Debate Based on Inquiry Learning (DBOIL): An Innovative Learning Model to Improve Students' Skills in Scientific Argumentation

Ahmad Fauzi Hendratmoko [1], Madlazim Madlazim [1], Wahono Widodo [1], Sri Astutik [2]

[1]*Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Surabaya, Indonesia*
[2]*Faculty of Teacher Training and Education, Universitas Jember, Jember, Indonesia*

Abstract **– In the 21st century, education places significant emphasis on developing scientific argumentation as a crucial skill. Teaching these skills requires an instructional design that allows students to construct and critique arguments actively, support claims with evidence and reasoning, and then reject opposing claims and evidence. Debate based on inquiry learning (DBOIL) is an innovative learning model that was developed and is believed to be able to facilitate these things. This research seeks to assess the influence of implementing DBOIL on enhancing students' skills in scientific argumentation. This research employed a one-group pretest-posttest design, with normalized change analysis and paired t-test. Research findings indicate that the implementation of DBOIL has demonstrably improved scientific argumentation skills, with a notable 76.67% of students exhibiting improvement in the high category. Other findings show that each phase of DBOIL significantly contributes to increasing the achievement of indicators of scientific argumentation. To maintain the reliability of DBOIL in enhancing students' skills in scientific argumentation, conducting future research on a broader scale is imperative.**

DOI: 10.18421/TEM134-64
https://doi.org/10.18421/TEM134-64

Corresponding author: Madlazim,
Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Surabaya, Indonesia.
Email: madlazim@unesa.ac.id

Received: 19 May 2024.
Revised: 04 September 2024.
Accepted: 26 October 2024.
Published: 27 November 2024.

Keywords **– Scientific argumentation, debate based on inquiry learning, innovative learning models, 21^{st} century skills, inquiry approaches.**

1. Introduction

Scientific argumentation stands as a pivotal focal point in contemporary educational priorities. These are skills needed by students to be successful in a variety of academic and professional domains [1], [2], [3]. This is because scientific argumentation is an integral part of academic discourse which plays an important role in building and disseminating knowledge [4], [5]. In addition, these skills have also been considered as one of the key components in critical thinking [6], [7], [8], [9]. These skills are equally essential for articulating viewpoints, decision-making, and resolving everyday challenges [10].

Educational designs for teaching scientific argumentation skills necessitate learning frameworks that offer ample opportunities for students to construct and critique arguments, assert claims, and employ evidence within the context of inquiry-based activities [11]. Another thing that is crucial to acknowledge is that the essence of argumentation lies in substantiating claims with evidence and sound reasoning, while also engaging in the critical evaluation or rebuttal of opposing claims and evidence [12]. However, the currently available learning models are not capable enough to facilitate these things.

The results of a preliminary study conducted by researchers show information that inquiry-based learning models and debate are learning models that are commonly used to teach scientific argumentation skills to students. Indeed, the inquiry-based learning model has demonstrated efficacy in enhancing these skills, particularly in the aspects of formulating claims, presenting evidence, and constructing sound reasoning [13], [14], [15], [16] it may not yield the same impact on aspects like counterclaim development and rebuttal [17].

On the other hand, debate in learning activities is more capable of increasing these two things, namely counterclaim and rebuttal [1], [18], [19], [20]. Nevertheless, debates alone may not adequately facilitate opportunities for students to engage in inquiry activities, gather evidence, and construct reasoning based on this evidence. Another interesting finding from the preliminary study suggests integrating inquiry and debate. This is regarded as a promising learning strategy for enhancing students' skills in scientific argumentation [21].

Building upon the findings from the preliminary study, debate based on inquiry learning (DBOIL) was formulated. This represents an innovative learning model aimed at enhancing students' skills in scientific argumentation. This learning model is constructed based on the advantages of inquiry-based learning models and debate. DBOIL also serves as a solution to mitigate the constraints encountered by both inquiry-based learning models and debate, thereby maximizing the potential increase in students' scientific argumentation skills. The DBOIL syntax was built through modification and integration between the syntax of inquiry-based learning models and debate.

Given its myriad advantages, DBOIL is perceived as a potent learning model for enhancing students' skills in scientific argumentation. Hence, this research endeavors to validate this assertion by describing the initial and final scientific argumentation skills of students, as well as quantifying the improvement in these scientific argumentation skills attributed to the implementation of DBOIL. Additionally, this research aims to elucidate the individual contributions of each phase within DBOIL towards enhancing the achievement of the indicators of scientific argumentation, encompassing claim, evidence, reasoning, counterclaim, and rebuttal. These indicators are an integration between the Toulmin argument pattern [22] and the work of Erduran [23].

2. Methodology

In the following sub-sections, the research design, participants, data gathering, and analysis are presented.

2.1. Research Design

This research utilized a one-group pretest-posttest design. This is a single-group research design, has limited internal validity, and there is no control group [24]. The selection of this research design was informed by findings suggesting that small groups offer an ideal setting for fostering critical-analytical thinking in students through inquiry and argumentation [25], [26].

Additionally, research in small groups puts students in a better position to handle the challenging problems of the 21st century [27]. The research design is depicted in Figure 1.

Figure 1. Research design

Before implementing DBOIL, the pretest is utilized to determine the students' foundational skills in scientific argumentation. Meanwhile, the posttest aims to evaluate the students' ultimate scientific argumentation skills after the DBOIL implementation. The pretest and posttest scores are subsequently employed as benchmarks for gauging the enhancement in students' scientific argumentation skills attributable to the implementation of DBOIL.

The treatment given in this research is the implementation of DBOIL in classroom learning activities. DBOIL is a learning model comprising six distinct phases in its syntax, namely: 1) problem orientation, 2) making claims, 3) collecting data or scientific evidence, 4) formulating reasoning, 5) structured debate, and 6) evaluation and reflection. Learning activities in each phase of DBOIL are described in detail in Table 1.

Table 1. Learning activities with DBOIL

DBOIL Phase	Student Activities
Phase 1: Problem orientation	Students concentrate their attention and elevate their motivation to actively engage in learning tasks, comprehend the intended learning outcomes, and grasp the problems presented in the worksheet.
Phase 2: Making claims	Students conduct group discussions to analyze problems and make claims about these problems.
Phase 3: Collecting data or scientific evidence	Students in groups design and carry out investigative activities to collect data or evidence to strengthen claims that have been prepared previously.
Phase 4: Formulating reasoning	Students in groups formulate reasoning by analyzing evidence and identifying related concepts, principles, laws, or theories to show the connection between the evidence used to strengthen claims.
Phase 5: Structured debate	Students conduct debate activities by presenting their prepared arguments, defending them from various conflicting criticisms, and refuting opposing arguments.
Phase 6: Evaluation and reflection	Under the guidance of lecturers, students assess and contemplate the learning activities they have undertaken.

2.2. Participants

Participants in this research were 30 students majoring in science education at a university in Surabaya, Indonesia. The participants were dominated by female students, with a percentage of 86.67%. They are prospective science teacher students who are required to have good scientific argumentation skills. Therefore, to develop their scientific argumentation skills, participants will take part in learning activities using DBOIL for 8 meetings.

2.3. Data Gathering and Analysis

The data gathered and analyzed in this research comprised the pretest and posttest scores describing students' skills in scientific argumentation. The pretest and posttest questions were developed based on 5 indicators of scientific argumentation, namely claim, evidence, reasoning, counterclaim, and rebuttal [22], [23]. The pretest and posttest scores were analyzed descriptively to determine the level of students' skills in scientific argumentation. Determination of these levels is based on findings from [17], as described in detail in Table 2.

Table 2. Level of students' skills in scientific argumentation

Score	Level
2.25 < n ≤ 3.00	Proficient
1.50 < n ≤ 2.25	Advanced
0.75 < n ≤ 1.50	Intermediate
0.00 < n ≤ 0.75	Beginner

The improvement of students' skills in scientific argumentation resulting from the implementation of DBOIL is grounded in the outcomes of the normalized change (*c*) analysis (Equation 1) [28], [29]. The scores derived from this analysis were subsequently subjected to descriptive analysis to identify the various categories of improvement of students' skills in scientific argumentation attributable to the adoption of DBOIL. These improvement categories are described in Table 3.

$$c = \begin{cases} \dfrac{\text{Posttest} - \text{Pretest}}{\text{Max} - \text{Pretest}} & \text{Posttest} > \text{Pretest} \\ \text{drop} & \text{Posttest} = \text{Pretest} = \text{Max or Min} \\ 0 & \text{Posttest} = \text{Pretest} \\ \dfrac{\text{Posttest} - \text{Pretest}}{\text{Pretest} - \text{Min}} & \text{Posttest} < \text{Pretest} \end{cases} \quad (1)$$

Table 3. Categories of improvement of students' skills in scientific argumentation

Normalized Change Score (c)	Improvement Category
c ≥ 0.7	High
0.7 < c ≤ 0.3	Medium
0.3 < c ≤ 0.0	Low
c < 0.0	No Increase Occurs (Decrease)

Data on improving students' skills in scientific argumentation is also strengthened by statistical analysis through the paired t-test. This is employed to ascertain whether there exists a notable disparity between the pretest and posttest scores reflecting students' skills in scientific argumentation due to the adoption of DBOIL. The paired t-test was carried out using the software IBM SPSS Statistics version 26.

3. Results

Students' skills in scientific argumentation are measured based on pretest and posttest scores. The pretest and posttest scores were utilized to assess the level of students' skills in scientific argumentation both before and after engaging in learning activities with DBOIL. It is additionally employed to gauge the rise in students' skills in scientific argumentation resulting from the implementation of DBOIL, as assessed through normalized change analysis. The pretest, posttest scores, and improvement of students' skills in scientific argumentation in the research are presented in Table 4.

Table 4. Pretest, posttest scores, and improvement of students' skills in scientific argumentation

No.	Pretest		Posttest		Increase	
	Score	Lvl.	Score	Lvl.	Score *c*	Cat.
S-01	0.67	B	2.33	P	0.71	High
S-02	1.33	I	2.73	P	0.84	High
S-03	1.00	I	2.53	P	0.77	High
S-04	1.40	I	2.80	P	0.88	High
S-05	1.00	I	2.53	P	0.77	High
S-06	1.47	I	2.67	P	0.78	High
S-07	0.53	B	2.00	A	0.59	Med.
S-08	0.93	I	2.87	P	0.94	High
S-09	1.00	I	2.07	A	0.53	Med.
S-10	0.93	I	2.47	P	0.74	High
S-11	0.20	B	2.20	A	0.71	High
S-12	1.00	I	2.60	P	0.80	High
S-13	0.67	B	2.47	P	0.77	High
S-14	1.13	I	2.93	P	0.96	High
S-15	0.80	I	2.47	P	0.76	High
S-16	1.20	I	2.73	P	0.85	High
S-17	0.53	B	2.33	P	0.73	High
S-18	0.80	I	2.20	A	0.64	Med.
S-19	1.13	I	2.87	P	0.93	High
S-20	0.67	B	2.60	P	0.83	High
S-21	0.53	B	2.20	A	0.68	Med.
S-22	0.73	B	2.53	P	0.79	High
S-23	0.53	B	2.47	P	0.78	High
S-24	0.93	I	2.40	P	0.71	High
S-25	0.87	I	2.33	P	0.69	Med.
S-26	0.87	I	2.20	A	0.63	Med.
S-27	0.80	I	2.80	P	0.91	High
S-28	0.53	B	2.53	P	0.81	High
S-29	0.67	B	3.00	P	1.00	High
S-30	0.87	I	2.20	A	0.63	Med.
Ave.	**0.81**	**I**	**2.33**	**P**	**0.72**	**High**

Information:
B = Beginner, I = Intermediate, A = Advanced, and
P = Proficient

The pretest scores show that students have initial skills in scientific argumentation, the majority of which are at the intermediate level and the rest are at the beginner level. Meanwhile, the posttest results show data that is quite contrasting with the pretest scores.

The posttest scores show that the majority of students' final skills in scientific argumentation after participating in learning activities with DBOIL are at the proficient level and the rest are at the advanced level. A comparison of the level of students' skills in scientific argumentation before and after engaging in learning activities with DBOIL is presented in Figure 2.

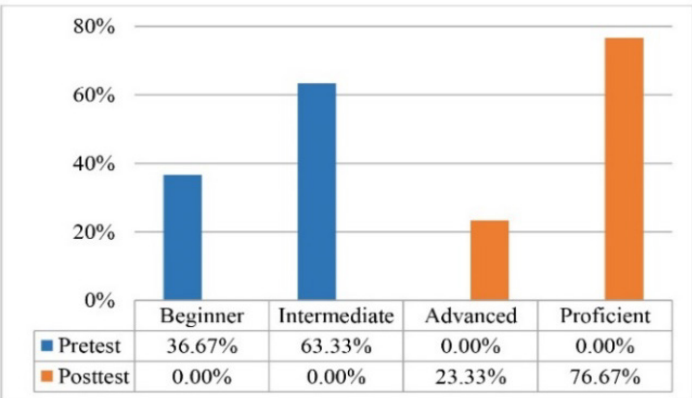

Figure 2. Comparison of the level of students' skills in scientific argumentation based on pretest and posttest results

Overall, the improvement of students' skills in scientific argumentation as a result of the implementation of DBOIL is in the high category. Most students witnessed an elevation in their skills in scientific argumentation categorized as high, while a small percentage experienced an increase classified as medium. An interesting finding in this research is that there were no students who experienced improvement in the low category and there were also no students who experienced a decline in scientific argumentation skills after taking part in learning activities with DBOIL (Figure 3).

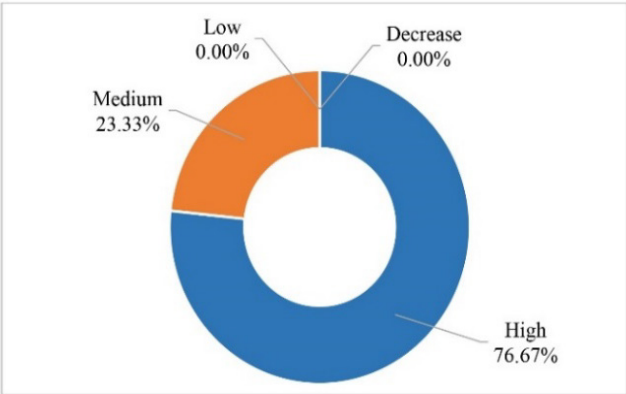

Figure 3. Categories of improvement in students' skills in scientific argumentation as a result of implementing DBOIL

On average, the improvement in students' skills in scientific argumentation following participation in learning activities with DBOIL falls within the high category. From the pretest and posttest scores, it is evident that the average student initially had skills in scientific argumentation at an intermediate level, which enhanced to a proficient level following the implementation of DBOIL (Table 4). The validity of these findings was further supported by the outcomes of statistical analysis using the paired t-test, which indicated a significant disparity between the pretest and posttest results of students' skills in scientific argumentation. The results of the paired t-test and normality test, conducted as prerequisite analyses are displayed in Table 5.

Table 5. Results paired t-test

Test	Test of Normality			Paired t Test		
	Shapiro-Wilk			t	df	Sig.
	Statistic	df	Sig.			
Pretest	.974	30	.660	-32.236	29	.000
Posttest	.971	30	.580			

The implementation of DBOIL not only has an impact on improving overall students' skills in scientific argumentation.

However, this also has an impact on increasing the achievement of each indicator of scientific argumentation. The mean score for the enhanced attainment of these skill indicators is outlined in Table 6.

Table 6. Enhancement in the attainment of scientific argumentation indicators

Indicators	Average Score c	Category
Claim	0.74	High
Evidence	0.72	High
Reasoning	0.72	High
Counterclaim	0.71	High
Rebuttal	0.71	High

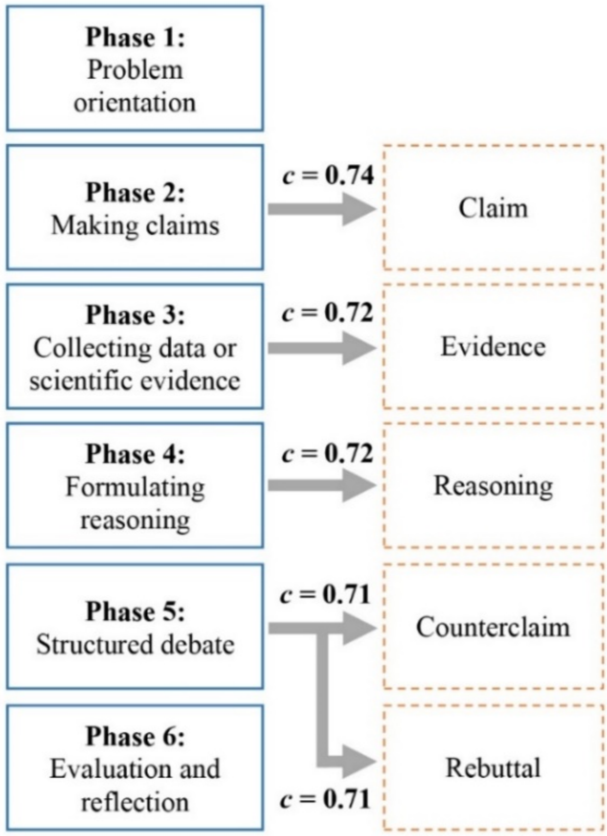

Figure 4. Contribution of the DBOIL phase to increasing the achievement of indicators of scientific argumentation

The rise in the attainment of indicators for scientific argumentation skills, all falling within the high category, underscores the tangible contribution from each phase of DBOIL to bolstering these indicators. Each phase in DBOIL was deliberately developed to facilitate, teach, and improve the achievement of indicators of scientific argumentation. The contribution of the DBOIL phase to increasing the achievement of scientific argumentation indicators is illustrated in Figure 4.

4. Discussion

Scientific argumentation involves a multifaceted disciplinary practice where students are engaged in investigating, critiquing, and revising claims [30], [31]. Uniquely, scientific argumentation also encompasses a student's skills to debate scientific concepts through collaborative discussions with others in an interactive environment [26].

In this case, two crucial parts of scientific argumentative discourse are evident: asking questions and generating effective responses to these inquiries [27], [32]. DBOIL, as an innovative learning model, has the potential to enable students to engage in inquiry activities and debate the outcomes of their inquiries, thereby potentially enhancing the quality of their skills in scientific argumentation.

The results of this research show that the implementation of DBOIL has an impact on improving students' skills in scientific argumentation, with the average increase being in the high category (Table 4). This increase in the high category is also reinforced by findings showing information that the majority of students, as many as 63.33%, have initial skills in scientific argumentation at an intermediate level (Figure 2). This shows that initially students were only able to make claims with the support of evidence, but were not yet able to explain how the evidence could strengthen the claims they made. After participating in learning activities using DBOIL, the students' skills in scientific argumentation experienced changes, the majority of students had final skills in scientific argumentation that were at the proficient level (Figure 2). In this case, students have been able to present scientific arguments consisting of claims, evidence, and reasoning regarding the relationship between claims and evidence, and students have also been able to provide criticism and rebuttal to opposing arguments. These findings show the effectiveness of DBOIL in improving students' skills in scientific argumentation.

The enhancement of the skills in scientific argumentation resulting from the implementation of DBOIL predominantly falls within the high category, comprising 76.67%, with the remaining portion categorized as medium (Figure 3). The enhancement within the high category is further corroborated by the results of statistical analysis conducted through the paired t-test (Table 5). The test results indicate a significant disparity between the pretest and posttest outcomes of students' skills in scientific argumentation. This suggests that there exists a notable contrast in the proficiency level of students' skills in scientific argumentation before and after engaging in learning activities with DBOIL.

These findings further reinforce the notion that DBOIL can effectively facilitate and enhance students' skills in scientific argumentation.

The high level of improvement and achievement of students' skills in scientific argumentation after participating in learning activities with DBOIL is because this learning model is characterized by inquiry and debate in its learning activities. Inquiry is intricately linked to scientific argumentation [33], it allows students to make claims through answers to given questions [15], [34] and selects correct hypotheses after experiments to build their arguments and conclusions [35]. On the other hand, debate in learning activities is considered a potentially effective pedagogical tool in helping improve students' argumentative skills [36], [37], [38]. Debate provides an excellent mechanism for implementing and applying the principles of critical thinking [39]. Participation in debate compels students to seek out, scrutinize, and assess arguments, transcend personal prejudices and biases, pinpoint inconsistencies and flaws in opponents' reasoning, and ultimately construct well-considered and persuasive arguments [40].

Each phase of DBOIL has demonstrated its capacity to facilitate and instruct students in each indicator of scientific argumentation. The indicators of scientific argumentation, including claim, evidence, reasoning, counterclaim, and rebuttal, all demonstrated an elevation to the high category in terms of average improvement (Table 6). The contribution of each DBOIL phase to increasing the achievement of scientific argumentation indicators is explained in detail in Figure 4.

The first phase of DBOIL is problem orientation. This phase does not directly lead to the achievement of indicators of scientific argumentation. However, this phase is needed as a bridge for students to build scientific arguments. This aligns with prior research findings indicating that initiating learning activities with problem orientation can assist students in effectively addressing these issues with appropriate strategies [41], [42], [43], which in the end can affect the quality of the arguments produced.

The second phase of DBOIL is making claims. In this phase, students are encouraged to formulate claims based on the problems given in the previous phase. This has an impact on increasing the achievement of claim indicators. Claims are an intrinsic component of every argument, significantly influencing the structure of the ensuing argumentation representation [44].

The third phase of DBOIL is collecting data or scientific evidence. In this phase, students are encouraged to devise and execute inquiry activities aimed at gathering data as evidence to bolster claims formulated in the preceding phase.

This activity has an impact on increasing the achievement of evidence indicators. This corresponds with the findings of previous research, which assert that scientific inquiry constitutes a crucial aspect of scientific argumentation aimed at generating conclusions supported by evidence and rational justification [14]. In addition, scientific argumentation is a determining factor in the progress of scientific knowledge, where it relies on open, clear, and direct arguments and evidence [45], [46].

The fourth phase of DBOIL is formulating reasoning. In this phase, students are encouraged to make reasoning that shows the connection between the evidence used and the claims that have been formulated. This is based on related scientific concepts, principles, laws, or theories. This phase has an impact on increasing the achievement of reasoning indicators. In broad terms, reasoning can be defined as the ability to comprehend and utilize concepts, methods, and scientific findings or evidence effectively when addressing problems in scientific research, professional practice, and daily life [47]. This is an important part of scientific argumentation [48], [49].

The fifth phase of DBOIL is structured debate. In this phase, students are encouraged to convey arguments that have been prepared in the previous phases, which consist of claims, evidence, and reasoning. Apart from that, students are also directed to provide responses, rebuttals, and criticisms of opposing arguments. Debate entails a structured approach to persuasion, wherein individuals adopt a stance and articulate multiple points to bolster that stance. This process involves employing logical argumentation and presenting contrasting viewpoints from two opposing sides [45]. In this activity, students are divided into two groups, namely the pro and con parties, with the pro party advocating for the position and the con party arguing against it [9], [50]. These debating or arguing activities have an impact on increasing the achievement of counterclaim and rebuttal indicators.

The sixth phase of DBOIL is evaluation and reflection, serving as the concluding phase of learning, which does not directly contribute to the attainment of indicators of scientific argumentation. However, this phase is needed to strengthen the knowledge construction and scientific argumentation skills that students have built. This aligns with previous research findings suggesting that reflection is essential for students to review what they have learned, serving as material for improvement and fostering in-depth learning [51], [52].

5. Conclusion

DBOIL stands as an innovative learning model that has demonstrated its efficacy in enhancing students' skills in scientific argumentation. The development of this learning model is grounded in excellence and serves as a solution to address the shortcomings found in inquiry-based learning models and debates, aiming to optimize the enhancement of students' skills in scientific argumentation. The DBOIL syntax was built through modification and integration between the syntax of inquiry and debate-based learning models, this makes it able to facilitate, teach, and develop all indicators of scientific argumentation.

The findings that have been revealed in this research show important information, namely that the implementation of DBOIL in learning activities has proven to be effective in improving students' skills in scientific argumentation. However, this research was only limited to small classes. Thus, to ensure its efficacy, it is crucial to conduct additional research on a broader scale in the future. Research was conducted at several universities at different levels and with different student academic skills. This will later reveal DBOIL's consistency in improving students' skills in scientific argumentation.

References:

[1]. Guo, K., Zhong, Y., Li, D., & Chu, S. K. W. (2023). Effects of chatbot-assisted in-class debates on students' argumentation skills and task motivation. *Computers & Education*, *203*, 104862. Doi: 10.1016/j.compedu.2023.104862.

[2]. Fan, C. Y., & Chen, G. D. (2021). A scaffolding tool to assist learners in argumentative writing. *Computer Assisted Language Learning*, *34*(1-2), 159-183. Doi: 10.1080/09588221.2019.1660685.

[3]. Wang, L., Chen, X., Wang, C., Xu, L., Shadiev, R., & Li, Y. (2024). ChatGPT's capabilities in providing feedback on undergraduate students' argumentation: A case study. *Thinking Skills and Creativity*, *51*, 101440. Doi: 10.1016/j.tsc.2023.101440.

[4]. Yasuda, S. (2023). What does it mean to construct an argument in academic writing? A synthesis of English for general academic purposes and English for specific academic perspectives. *Journal of English for Academic Purposes*, *66*, 101307. Doi: 10.1016/j.jeap.2023.101307.

[5]. Ouyang, F., Zhang, L., Wu, M., & Jiao, P. (2024). Empowering collaborative knowledge construction through the implementation of a collaborative argument map tool. *The Internet and Higher Education*, *62*, 100946. Doi:: 10.1016/j.iheduc.2024.100946.

[6]. Lytzerinou, E., & Iordanou, K. (2020). Teachers' ability to construct arguments, but not their perceived self-efficacy of teaching, predicts their ability to evaluate arguments. *International Journal of Science Education*, *42*(4), 617-634. Doi: 10.1080/09500693.2020.1722864.

[7]. Su, G., & Long, T. (2021). Is the text-based cognitive tool more effective than the concept map on improving the pre-service teachers' argumentation skills?. *Thinking Skills and Creativity*, *41*, 100862. Doi: 10.1016/j.tsc.2021.100862.

[8]. Yilmaz-Na, E., & Sönmez, E. (2023). Having qualified arguments: Promoting Pre-service teachers' critical thinking through deliberate computer-assisted argument mapping practices. *Thinking Skills and Creativity*, *47*, 101216. Doi: 10.1016/j.tsc.2022.101216.

[9]. Chen, X., Zhao, H., Jin, H., & Li, Y. (2024). Exploring college students' depth and processing patterns of critical thinking skills and their perception in argument map (AM)-supported online group debate activities. *Thinking Skills and Creativity*, *51*, 101467. Doi: 10.1016/j.tsc.2024.101467.

[10]. 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. Doi: 10.1186/s41029-019-0035-x.

[11]. Mikeska, J. N., & Howell, H. (2020). Simulations as practice-based spaces to support elementary teachers in learning how to facilitate argumentation-focused science discussions. *Journal of Research in Science Teaching*, *57*(9), 1356-1399. Doi: 10.1002/tea.21659.

[12]. Woolfolk, A. (2016). *Educational Psychology (Thirteenth Edition)*. Essex: Pearson.

[13]. Conn, C. A., Bohan, K. J., Pieper, S. L., & Musumeci, M. (2020). Validity inquiry process: Practical guidance for examining performance assessments and building a validity argument. *Studies in Educational Evaluation*, *65*, 100843. Doi: 10.1016/j.stueduc.2020.100843.

[14]. Muntholib, M., Hidayati, K., Purnajanti, L., Utomo, Y., & Hariyanto, H. (2021). Impact of explicit scientific inquiry instruction on students' scientific argumentation skills in salt hydrolysis. *AIP Conference Proceedings*, *2330*(1). AIP Publishing. Doi: 10.1063/5.0043237.

[15]. Hinostroza, J. E., Armstrong-Gallegos, S., & Villafaena, M. (2024). Roles of digital technologies in the implementation of inquiry-based learning (IBL): A systematic literature review. *Social Sciences & Humanities Open*, *9*, 100874. Doi: 10.1016/j.ssaho.2024.100874.

[16]. Dah, N. M., Noor, M. S. A. M., Kamarudin, M. Z., & Azziz, S. S. S. A. (2024). The impacts of open inquiry on students' learning in science: A systematic literature review. *Educational Research Review*, 100601. Doi: 10.1016/j.edurev.2024.100601.

[17]. Hendratmoko, A. F., Madlazım, M., Wıdodo, W., & Sanjaya, I. G. M. (2023). The Impact of Inquiry-Based Online Learning with Virtual Laboratories on Students' Scientific Argumentation Skills. *Turkish Online Journal of Distance Education, 24(4), 1-20.* Doi: 10.17718/tojde.1129263.

[18]. Lytos, A., Lagkas, T., Sarigiannidis, P., Argyriou, V., & Eleftherakis, G. (2022). Modelling argumentation in short text: A case of social media debate. *Simulation Modelling Practice and Theory*, *115*, 102446. Doi: 10.1016/j.simpat.2021.102446.

[19]. Martini, M., Widodo, W., Qosyim, A., Mahdiannur, M. A., & Jatmiko, B. (2021). Improving undergraduate science education students' argumentation skills through debates on socioscientific issues. *Jurnal Pendidikan IPA Indonesia*, *10*(3), 428-438. Doi: 10.15294/jpii.v10i3.30050.

[20]. Box, G., & Chambaere, K. (2024). The use of arguments and justifications in Westminster parliamentary debates on assisted dying. *Health Policy*, *144*, 105059. Doi: 10.1016/j.healthpol.2024.105059.

[21]. Hendratmoko, A. F., Madlazim, M., Widodo, W., Suyono, S., & Supardi, Z. A. I. (2024). Inquiry and Debate in Science Learning: Potential Strategy for Improving Students' Scientific Argumentation Skills. *International Journal of Education in Mathematics, Science and Technology*, *12*(1), 114-138. Doi: 10.46328/ijemst.3152.

[22]. Toulmin, S. E. (2003). *The uses of argument*. Cambridge university press.

[23]. Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science education*, *88*(6), 915-933. Doi: 10.1002/sce.20012.

[24]. Ventura, M., Moadebi, S., & Damian, D. (2021). Impact of motivational interviewing training on emergency department nurses' skills: A one-group pretest–posttest pilot study. *International Emergency Nursing*, *56*, 100980. Doi: 10.1016/j.ienj.2021.100980.

[25]. Murphy, P. K., Wilkinson, I. A., Soter, A. O., Hennessey, M. N., & Alexander, J. F. (2009). Examining the effects of classroom discussion on students' comprehension of text: A meta-analysis. *Journal of educational psychology*, *101*(3), 740. Doi: 10.1037/a0015576.

[26]. 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. Doi: 10.1016/j.cedpsych.2020.101925.

[27]. Murphy, P. K., Greene, J. A., Allen, E., Baszczewski, S., Swearingen, A., Wei, L., & Butler, A. M. (2018). Fostering high school students' conceptual understanding and argumentation performance in science through Quality Talk discussions. *Science education*, *102*(6), 1239-1264. Doi: 10.1002/sce.21471.

[28]. Marx, J. D., & Cummings, K. (2007). Normalized change. *American Journal of Physics*, *75*(1), 87-91. Doi: 10.1119/1.2372468.

[29]. Sriyansyah, S. P., & Azhari, D. (2017). Addressing an undergraduate research issue about normalized change for critical thinking test. *Jurnal Pendidikan IPA Indonesia*, *6*(1). Doi: 10.15294/jpii.v6i1.9602.

[30]. Jiménez-Aleixandre, M. P., & Erduran, S. (2007). Argumentation in science education: An overview. *Argumentation in science education: Perspectives from classroom-based research*, 3-27.

[31]. McNeill, K. L., González-Howard, M., Katsh-Singer, R. & Loper, S. (2017). Moving beyond pseudoargumentation: Teachers' enactments of an educative science curriculum focused on argumentation. *Science Education*, *101*(3), 426-457. Doi: 10.1002/sce.21274.

[32]. Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and instruction*, *20*(4), 399-483. Doi: 10.1207/S1532690XCI2004_1.

[33]. Alfarraj, Y. F., Aldahmash, A. H., & Omar, S. H. (2023). Teachers' perspectives on teaching science through an argumentation-driven inquiry model: A mixed-methods study. *Heliyon*, *9*(9). Doi: 10.1016/j.heliyon.2023.e19739.

[34]. Seibert, J., *et al.* (2021). Multitouch experiment instructions to promote self-regulation in inquiry-based learning in school laboratories. *Journal of Chemical Education*, *98*(5), 1602-1609.

[35]. Doi: 10.1021/acs.jchemed.0c01177.

[36]. Sui, C. J., Chen, H. C., Cheng, P. H., & Chang, C. Y. (2023). The Go-Lab platform, an inquiry-learning space: Investigation into students' technology acceptance, knowledge integration, and learning outcomes. *Journal of Science Education and Technology*, *32*(1), 61-77. Doi: 10.1007/s10956-022-10008-x.

[37]. Malloy, J. A., Tracy, K. N., Scales, R. Q., Menickelli, K., & Scales, W. D. (2020). It's not about being right: Developing argument through debate. *Journal of Literacy Research*, *52*(1), 79-100. Doi: 10.1177/1086296X19896495.

[38]. Oros, A. L. (2007). Let's debate: Active learning encourages student participation and critical thinking. *Journal of Political Science Education*, *3*(3), 293-311. Doi: 10.1080/15512160701558273.

[39]. Zorwick, L. W., & Wade, J. M. (2016). Enhancing civic education through the use of assigned advocacy, argumentation, and debate across the curriculum. *Communication Education*, *65*(4), 434-444. Doi: 10.1080/03634523.2016.1203005.

[40]. Roy, A., & Macchiette, B. (2005). Debating the issues: A tool for augmenting critical thinking skills of marketing students. *Journal of Marketing Education*, *27*(3), 264-276. Doi: 10.1177/0273475305280533.

[41]. 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. Doi: 10.1016/j.system.2021.102576.

[42]. Mulyati, T. (2016). Kemampuan pemecahan masalah matematis siswa sekolah dasar. *EduHumaniora| Jurnal Pendidikan Dasar Kampus Cibiru*, *3*(2). Doi: 10.17509/eh.v3i2.2807.

[43]. D'zurilla, T. J., & Goldfried, M. R. (1971). Problem solving and behavior modification. *Journal of abnormal psychology*, *78*(1), 107. Doi: 10.1037/h0031360.

[44]. Llera, S. J., & Newman, M. G. (2023). Incremental validity of the contrast avoidance model: A comparison with intolerance of uncertainty and negative problem orientation. *Journal of anxiety disorders*, *95*, 102699. Doi: 10.1016/j.janxdis.2023.102699.

[45]. Dvořák, W., Rapberger, A., & Woltran, S. (2023). A claim-centric perspective on abstract argumentation semantics: Claim-defeat, principles, and expressiveness. *Artificial Intelligence*, *324*, 104011. Doi: 10.1016/j.artint.2023.104011.

[46]. Meedya, S., Zaden, H., & Davis, D. (2024). Writing for publication: Argument and evidence. *Women and Birth*, *37*(3), 101595. Doi: 10.1016/j.wombi.2024.101595.

[47]. Fahy, K. (2008). Writing for publication: Argument and evidence. *Women and Birth*, *21*(3), 113-117. Doi: 10.1016/j.wombi.2008.04.001.

[48]. Fischer, F., Chinn, C. A., Engelmann, K., & Osborne, J. (2018). *Scientific Reasoning and Argumentation*. New York: Routledge.

[49]. Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *science*, *328*(5977), 463-466. Doi: 10.1126/science.1183944.

[50]. Berndt, M., *et al.* (2021). Investigating statistical literacy and scientific reasoning & argumentation in medical-, social sciences-, and economics students. *Learning and Individual Differences*, *86*, 101963. Doi: 10.1016/j.lindif.2020.101963.

[51]. [50] Dundes, L. (2001). Small group debates: Fostering critical thinking in oral presentations with maximal class involvement. *Teaching Sociology*, *29*(2), 237-243.

[52]. Chang, B. (2019). Reflection in learning. *Online learning*, *23*(1), 95-110. Doi: 10.24059/olj.v23i1.1447.

[53]. Lynch, M., Kamovich, U., Longva, K. K., & Steinert, M. (2021). Combining technology and entrepreneurial education through design thinking: Students' reflections on the learning process. *Technological Forecasting and Social Change*, *164*, 119689. Doi: 10.1016/j.techfore.2019.06.015.