, and external factors such as from the environment and social life. Argumentation skills are considered important in learning activities because they affect the intellectual development of an individual. The suggestions that must be made in future studies are that researchers find out the right way so that the argumentation skills of students in learning are more improved, especially in learning and applying Physics.

ACKNOWLEDGMENTS

Appreciate to say thank you very much to all those who participated in the making of this article. The researcher would like to thank also the lecturers of yogyakarta state university especially for Prof. Dr. Heru Kuswanto, M.Si and Prof. Jumadi, M.Pd. whom as the lecturers in charge of the latest studies and research in physics education where you have guided and helped in the work on this research article. Hopefully the article can be useful in the development of other scientific articles.

REFERENCES

[1] Farida, L., Rosidin, U., Herlina, K., & Hasnunidah, N. (2018). Pengaruh Penerapan Model Pembelajaran Argumentdriven Inquiry (Adi) Terhadap Keterampilan Argumentasi Siswa Smp Berdasarkan Perbedaan Jenis Kelamin. *Journal of Physics and Science Learning*, *2*(2), 25-36.
[2] Imaniar, B. O., & Astutik, S. (2019). Analisis kemampuan argumentasi siswa SMP pada pembelajaran IPA. *FKIP e-PROCEEDING*, *4*(1), 92-96.
[3] Handayani, P. (2015). Analisis argumentasi peserta didik kelas x sma muhammadiyah 1 palembang dengan menggunakan model argumentasi toulmin. *Jurnal Inovasi dan Pembelajaran Fisika*, *2*(1), 60-68.
[4] Eliana, D. I. N. A., & Admoko, S. (2020). Tren Pembelajaran Argumentasi Berbasis Toulmins Argument Pattern (Tap) Dalam Meningkatkan Kemampuan Argumentasi Dan Pemahaman Konsep Fisika Peserta Didik. *Inovasi Pendidikan Fisika*, *9*(2), 246-255.
[5] Ambarawati, D. S. H. E., Muslim, M., & Hernani, H. (2021). Analisis kemampuan argumentasi siswa SMP pada materi pencemaran lingkungan. *Inkuiri: Jurnal Pendidikan IPA*, *10*(1), 13-17.
[6] Nugraha, T. H., & Pujiastuti, H. (2019). Analisis kemampuan komunikasi matematis siswa berdasarkan perbedaan gender. *Edumatica: Jurnal Pendidikan Matematika*, *9*(1), 1-7.
[7] Afgani, T., Hasnunidah, N., & Surbakti, A. (2020). Pengaruh Model Pembelajaran Argument-Driven Inquiry (ADI) Dan Gender Terhadap Keterampilan Argumentasi Siswa. *Jurnal Bioterdidik: Wahana Ekspresi Ilmiah*, *8*(1), 1-10.
[8] Hendri, S., & Defianti, A. (2015). Membentuk keterampilan argumentasi siswa melalui isu sosial ilmiah dalam pembelajaran sains. *Prosiding Simposium Inovasi dan Pembelajaran Sains*, 545-548.
[9] Dafrida,, Maria Rezti (2018) *Pemanfaatan elemen-elemen dasar argument dan kadar ketajamannya dalam esai argumentatif.* Skripsi thesis, Sanata Dharma University.
[10] Ginanjar, W. S., Utari, S., & Muslim, M. (2015). Penerapan model argument-driven inquiry dalam pembelajaran IPA untuk meningkatkan kemampuan argumentasi ilmiah siswa SMP. *Jurnal Pengajaran Matematika Dan Ilmu Pengetahuan Alam*, *20*(1), 32-37.
[11] Widhi, M. T. W., Hakim, A. R., Wulansari, N. I., Solahuddin, M. I., & Admoko, S. (2021). Analisis keterampilan argumentasi ilmiah peserta didik pada model pembelajaran berbasis toulmin's argumentation pattern (TAP) dalam memahami konsep fisika dengan metode library research. *PENDIPA Journal of Science Education*, *5*(1), 79-91.
[12] Siregar, N., & Pakpahan, R. A. (2020). Kemampuan Argumentasi IPA Siswa Melalui Pembelajaran Argument Driven Inquiry (ADI). *LENSA (Lentera Sains): Jurnal Pendidikan IPA*, *10*(2), 94-103.
[13] National Research Council, Board on Science Education, National Committee on Science Education Standards, & Assessment. (1995). *National science education standards*. National Academies Press.
[14] Febriyanti, D., Sjaifuddin, S., & Biru, L. T. (2022). Analisis proses pembelajaran IPA terpadu dalam pelaksanaan kurikulum 2013 di SMP kecamatan sumur. *PENDIPA Journal of Science Education*, *6*(1), 218-225.
[15] Marhamah, O. S., Nurlaelah, I., & Setiawati, I. (2017). Penerapan model argument-driven inquiry (ADI) dalam meningkatkan kemampuan berargumentasi siswa pada konsep pencemaran lingkungan di kelas X SMA Negeri 1 Ciawigebang. *Quagga: Jurnal Pendidikan dan Biologi*, *9*(02), 39-45.
[16] Murdani, E., Suhandi, A., Muslim, M., Setiawan, A., Samsudin, A., & Costu, B. (2023). Physics Argumentation-Based Computer-Supported Collaborative Hybrid Learning to Increase Concept Mastery and Argumentation Skills. *Jurnal Pendidikan IPA Indonesia*, *12*(2), 232-240.
[17] Cari, C., Pratiwi, S. N., Aminah, N. S., & Nugraha, D. A. (2019, December). Analysis of student argumentation skills on static fluid topics. In *AIP Conference Proceedings* (Vol. 2202, No. 1). AIP Publishing.
[18] Franqueira, V. N., & Horsman, G. (2020). Towards sound forensic arguments: structured argumentation applied to digital forensics practice. *Forensic Science International: Digital Investigation*, *32*, 300923.

[19] Rø, K., & Arnesen, K. K. (2020). The opaque nature of generic examples: The structure of student teachers' arguments in multiplicative reasoning. *The Journal of Mathematical Behavior*, *58*, 100755.
[20] Yilmaz-Na, E., & Sönmez, E. (2023). Unfolding the potential of computer-assisted argument mapping practices for promoting self-regulation of learning and problem-solving skills of pre-service teachers and their relationship. *Computers & Education*, *193*, 104683.
[21] Canoz, G. M., Ucar, S., & Demircioglu, T. (2022). Investigate the effect of argumentation-promoted interactive simulation applications on students' argumentation levels, academic achievements, and entrepreneurship skills in science classes. *Thinking Skills and Creativity*, *45*, 101106.
[22] Figueira, M. J. S., Nardi, R., & Cortela, B. S. C. (2019, August). Introducing scientific argumentation practices in physics teacher's undergraduate curricula. In *Journal of Physics: Conference Series* (Vol. 1286, No. 1, p. 012038). IOP Publishing.
[23] Rosmiati, R., Liliasari, L., Tjasyono, B., Ramalis, T. R., & Satriawan, M. (2020). Measuring level of reflective thinking of physics pre-service teachers using effective essay argumentation. *Reflective practice*, *21*(4), 565-586.
[24] Cikmaz, A., Fulmer, G., Yaman, F., & Hand, B. (2021). Examining the interdependence in the growth of students' language and argument competencies in replicative and generative learning environments. *Journal of Research in Science Teaching*, *58*(10), 1457-1488.
[25] Nurjannah, N., Setiawan, A., Rusdiana, D., & Muslim, M. (2019, February). Students' critical thinking skills toward analyzing argumentation on heat conductivity concept. In *Journal of Physics: Conference Series* (Vol. 1157, No. 3, p. 032053). IOP Publishing.
[26] Noviyanti, N. I., Mukti, W. R., Yuliskurniawati, I. D., Mahanal, S., & Zubaidah, S. (2019, June). Students' scientific argumentation skills based on differences in academic ability. In *Journal of Physics: Conference Series* (Vol. 1241, No. 1, p. 012034). IOP Publishing.
[27] Arslan, H. O., Genc, M., & Durak, B. (2023). Exploring the effect of argument-driven inquiry on pre-service science teachers' achievement, science process, and argumentation skills and their views on the ADI model. *Teaching and Teacher Education*, *121*, 103905.
[28] Lawrence, J., Visser, J., & Reed, C. (2023). Translational argument technology: Engineering a step change in the argument web. *Journal of Web Semantics*, *77*, 100786.
[29] Lobczowski, N. G., Allen, E. M., Firetto, C. M., Greene, J. A., & Murphy, P. K. (2020). An exploration of social regulation of learning during scientific argumentation discourse. *Contemporary Educational Psychology*, *63*, 101925.
[30] Hahn, U., & Tešić, M. (2023). Argument and explanation. *Philosophical Transactions of the Royal Society A*, *381*(2251), 20220043.
[31] Athe, P., & Dinh, N. (2019). A framework for assessment of predictive capability maturity and its application in nuclear thermal hydraulics. *Nuclear Engineering and Design*, *354*, 110201.
[32] D'auria, F. (2012). Perspectives in system thermal-hydraulics. *Nuclear Engineering and Technology*, *44*(8), 855-870.
[33] Suliyanah, S., Fadillah, R. N., & Deta, U. A. (2020, March). The process of developing students' scientific argumentation skill using argument-driven inquiry (ADI) model in senior high school on the topic of elasticity. In *Journal of Physics: Conference Series* (Vol. 1491, No. 1, p. 012046). IOP Publishing.
[34] Wang, J. (2020). Scrutinising the positions of students and teacher engaged in argumentation in a high school physics classroom. *International Journal of Science Education*, *42*(1), 25-49.
[35] Foutz, T. L. (2019). Using argumentation as a learning strategy to improve student performance in engineering Statics. *European Journal of Engineering Education*, *44*(3), 312-329.
[36] Kilpelä, J., Hiltunen, J., Hähkiöniemi, M., Jokiranta, K., Lehesvuori, S., Nieminen, P., & Viiri, J. (2023). Analyzing science teachers' support of dialogic argumentation using teacher roles of questioning and communicative approaches. *Dialogic Pedagogy: A Journal for Studies of Dialogic Education*, *11*(3), A88-A118.
[37] Utomo, Y. S., Ashadi, A., & Sarwanto, S. (2019, June). Argumentation skills profile on 8th grade students using Toulmin's argument pattern on controversial topic. In *Journal of Physics: Conference Series* (Vol. 1233, No. 1, p. 012095). IOP Publishing.
[38] Nakrowi, Z. S., & Mulyati, Y. (2021). Evaluasi Kualitas Argumen Pada Artikel Jurnal. *LITERA*,

20(1), 90-109.
[39] El Majidi, A., Janssen, D., & de Graaff, R. (2021). The effects of in-class debates on argumentation skills in second language education. *System*, *101*, 102576.
[40] Barrera Lemarchand, F., Semeshenko, V., Navajas, J., & Balenzuela, P. (2020). Polarizing crowds: Consensus and bipolarization in a persuasive arguments model. *Chaos: An Interdisciplinary Journal of Nonlinear Science*, *30*(6).
[41] Demircioglu, S., & Cin, M. O. (2019). An argumentation-based demonstration experiment in teaching the light–matter interaction. *Physics Education*, *54*(5), 055010.
[42] Iwuanyanwu, P. N., & Ogunniyi, M. B. (2020). Effects of dialogical argumentation instructional model on pre-service teachers' ability to solve conceptual mathematical problems in physics. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(1), 129-141.
[43] Strasberg, P., Modi, K., & Skotiniotis, M. (2022). How long does it take to implement a projective measurement?. *European Journal of Physics*, *43*(3), 035404.
[44] Gingras, Y. (2022). Towards a moralization of bibliometrics? A response to Kyle Siler. *Quantitative Science Studies*, *3*(1), 315-318.
[45] Wu, C. J., & Liu, C. Y. (2021). Eye-movement study of high-and low-prior-knowledge students' scientific argumentations with multiple representations. *Physical Review Physics Education Research*, *17*(1), 010125.
[46] Pols, F., Dekkers, P., & de Vries, M. (2019). Introducing argumentation in inquiry—a combination of five exemplary activities. *Physics education*, *54*(5), 055014.
[47] Sundstrom, M., & Cardetti, F. (2021). Exploring the introductory physics classroom through the lens of intellectual humility: Handling what you do not know. *Physical Review Physics Education Research*, *17*(2), 020135.
[48] Vörös, A. I. V. (2020). Panel debate on energy production in high school physics teaching. *Canadian Journal of Physics*, *98*(6), 579-587.
[49] Tóth, K., & Tél, T. (2023). Quantum uncertainty: what to teach?. *Physics Education*, *58*(2), 025019.
[50] Van den Eynde, S., Van Kampen, P., Van Dooren, W., & De Cock, M. (2019). Translating between graphs and equations: The influence of context, direction of translation, and function type. *Physical Review Physics Education Research*, *15*(2), 020113.
[51] Possebom, A. T., Morveli-Espinoza, M., & Tacla, C. A. (2019). A framework for the consensus decision-making based on arguments and common knowledge formation. *Acta Scientiarum. Technology*, *41*, e37955.
[52] Benz, G., Buhlinger, C., & Ludwig, T. (2022). 'Big data'in physics education: discovering the stick-slip effect through a high sample rate. *Physics Education*, *57*(4), 045004.
[53] Siverling, E. A., Suazo-Flores, E., Mathis, C. A., & Moore, T. J. (2019). Students' use of STEM content in design justifications during engineering design-based STEM integration. *School Science and Mathematics*, *119*(8), 457-474.
[54] Pols, C. F. J., Dekkers, P. J. J. M., & De Vries, M. J. (2022). Defining and assessing understandings of evidence with the assessment rubric for physics inquiry: Towards integration of argumentation and inquiry. *Physical Review Physics Education Research*, *18*(1), 010111.
[55] Bøe, M. V. (2023). Staying recognised as clever: high-achieving physics students' identity performances. *Physics Education*, *58*(3), 035012.
[56] Ruiz-Dolz, R., Nofre, M., Taulé, M., Heras, S., & García-Fornes, A. (2021). Vivesdebate: A new annotated multilingual corpus of argumentation in a debate tournament. *Applied Sciences*, *11*(15), 7160.
[57] Conceição, L., Rodrigues, V., Meira, J., Marreiros, G., & Novais, P. (2022). Supporting Argumentation Dialogues in Group Decision Support Systems: An Approach Based on Dynamic Clustering. *Applied Sciences*, *12*(21), 10893.
[58] Hadianto, D., Damaianti, V. S., Mulyati, Y., & Sastromiharjo, A. (2021, November). Enhancing scientific argumentation skill through partnership comprehensive literacy. In *Journal of Physics: Conference Series* (Vol. 2098, No. 1, p. 012015). IOP Publishing.
[59] Ain, T. N., Wibowo, H. A. C., Rohman, A., & Deta, U. A. (2018, March). The scientific argumentation profile of physics teacher candidate in Surabaya. In *Journal of Physics:*

Conference Series (Vol. 997, No. 1, p. 012025). IOP Publishing.
[60] Woodcox, A. (2022). Logikôs Argumentation in Aristotle's Natural Science. *apeiron*, *55*(1), 65-95.
[61] Pols, C. F. J., Dekkers, P. J. J. M., & De Vries, M. J. (2022). 'Would you dare to jump?'Fostering a scientific approach to secondary physics inquiry. *International Journal of Science Education*, *44*(9), 1481-1505.
[62] Hähkiöniemi, M., Hiltunen, J., Jokiranta, K., Kilpelä, J., Lehesvuori, S., & Nieminen, P. (2022). Students' dialogic and justifying moves during dialogic argumentation in mathematics and physics. *Learning, Culture and Social Interaction*, *33*, 100608.
[63] Hähkiöniemi, M., Nieminen, P., & Jokiranta, K. (2019). Three dimensions of dialogicity in dialogic argumentation. *Studia paedagogica*, *24*(4), 199-219.
[64] Ludwig, T., Priemer, B., & Lewalter, D. (2021). Assessing secondary school students' justifications for supporting or rejecting a scientific hypothesis in the physics lab. *Research in Science Education*, *51*(3), 819-844.
[65] Durango-Urrego, J. H., Castro, W. F., Goizueta, M., & López, C. M. J. (2023). Assessment of students' understanding of physical phenomena through argumentative qualities of written texts. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(3), em2239.