



## Scientific Argumentation Abilities among Undergraduate Biology Students: An Analysis Using the Toulmin's Argument Pattern (TAP) Framework

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**Abstract:** This study aims to examine the level of scientific argumentation skills among biology students using Toulmin's Argument Pattern (TAP) framework. The research employed a quantitative descriptive method using essay questions designed to elicit key components of scientific argumentation. The participants consisted of 82 undergraduate students enrolled in a Genetics course during the even semester of the 2025 academic year. Data were collected through an essay test developed based on Genetics-related topics. Data analysis focused on the presence of TAP components and the classification of students' levels of scientific argumentation. The results reveal that students' scientific argumentation skills remain low, with 47.56% of students categorized at Level 1 and 30.5% at Level 2. Analysis of TAP component distribution indicates that 91.46% of students were able to state claims; however, these claims were predominantly unsupported by warrants or reasoning that meaningfully connected the evidence to the conclusions. The low levels of scientific argumentation observed reflect limitations in students' critical thinking and scientific reasoning skills. Therefore, the implementation of instructional models such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), and TAP-guided formative assessment strategies is recommended to enhance students' scientific argumentation abilities.

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## Introduction

Scientific argumentation skills are one of the essential skills that students must possess. Scientific argumentation is a higher-order thinking skill that plays a role in constructing students' understanding and knowledge (Hendratmoko et al., 2023; Muntholib et al., 2021). Scientific argumentation is important for students not only in terms of building deep conceptual knowledge (Faize & Akhtar, 2020; Zhang & Browne, 2023) but also in fostering critical thinking skills needed to deal with complex scientific problems (Asmi et al., 2024; Faize & Akhtar, 2020; Giri & Paily, 2020; Noviyanti et al., 2019). These skills can also help students develop, validate, and communicate scientific knowledge effectively (Hikmawati & Gaffar, 2022; Mulyani et al., 2024).

In the context of biology education, developing scientific argumentation skills is crucial (Rohayati et al., 2020). Biology is a field of science that not only studies empirical facts but also emphasizes the process of cause-and-effect reasoning in relation to various surrounding events (Anwar et al., 2019). Therefore, biology students should be equipped with strong argumentation skills so that they can critically connect theory, data, and interpretation (Dinata et al., 2021; Krell et al., 2024). One manifestation of scientific argumentation skills is evident in genetic reasoning, which involves integrating theoretical frameworks and



empirical evidence to substantiate conclusions (Green, 2017). This process is essential for developing a deep understanding of genetic concepts and for making informed decisions based on genetic data. According to Berndt et al. (2021), scientific argumentation is essential for students to possess as a skill, enabling them to understand and apply scientific concepts, methods, and findings appropriately when solving problems in scientific research or everyday life.

To determine students' scientific argumentation skills, a test based on the Toulmin Argumentation Pattern (TAP) can be administered. The argumentation framework in TAP consists of a claim, data, warrant, backing, qualifier, and rebuttal (Toulmin, 2003). Through this framework, the quality and completeness of students' arguments can be analyzed systematically, providing a comprehensive picture of their scientific argumentation skills (Utomo et al., 2019). In its implementation, TAP can also help students develop critical thinking skills through learning to formulate claims, provide supporting evidence, and anticipate counterarguments (Zhu et al., 2020). However, empirical findings in various educational contexts still vary, especially at the higher education level in biology, which theoretically should demonstrate more mature reasoning skills.

Several studies show that students' scientific argumentation skills are still low (Rahayu et al., 2023; Setiono et al., 2021). Based on the study by Rahayu et al. (2023), science education students at Mataram University have low argumentation skills. Research by Setiono et al. (2021) with respondents from the FKIP Bengkulu University PGSD program found that they had low scientific argumentation skills (65.63%). Another study showed that 97.25% of students had argumentation skills at levels 0-3, which indicates a very basic level of argumentation (Gazali et al., 2024). Students experience difficulties, especially in advanced argumentation components such as rebuttal (Perdana et al., 2020). However, despite these findings, the Toulmin Argumentation Pattern (TAP) has been widely used to analyze students' argument structures; very few studies have conducted a systematic quantitative assessment of TAP components by calculating the percentage occurrence of each indicator.

This study aims to analyze the scientific argumentation skills of 82 biology students through open-ended essay questions designed to stimulate evidence-based reasoning. The study targets undergraduate biology students, a group that has received limited attention in prior argumentation research, which has predominantly focused on general science education cohorts or pre-service teacher populations. The analysis was conducted using Toulmin's Argument Pattern (TAP) framework, employing two main approaches: grouping students' arguments based on the level of scientific argumentation and calculating the frequency of each TAP component in each student's response. Integration of level-based and component-based analyses distinguishes the present study from previous research, which typically employs only a single form of TAP assessment, and enables a more comprehensive understanding of students' reasoning structures.

## **Research Method**

This study is a quantitative descriptive investigation aimed at determining the level of scientific argumentation among students in Genetics courses. The subjects in this study were 82 biology undergraduate students from Universitas Negeri Malang who were enrolled in Genetics courses during the even semester of 2025. The subjects were selected using simple random sampling techniques. Data collection was conducted using an essay test developed based on topics related to Genetics. The scientific argumentation test consisted of essay



questions measured using the argumentation skills scoring rubric by Osborne et al. (2019). The scientific argumentation skills scoring rubric is presented in Table 1.

**Table 1. Scientific Argumentation Skills Scoring Rubric**

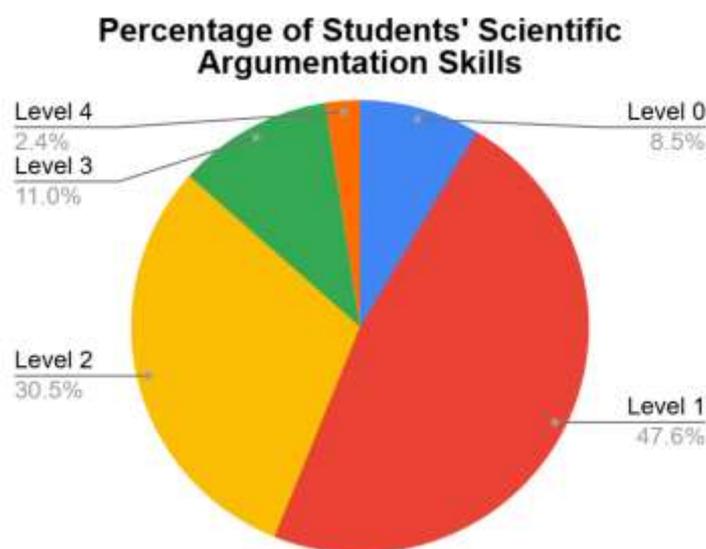
Level	Kriteria
0	There is no response or argument.
1	Contains only claims
2	Contains claims and data (evidence/grounds)
3	Contains claims, data (evidence/grounds) and warrants
4	Contains claims, data (evidence/grounds), warrants and backing
5	Contains claim, data (evidence/grounds), warrants, backing, qualifier and rebuttal

Sumber: (Osborne et al., 2019)

The measurement of students' scientific argumentation is used to assess the extent to which students can construct a sound argument. Data analysis is performed using descriptive statistics, which involve calculating the percentage of occurrence of each TAP component in the respondents' answers and the distribution of scientific argumentation levels based on Toulmin's classification. In addition, the data obtained will be analyzed descriptively.

### Results and Discussion

In this study, 82 students in the even semester of 2025 completed individual answers to scientific argumentation essay questions without discussing the questions with other students. The use of the internet was permitted for searching relevant data, but the use of AI in any form was not permitted. Based on the students' answers, an analysis was conducted to assess the level of scientific argumentation and was calculated as a percentage, as shown in Figure 1.



**Figure 1. Percentage of Students' Scientific Argumentation Skills**

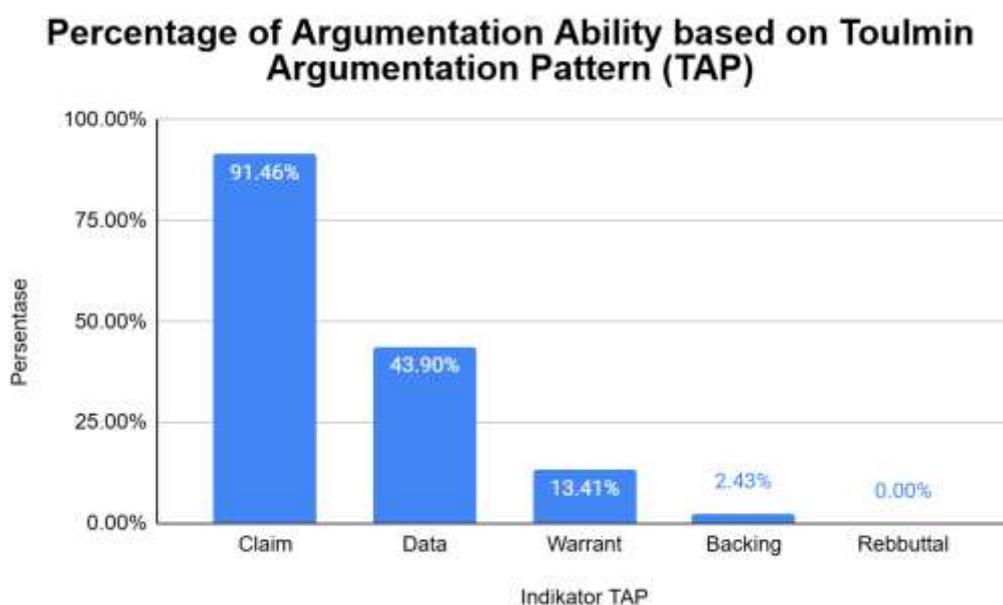
Based on Figure 1, it is evident that many students still lack practical argumentation skills. The distribution of students' argumentation abilities reveals an intense concentration at the lower levels, with nearly half classified at Level 1 and only a small proportion reaching Levels 3 and 4. This pattern suggests that while most students can articulate a claim, they struggle to construct more complex arguments that require integrating data, warrant, backing, and rebuttal.



The quality of arguments is often evaluated based on components such as claims, data, warrant, backing, and rebuttals (Siswanto et al., 2020). There is a level of scientific argumentation among students at level 0 (8.5%), which indicates an inability to construct a complete scientific argument structure because they are not yet able to present claims that are relevant to the issues being studied. This may be due to students' poor prior knowledge, which is the foundation for building a good scientific argument (Liu et al., 2018). Most students possess scientific argumentation skills at level 1 (53.7%), meaning that they can only claim without providing any supporting data. This indicates that the scientific thinking process remains largely deductive, where claims are often based more on opinion or intuition than on empirical justification (Ludwig et al., 2021). These analysis results align with the findings of research conducted by Pratiwi et al. (2023), specifically that students encounter difficulties in developing the backing and rebuttal components.

Meanwhile, 31.7% of students possess level 2 scientific argumentation skills, which means that they can construct a scientific argument that contains a claim and is supported by data. Scientific argumentation skills at levels 0 to 2 can be categorized as low scientific argumentation skills (Hendratmoko et al., 2024). Arguments at levels 1 and 2 also generally lack comprehensive justification and rebuttal, which are very important for higher-level arguments (Pertwi et al., 2023). Only a small percentage of students reached level 3 (11%) and level 4 (2.4%). At these levels, students can demonstrate more complex scientific argumentation skills, such as justification and theoretical support. Higher levels of argumentation indicate that students have a deeper understanding of the topic and the ability to critically evaluate and respond to opposing arguments, which ultimately improves their overall cognitive abilities (Hendrayatno et al., 2022).

The results of students' scientific arguments can also be assessed based on the Toulmin Argumentation Pattern (TAP). The components of TAP include claim, data, warrant, backing, and qualifier (Osborne et al., 2019). Based on the students' answers, an analysis was conducted using TAP and calculated as a percentage, as shown in Figure 2.



**Figure 2. Percentage of Scientific Argumentation Among Students Based on TAP**



Based on Figure 2, the TAP analysis shows that claims are the most consistently present component (91.46%), followed by data components 43.9%, warrant components 13.41%, and backing 2.43%. This pattern indicates that students often express their opinions or positions without providing logical reasoning and adequate empirical evidence to support them. The high frequency of claims suggests that most students already possess the ability to identify issues and take a stance on a problem. However, students tend to only express their opinions without reasoning that connects the evidence to their claims (Suryani et al., 2020). This is in line with research conducted by Rusmini et al (2021), which found that students have good skills in creating claims and data components, but struggle with making TAP components in the form of warrants, backing, and rebuttals.

The low frequency of backing and rebuttal indicates that although students can formulate claims, they are less able to provide causal explanations or theoretical support that make these claims valid and persuasive (Petritis et al., 2021). Components such as backing and rebuttal are important components used in strengthening scientific arguments (Toulmin, 2003). Backing as a TAP component serves to support and strengthen the warrant behind a claim, thereby justifying the argument. Meanwhile, rebuttal has the function of refuting arguments that contradict by identifying the weaknesses of scientific claims (Wu et al., 2022). Overall, these findings suggest that students' scientific argumentation skills are still primarily characterized by declarative aspects (*claims and data*), while analytical and evaluative aspects (*warrants, backing, and rebuttals*) remain underdeveloped.

To obtain an overview of students' responses regarding scientific argumentation, the responses of students with various levels and components of scientific argumentation are presented in Table 2. Students' responses were analyzed using the TAP framework by identifying the components of argumentation that appeared in students' responses to contextual problems. The essay question given was about cancer treatment using Natural Health Products (NHPs).

**Table 2. Student Answers to Scientific Argumentation Skills Essay Questions**

Essay Questions		
Perhatikan wacana berikut! Seiring meningkatnya jumlah kasus kanker, berbagai pendekatan pengobatan bermunculan, termasuk terapi-terapi alternatif yang menimbulkan perdebatan luas di kalangan medis. Beberapa pasien beralih ke penggunaan vitamin C dosis tinggi, ivermectin, atau produk kesehatan alami (Natural Health Products/NHPs) dengan harapan menemukan jalan kesembuhan. Salah satu pendekatan yang paling banyak digunakan adalah konsumsi NHPs atau produk kesehatan alami. Namun, efektivitas dan keamanannya masih menjadi perdebatan dikarenakan sebagian penelitian memang menunjukkan adanya potensi manfaat, tetapi banyak juga studi lain yang justru mengungkapkan hasil yang tidak meyakinkan atau bahkan menimbulkan risiko efek samping yang berbahaya. Untuk lebih mendalami kasus tersebut silahkan untuk membaca artikel jurnal dibawah ini. <a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC11278393/">https://pmc.ncbi.nlm.nih.gov/articles/PMC11278393/</a> Berikanlah argumenmu mengenai wacana diatas, berikan klaim yang didukung oleh alasan berupa data-data penelitian, dll. Sertakan juga referensi dari sumber-sumber yang digunakan dalam analisis dan argumen.		
Respondent Code	Level of Argumentation	Answer
S2	L1	<b>Menggunakan produk kesehatan alami (Natural Health Products/NHPs) sebagai terapi komplementer bagi pasien kanker memiliki potensi signifikan, terutama dalam</b>



		<b>meredakan efek samping pengobatan konvensional seperti kemoterapi dan radioterapi (claim).</b>
S1	L2	Berdasarkan wacana tersebut, dapat dikemukakan argumen bahwa penggunaan <b>produk kesehatan alami (Natural Health Products/NHPs) dalam pengobatan kanker memang memiliki potensi terapeutik (claim)</b> , namun harus disertai pengawasan medis yang ketat karena bukti ilmiah terkait efektivitas dan keamanannya masih terbatas. Ulasan terkini menemukan bahwa <b>uji-uji klinis pada NHP (data)</b> sangat heterogen (indikasi, dosis, rute pemberian) sehingga sulit menarik kesimpulan umum; beberapa NHP menunjukkan manfaat pada efek samping terapi atau kualitas hidup, tetapi hasil antar-studi tidak konsisten.
S73	L3	Produk kesehatan alami (Natural Health Products/NHPs) <b>belum dapat dijadikan terapi utama dalam pengobatan kanker (claim)</b> karena bukti ilmiah yang tersedia masih terbatas dan tidak konsisten. Dalam pendekatan kedokteran berbasis bukti, <b>efektivitas suatu terapi baru dapat diakui jika terbukti melalui uji klinis acak terkontrol (RCT) dengan hasil yang konsisten (warrant)</b> . Karena penelitian tentang NHP belum mencapai tingkat bukti tersebut, klaim bahwa NHP efektif sebagai terapi utama tidak dapat dibenarkan secara ilmiah. <b>Menurut Conti et al. (2024) (data)</b> , banyak penelitian tentang NHP dilakukan dengan desain berbeda-beda, ukuran sampel kecil, dan hasil yang beragam. Sebagian studi memang menunjukkan manfaat dalam meningkatkan kualitas hidup pasien atau mengurangi efek samping terapi, tetapi tidak ada bukti uji klinis acak berskala besar yang membuktikan efektivitasnya sebagai terapi utama kanker.
S6	L4	Penggunaan produk kesehatan alami (Natural Health Products/NHPs) secara sembarangan <b>dapat menimbulkan risiko interaksi obat yang berpotensi mengganggu efektivitas kemoterapi (claim)</b> . <b>Chan et al. (2023) menunjukkan (data)</b> bahwa beberapa bahan alami, seperti ekstrak herbal tertentu, dapat memengaruhi aktivitas enzim metabolik dan protein transporter yang berperan dalam metabolisme obat kemoterapi, sehingga dapat menurunkan efektivitas atau bahkan meningkatkan toksisitas pengobatan. Karena <b>kemoterapi memiliki rentang dosis terapi yang sempit, sedikit perubahan kadar obat akibat interaksi dengan bahan alami dapat menimbulkan dampak signifikan (warrant)</b> terhadap keamanan dan efektivitas terapi. Temuan ini juga diperkuat oleh <b>laporan World Health Organization (WHO, 2022) yang menekankan pentingnya pemantauan (backing)</b> terhadap penggunaan obat herbal bersamaan dengan terapi konvensional.

Table 2 shows the differences in the quality of students' scientific arguments at each level. In respondents with level 1, the structure of scientific arguments only contains claim components without any supporting data or other components. This form of response suggests that there is no connection between the claim and the evidence, resulting in low scientific validity (Jiao et al., 2022). This may be because students struggle to integrate



various aspects of scientific argumentation and select the data that should support the claim (Walker et al., 2019).

The following response is from respondents at level 2, whose argumentation structure not only contains claim components but also additional data. This data element appears through the keyword "Recent reviews find that clinical trials on NHPs are highly heterogeneous." Although students at this level can present arguments and data, their ability to justify is often limited (Pertiwi et al., 2023). At this level, students have deficiencies in other components such as warrant, backing, and rebuttal (Fitria et al., 2023).

At level 3, students not only make claims, but also supplement them with relevant data and include warrant components. The warrant in this response serves as an inferential bridge connecting the data and the claim (Toulmin, 2003). The argument at level 3 demonstrates good conceptual understanding: the claim is formulated appropriately, the data used are relevant, and the warrant explains the basis for evaluating clinical evidence (Lim, 2025). However, the structure of this level 3 argument still shows limitations, namely the absence of explicit backing, rebuttal, and qualifier to strengthen the warrant (Turós et al., 2025).

In addition, at level 4, students demonstrate the most comprehensive and critical arguments, covering the components of claim, data, warrant, and backing. The structure of arguments at this level exhibits a higher level of complexity, indicating a deep conceptual understanding and the ability to construct logically supported arguments (Kundariati et al., 2024). The presence of the four main components of TAP indicates a high level of critical thinking maturity, where students are not only able to present claims and data but also explain the relationships and reinforce them with valid scientific support (Naovalia et al., 2021). In the context of science learning, this ability demonstrates epistemic mastery, which is understanding how scientific knowledge is constructed, validated, and argued (Giri & Paily, 2020).

Poor scientific argumentation skills have broader implications for higher-order thinking skills and academic achievement. Scientific argumentation skills are significantly correlated with critical thinking skills, which include the process of evaluating evidence, constructing logical reasoning, and considering various alternatives (Fu & Zhan, 2025). Students with low levels of scientific argumentation skills often encounter challenges in completing tasks that require complex reasoning abilities (Gou et al., 2024). Low scientific argumentation skills can also impact students' academic achievement. This is because these skills can support a deeper conceptual understanding (Quintana & Schunn, 2019).

In the context of genetics learning, low scientific argumentation skills are closely related to shallow or fragmented conceptual understanding (Cahyani et al., 2024). Genetics requires students to integrate abstract concepts into logical and cohesive explanations (Bueno, 2019). When students are unable to construct arguments supported by data, evidence, or biological principles, this generally reflects their difficulty in connecting concepts in a meaningful way (Nugroho et al., 2023). Students with weak conceptual frameworks tend to provide descriptive answers, rely on memorized facts, and struggle to justify claims through mechanistic reasoning (Herak et al., 2025).

Efforts to empower scientific argumentation skills can be carried out in several ways. Activities such as providing opportunities for students to participate in productive scientific arguments require structured learning transformation and scaffolding (Mikeska & Howell, 2020). Scientific argumentation skills can be empowered through inquiry and debate activities (Belay, 2024). Inquiry activities encourage students to support their arguments with



evidence and reasoning, while debate activities help them refute opposing claims (Hendratmoko et al., 2023). Additionally, the application of problem-solving-based learning strategies to local socio-scientific issues can effectively enhance students' argumentation skills (Illahi et al., 2024).

Various studies show that students' scientific argumentation skills can also be significantly improved through the use of digital learning media. The use of Project-Based Learning combined with web-based interactive media has been proven to improve students' scientific argumentation (Rohmawati et al., 2024). Additionally, the use of digital concept mapping media, combined with argument-based learning, can help teach students' scientific argumentation skills (Alt & Kapshuk, 2022). These findings confirm that the integration of digital media in learning not only enriches the learning experience of students but also strengthens their scientific argumentation skills.

The findings of this study indicate that students' limited use of essential TAP components suggests a shallow and fragmented conceptual understanding of genetics. Conceptually, this suggests that students face challenges in linking genetic principles to evidence-based justifications, indicating a gap between content knowledge and reasoning processes. Practically, these findings emphasize the importance of incorporating explicit instruction on scientific argumentation in learning models such as PBL, PjBL, and inquiry (Jumadi et al., 2021; Rohmawati et al., 2024). At the same time, the use of TAP-guided formative assessments can enable lecturers to identify weaknesses in students' reasoning and deliver targeted instructional support.

## **Conclusion**

The results of the study indicate that the scientific argumentation skills of undergraduate biology students are still relatively low, as evidenced by the percentages, which are highest at levels 1 (47.6%) and 2 (30.5%). Although most students can make claims (91.46%), only a small number can support their arguments with data (43.90%), warrants (13.41%), and backing (2.43%). This condition indicates that students tend to express their opinions without scientific reasoning and adequate supporting evidence. This low level of scientific argumentation skills reflects limitations in critical thinking and the ability to connect scientific concepts in a logical manner. Therefore, more focused pedagogical efforts are needed to strengthen the reasoning component in scientific argumentation, particularly through learning approaches that incorporate argumentation, scientific inquiry, or digital media integration, encouraging students to reason, evaluate evidence, and construct arguments systematically.

## **Recommendation**

Further research needs to expand the number of participants to obtain a more comprehensive picture of students' scientific argumentation profiles. Qualitative analysis of reasoning patterns is also recommended to gain a deeper understanding of how students connect evidence with claims and the factors that influence the quality of their scientific argumentation. In addition, biology lecturers should integrate explicit argumentation instruction into their courses, use structured frameworks such as TAP to guide student argumentation, and integrate learning activities that require evidence-based justification rather than descriptive responses. Providing targeted feedback on students' use of data, arguments, and counterarguments can further support the development of more advanced scientific argumentation skills in the context of higher education in biology.



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## References

- Alt, D., & Kapshuk, Y. (2022). Argumentation - based learning with digital concept mapping and college students ' epistemic beliefs. *Learning Environments Research*, 25(3), 687–706. <https://doi.org/10.1007/s10984-021-09385-8>
- Anwar, Y., Susanti, R., & Ermayanti. (2019). Analyzing scientific argumentation skills of biology education students in general biology courses. *Journal of Physics: Conference Series*, 1166, 012001. <https://doi.org/10.1088/1742-6596/1166/1/012001>
- Asmi, A., Silaban, S., & Silaban, R. (2024). Developing An Interactive Chemistry E-module Based on Problem-based Learning to Improve Critical Thinking Skills of High School Students. *Jurnal Paedagogy: Jurnal Penelitian Dan Pengembangan Pendidikan*, 11(1), 94–101. <https://doi.org/10.33394/jp.v11i1.9875>
- Belay, E. B. (2024). Promoting secondary school students scientific argumentation skills through dialogic practical work. *Research in Science & Technological Education*, 1–17. <https://doi.org/10.1080/02635143.2024.2428622>
- Berndt, M., Schmidt, F. M., Sailer, M., Fischer, F., Fischer, M. R., & Zottmann, J. M. (2021). Investigating statistical literacy and scientific reasoning & argumentation in medical-, social sciences-, and economics students. *Learning and Individual Differences*, 86, 101963. <https://doi.org/10.1016/j.lindif.2020.101963>
- Bueno, D. (2019). Genetics and Learning : How the Genes Influence Educational Attainment. *Front. Psycho*, 10, 1–10. <https://doi.org/10.3389/fpsyg.2019.01622>
- Cahyani, D., Gloria, R. Y., & Roviati, E. (2024). Analysis of scientific argumentation skillsof prospective biology teacher students in inquiry-oriented laboratory activities. *Biosfer: Jurnal Pendidikan Biologi*, 17(1), 243–256. <https://doi.org/10.21009/biosferjpb.34021>
- Dinata, P. A. C., Rasidah, & Wardhana, V. W. (2021). The Validity of Electronic Practicum Module Based on Scientific Argumentation for Practicum Media During COVID-19 Pandemic. *Journal of Physics: Conference Series*, 1805(1), 012022. <https://doi.org/10.1088/1742-6596/1805/1/012022>
- Faize, F. A., & Akhtar, M. (2020). Addressing environmental knowledge and environmental attitude in undergraduate students through scientific argumentation. *Journal of Cleaner Production*, 252, 119928. <https://doi.org/10.1016/j.jclepro.2019.119928>
- Fitria, R., Wiyarsi, A., Rosyidah, D. M., & Arifa, M. F. (2023). Analysis of Students ' Argumentation skill towards Socio-Scientific Issues in Chemistry Learning. *Proceedings of the 2023 5th World Symposium on Software Engineering*, 158–162. <https://doi.org/10.1145/3631991.3632015>
- Fu, X., & Zhan, Q. (2025). Effectiveness of argument in science education: a meta-analysis based on the results of 17 experiments. *Research in Science & Technological Education*, 1–21. <https://doi.org/10.1080/02635143.2025.2527603>
- Gazali, F., Rahayu, S., Munzil, M., & Wonorahardjo, S. (2024). Profile of The First Year Student's Argumentation Skills on General Chemistry Courses at a Public University in West Sumatera: A Preliminary Study. *E3S Web of Conferences*, 481,



04004. <https://doi.org/10.1051/e3sconf/202448104004>
- Giri, V., & Paily, M. U. (2020). Effect of Scientific Argumentation on the Development of Critical Thinking. *Science & Education*, 29(3), 673–690. <https://doi.org/10.1007/s11191-020-00120-y>
- Gou, T., Guo, D., & Fan, M. (2024). Design and empirical research of critical thinking training model based on digital science argument mapping. *2024 International Symposium on Educational Technology (ISET)*, 324–328. <https://doi.org/10.1109/ISET61814.2024.00070>
- Green, N. L. (2017). Argumentation Scheme-Based Argument Generation to Support Feedback in Educational Argument Modeling Systems. *International Journal of Artificial Intelligence in Education*, 515–533. <https://doi.org/10.1007/s40593-016-0115-y>
- Hendratmoko, A. F., Hendratmoko, A. F., Madlazim, M., Widodo, W., Suyono, S., & Arifin, Z. (2024). *Inquiry and Debate in Science Learning: Potential Strategy for Improving Students' Scientific Argumentation Skills To cite this article: argumentation skills . International Journal of Education in Mathematics , Science , and Inquiry and Debate in Science Learning: Potential Strategy for Improving Students' Scientific Argumentation Skills.*
- Hendratmoko, A. F., Madlazim, M., Widodo, 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. <https://doi.org/10.17718/tojde.1129263>
- Hendrayatno, A., Widodo, A., Riandi, R., & Muslim, M. (2022). Students' Argumentation in Science Lessons: How effective is Rebuttal Analysis Framework in Representing the Complexity of Classroom Argumentation? *Science & Education*, 32(5), 669–687. <https://doi.org/10.1007/s11191-022-00320-8>
- Herak, R., Mahanal, S., Zubaidah, S., & Novianti, V. (2025). Exploring Misconceptions in Biology Learning : A Systematic Literature Review. *Salud, Ciencia y Tecnología*, 5(1743). <https://doi.org/10.56294/saludcyt20251743>
- Hikmawati, V. Y., & Gaffar, A. A. (2022). *Scaffolding scientific argumentation skills in online learning environment to support 21st century skills.* 030027. <https://doi.org/10.1063/5.0102751>
- Illahi, V. A., Rahayu, S., Widarti, H. R., & Yahmin, Y. (2024). SMART-Problem Solving Strategy to Improve Students Scientific Argumentation Skills on “Rain and Malin Kundang Stone Issue” as Local Socio-Scientific Issues (LSSI). *Jurnal Penelitian Pendidikan IPA*, 10(6), 3423–3432. <https://doi.org/10.29303/jppipa.v10i6.7300>
- Jiao, X., Wang, R., & Cai, S. (2022). Exploring the Argumentation Characteristics in SSI Video Discussion Area of Online Video Learning Website. *10th International Conference on Information and Education Technology, December*, 166–170. <https://doi.org/10.1109/ICIET55102.2022.9778977>
- Jumadi, J., Perdana, R., Riwayani, R., & Rosana, D. (2021). The impact of problem-based learning with argument mapping and online laboratory on scientific argumentation skill. *International Journal of Evaluation and Research in Education (IJERE)*, 10(1), 16. <https://doi.org/10.11591/ijere.v10i1.20593>
- Krell, M., Garrecht, C., & Minkley, N. (2024). Preservice Biology Teachers' Socioscientific Argumentation: Analyzing Structural and Content Complexity in the Context of a Mandatory COVID-19 Vaccination. *International Journal of Science and*



- Mathematics Education*, 22(1), 121–141. <https://doi.org/10.1007/s10763-023-10364-z>
- Kundariati, M., Susilo, H., & Balqis, B. (2024). An investigation into prospective biology teachers' scientific argumentation: Have they mastered it? *AIP Conference Proceedings*, 3106(1). <https://doi.org/https://doi.org/10.1063/5.0214951>
- Lim, W. M. (2025). What Is Qualitative Research? An Overview and Guidelines. *Australasian Marketing Journal*, 33(2), 199–229. <https://doi.org/10.1177/14413582241264619>
- Liu, B., Liu, X., & Lin, Y. (2018). *Applying Online Learning Environment for Argumentation of Students with Different Level of Prior-knowledge*.
- Ludwig, T., Priemer, B., & Lewalter, D. (2021). *Assessing Secondary School Students' Justifications for Supporting or Rejecting a Scientific Hypothesis in the Physics Lab*. 819–844.
- 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. <https://doi.org/10.1002/tea.21659>
- Mulyani, A., Hartono, H., & Subali, B. (2024). Literature Review: A Snapshot of Research on the Argumentation of Bibliometric Analysis in the Period 2015-2023. *International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE)*, 12(2), 451–465. <https://doi.org/10.23947/2334-8496-2024-12-2-451-465>
- 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*. 020045. <https://doi.org/10.1063/5.0043237>
- Naovalia, R., Amin, M., & Suwono, H. (2021). The effectiveness of research-based learning improves student arguments about genetic codes and genetic mutations. *AIP Conference Proceedings*, 2330(1). <https://doi.org/https://doi.org/10.1063/5.0043447>
- Noviyanti, N. I., Rosyadah Mukti, W., Dahlia Yuliskurniawati, I., Mahanal, S., & Zubaidah, S. (2019). Students' Scientific Argumentation Skills Based on Differences in Academic Ability. *Journal of Physics: Conference Series*, 1241(1), 012034. <https://doi.org/10.1088/1742-6596/1241/1/012034>
- Nugroho, A. A., Sajidan, S., Suranto, S., & Masykuri, M. (2023). Analysis of students argumentation skills in biotechnological socioscientific issue for designing innovative learning. *AIP Conf. Proc.* <https://doi.org/https://doi.org/10.1063/5.0143258>
- Osborne, J., Borko, H., Fishman, E., Gomez Zaccarelli, F., Berson, E., Busch, K. C., Reigh, E., & Tseng, A. (2019). Impacts of a Practice-Based Professional Development Program on Elementary Teachers' Facilitation of and Student Engagement With Scientific Argumentation. *American Educational Research Journal*, 56(4), 1067–1112. <https://doi.org/10.3102/0002831218812059>
- Perdana, R., Riwayani, R., Jumadi, J., & Rosana, D. (2020). Modification level and test of scientific argumentation skill: Development and validity. *International Journal of Evaluation and Research in Education (IJERE)*, 9(3), 769. <https://doi.org/10.11591/ijere.v9i3.20594>
- Pertiwi, W. A., Kusairi, S., Kusumawati, A. D., Shanthie, A. P. K., & Haeruman, L. D. (2023). Profile of scientific argumentation of elementary school teachers using



- Toulmin's Argumentation Pattern (TAP) in Physics concept of potable water sources. *Journal of Physics: Conference Series*, 1–6. <https://doi.org/10.1088/1742-6596/2596/1/012077>
- Petritis, S. J., Kelley, C., & Talanquer, Vi. (2021). Analysis of factors that affect the nature and quality of student laboratory argumentation. *Chemistry Education Research and Practice*, 23, 257–274. <https://doi.org/10.1039/D1RP00298H>
- Pratiwi, A. D., Afandi, A., Wahyuni, E. S., & Mahisa, R. D. P. (2023). Analysis of argumentation skills in biology learning. *The 3rd International Conference on Science, Mathematics, Environment, and Education*, 2540, 1–5. <https://doi.org/10.1063/5.0105733>
- Quintana, R., & Schunn, C. (2019). Who Benefits From a Foundational Logic Course? Effects on Undergraduate Course Performance Who Benefits From a Foundational Logic Course? Effects on. *Journal of Research on Educational Effectiveness*, 12(2), 191–214. <https://doi.org/10.1080/19345747.2018.1543372>
- Rahayu, F., Nasir, M., & Fakhruddin. (2023). Efforts to Improve Science Process and Collaboration Skills with the Implementation of the REACT Learning Model on Students. *Jurnal Penelitian Pendidikan IPA*, 9(10), 8301–8307. <https://doi.org/10.29303/jppipa.v9i10.5170>
- Rohayati, Y. T., Zubaidah, S., Mahanal, S., & Setiawan, D. (2020). *The correlation between student scientific argumentation skills and cognitive achievement on PBL and RICOSRE learning models in biology classes*. 030014. <https://doi.org/10.1063/5.0000561>
- Rohmawati, O. Q., Parno, P., Latifah, E., Ghorbiy, B., & Bunyamin, M. A. H. (2024). Students' scientific argumentation skills through PjBL – STEAM model assisted by web-based interactive PowerPoint on static fluid. *Journal of Physics: Conference Series*, 1–11. <https://doi.org/10.1088/1742-6596/2900/1/012015>
- Rusmini, R., Suyono, S., & Agustini, R. (2021). Profile of Argumentation Ability of Undergraduate Students In Chemistry Education Based On Non-Routine Problems. *E3S Web of Conferences*, 6007. <https://doi.org/10.1051/e3sconf/202132806007>
- Setiono, P., Yuliantini, N., Wurjinem, W., & Anggraini, D. (2021). Kemampuan Argumentasi Ilmiah Mahasiswa Melalui Penerapan Model Pembelajaran Project Based Learning. *ELSE (Elementary School Education Journal) : Jurnal Pendidikan Dan Pembelajaran Sekolah Dasar*, 5(1), 101. <https://doi.org/10.30651/else.v5i1.7039>
- Siswanto, S., Anci, S. Y., Yusiran, Y., Hartono, H., Subali, B., & Trisnowati, E. (2020). *Scientific or Not? Mapping Category of Students' Written Argument*. <https://doi.org/10.4108/eai.12-10-2019.2296492>
- Suryani, E., Yusiran, Y., Hairullah, O., Siswanto, S., & Nurfathurrahmah, N. (2020). *Identifying Argumentation Skills Using Three Tier Test on Pre-service Physics and Biology Teachers*. <https://doi.org/10.4108/eai.12-10-2019.2296428>
- Toulmin, S. E. (2003). *The Uses of Argument*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511840005>
- Turós, M., Kenyeres, A. Z., Balla, G., Gazdag, E., & Szabó, E. (2025). A Toulmin Model Analysis of Student Argumentation on Artificial Intelligence. *Educational Sciences*, 15(9), 1–21. <https://doi.org/https://doi.org/10.3390/educsci15091226>
- Utomo, Y. S., Ashadi, & Sarwanto. (2019). Argumentation Skills Profile on 8th Grade Students using Toulmin's Argument Pattern on Controversial Topic. *Journal of*



- Physics: Conference Series*, 1233, 012095. <https://doi.org/10.1088/1742-6596/1233/1/012095>
- Walker, J. P., Duzor, A. G. Van, & Lower, M. A. (2019). Facilitating Argumentation in the Laboratory: The Challenges of Claim Change and Justification by Theory. *Journal of Chemical Education*, 96, 435–444. <https://doi.org/10.1021/acs.jchemed.8b00745>
- Wu, P., Yen, A.-Z., Huang, H.-H., & Chen, H. (2022). Incorporating Peer Reviews and Rebuttal Counter-Arguments for Meta-Review Generation. *Proceedings of the 31st ACM International Conference on Information & Knowledge Management (CIKM '22)*, 2189–2198. <https://doi.org/https://doi.org/10.1145/3511808.3557360>
- Zhang, J., & Browne, W. J. (2023). *An Approach to Generating Guidelines for Designing Scientific Argumentation Competence Assessments* (pp. 201–218). [https://doi.org/10.1007/978-3-031-32225-9\\_13](https://doi.org/10.1007/978-3-031-32225-9_13)
- 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 & Education*, 143, 103668. <https://doi.org/10.1016/j.compedu.2019.103668>