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Revealing Argumentation Skills of High School Students in Biology Learning through Toulmin Argumentation Pattern

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Abstract

Argumentation skills are one of the skills that students must have in the 21st century. Argumentation skills are important to develop because they can train students to communicate effectively in education, especially in science learning. This study aims to determine the description of students' argumentation skills, especially in biology subjects on environmental change material. The type of research used is descriptive quantitative using essay tests. 51 high school X-grade students were selected as samples in this study. The validity value of each item instrument is 0.403-0.596, meaning that all instrument items are said to be valid. The reliability result of the instrument is q = 0.736 (Cronbac's Alpha>0.60), so the instrument used is reliable. The results showed that the argumentation ability of students of the claim component was included in the highest component, with 66.2%, followed by the data component 23%, warrant 5.9%, backing 2%, and rebuttal 0% and the level of argumentation ability of students was still at level 1-2, the argumentation ability of students using claims, level 1 as much as (67.5%), supported by evidence, level 2 as much as (11.75%), warrants, level 3 as much as (2%), backing, level 4 as much as (0.5%), while the appearance of qualifiers and rebuttal, level 5 as much as (0%). The results show that there is a need for more attention to students through future research efforts should focus on implementing interventions to improve argumentation skills in students such as structured debates or problem-based learning and other learning models. It is important for students and teachers to collaborate with each other in honing argumentation skills to improve the quality of learning.

Keywords: Argumentation Skills; Biology Learning; Toulmin Argumentation Pattern; High School Students

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INTRODUCTION

Various perspectives on argumentation skills demonstrate its power in learning in education today. Argumentation is a key component of critical thinking, a fundamental aspect of human scientific endeavour, and has the potential to improve students' understanding of science concepts from both a theoretical perspective (Cheong et al., 2021). Argumentation also represents both a process and an outcome, combining elements of fact-finding and persuasion, which are essential for effective communication (Salih, 2021). Argumentation skills include the Skills to construct, analyze, and evaluate arguments, integrating different perspectives while using logical reasoning and critical thinking in discourse (Dawson & Carson, 2020).

Good argumentation skills can lead students to express opinions in the form of arguments, provide evidence and reasons based on facts, and justify and evaluate information from sources to lead to conclusions (Ambarawati et al., 2021). Argumentation skills are closely related to high-level critical thinking because they require students to carefully consider various

perspectives on the issues being debated and justify their positions with evidence (Cheong et al., 2021). Developing argumentation skills is one way to prepare students to be effective communicators and critical thinkers in the 21st century. Argumentation skills are essential for critical thinking and effective communication in education (Swastika et al., 2022).

Argumentation skills must also be developed in science learning, one of which is biology learning. Argumentation as an epistemic tool helps students think differently about biological concepts and apply them in real-life situations (Molina & Carlino, 2016). Argumentation fosters critical thinking skills and science literacy. Constructing and critiquing arguments provides students with learning to analyze, evaluate, and generate explanations that are critical to understanding complex biological concepts. Research has shown that argumentation significantly improves students' conceptual understanding of biology (Antonio & Prudente, 2021). Assessment of argumentation skills can use several argumentation model frameworks, one of which is the *Toulmin argumentation pattern* (TAP) (Toulmin, 1958).

TAP is a framework or model for constructing scientific arguments. TAP has six main components, *claim*, *data (evidence/grounds)*, *warrants*, *backing*, *qualifier* and *rebuttal.* Argumentation level indicators according to Osborne, Eduran, & Simon (2004) based on the framework are argumentation presents an extended argument with a series of one clear refutation. A *claim* is a statement of fact or truth that is proposed. Data *(evidence/grounds)* is any available information that is used as a foundation to support the proposed claim. *Warrant* is a statement that explains the general principle that links the data to the claim to strengthen the argument. *Backing* is an addition that strengthens the warrant in defence of the claim. *Rebuttal* is a refutation or rejection of a claim, argument, or *warrant* by another party.

Many studies have used TAP as a scientific argumentation model to profile students' argumentation skills. Research (Bermudez et al., 2024)in looking at argumentation skills in the field of biodiversity, research (Lee et al., 2022)to measure argumentation skills in the context of euclidean geometry, and research Polacsek et al., (2018)in measuring justification diagrams. In Indonesia, there have been many adaptations of TAP, Noviyanti et al. (2019)including research by on students' argumentation skills based on differences in academic ability, research by Anita et al. (2021)on the profile of students' argumentation skills in biology learning in senior high schools, research by Fadlika et al. (2022) related to students' argumentation skills in cell material in biology learning, and research by Yuanata et al. (2022) which examines the profile of students' argumentation skills in understanding physics concepts. In the covid-19 pandemic era, it also saw the importance of the argumentation profile of high school students on environmental pollution material (Puspitasari et al., 2022).

Several studies reported mixed results on students' argumentation skills. The average student's argumentation Skills is still at level 2 with a percentage of 74.9% (Hasmaningsih et al., 2022). Research by Härmä et al,. (2021) showed that most students developed reasoned arguments and clear claims but some students had difficulty in recognizing their main claims and arguments. Students also had weaknesses in providing evidence and refutation of the claims of their arguments (Maulidiyah et al., 2024). Argumentation skills are recognized as a core competency for students' readiness in the world of work to be professional in various fields (Sametova et al., 2020).

Science learning, especially in biology lessons, show a significant correlation between students' argumentation skills and student learning outcomes (Zahra et al., 2023). Research related to the profile of students' argumentation skills in biology learning has been carried out, but it is limited to certain materials such as the digestive system in the research of Ekanara et al., (2018)and ecosystem material in the research of Susilawati et al., (2023); Intan & Nasution (2023)Fitri et al., (2024). In fact, environmental change material is very relevant to research because it raises contextual global issues and demands the ability to think critically and argue scientifically (Sadulaeva, 2023). This study aims to determine the validity and reliability of the instrument on environmental change material to measure students' argumentation skills and to

determine the profile of argumentation skills of grade X high school students in biology learning.

METHOD

This study uses a survey method that aims to describe students' argumentation skills in biology learnings in natural conditions without any treatment. The subjects in this study were high school grade X students with a total of 51 students in the odd semester of 2024/2025. The selection of a sample size of 51 students was based on the criteria of being representative of the population and consideration of the effectiveness of data analysis. According to Sugiyono (2017), in non-experimental quantitative research such as surveys, the minimum sample size is 30 respondents so that the data can be analyzed statistically. Meanwhile, Gay, Mills, & Airasian (Gay et al., 2012)also suggest that for descriptive research, a sample size of about 10% of the population or a minimum of 30-50 respondents is adequate. Thus, the number of 51 students is considered to meet the minimum requirements and adequately represent the population of students studied in this context.

The data collection method was carried out by distributing essay test questions with as many as 4 items, then measured through indicators of argumentation skills levels according to Osborne, Eduran, & Simon (2004). In the implementation of filling out the essay test questions, the researcher has minimized the potential for bias by ensuring that all students work on the questions individually under conditions directly supervised by the subject teacher and the researcher. In addition, clear instructions were also given to ensure that answers reflected students' personal understanding, not the results of group discussions or online information searches. These control measures were aimed at maintaining the internal validity of the data collected. The indicator items and levels of argumentation skills can be seen in Table 1.

Table 1. Levels and Indicators of Argumentation Skills

Level	Indicator
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*

Source: Osborne, Eduran, & Simon *(2004)*

RESULTS AND DISCUSSION

Validity and Reliability of Essay Question Instrument

The results of the statistical analysis can be seen in Table 2, showing the instrument item *Scale Mean* (SD) ranges from 3.98 to 4.27. *Scale variance if items deleted* ranges from 3.300-2.603. The distribution of the r table value is df = n-1 so that the resulting r table = 0.991. Items in the research instrument can be said to be valid if the r count is less than 0.991 (r table). In this case, the r count (*Corrected Item-Total Correlation*) generated by each item is 0.403-0.596, meaning that r count ≤ r table so that all instrument items are said to be **valid.** The reliability results of the instruments that have been used in this study are q = 0.736 (Cronbac's Alpha>0.60), so the instruments used are **reliable.** Table 3 shows the results of Cronbac's Alpha.

Table 2. Results of descriptive statistical analysis of Instrument

Instrument	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Item 1	4.27	2.603	.596	.634

Instrument	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Item 2	4.02	2.500	.621	.617
Item 3	4.25	2.994	.499	.692
Item 4	3.98	3.300	.403	.740

Table 3. Reliability Results of The Instruments

Cronbach's Alpha	N of Items
.736	4

Quality of Students' Argumentation Skills on Each Problem

In this study, respondents high school X-grade students, filled in the answers to the four argumentative essay questions given, completed individually without communicating with other students in answering these questions. Based on the assessment of students' answers, the percentages were analyzed and calculated according to the level of argumentation as illustrated in the bar chart in Figure 1.

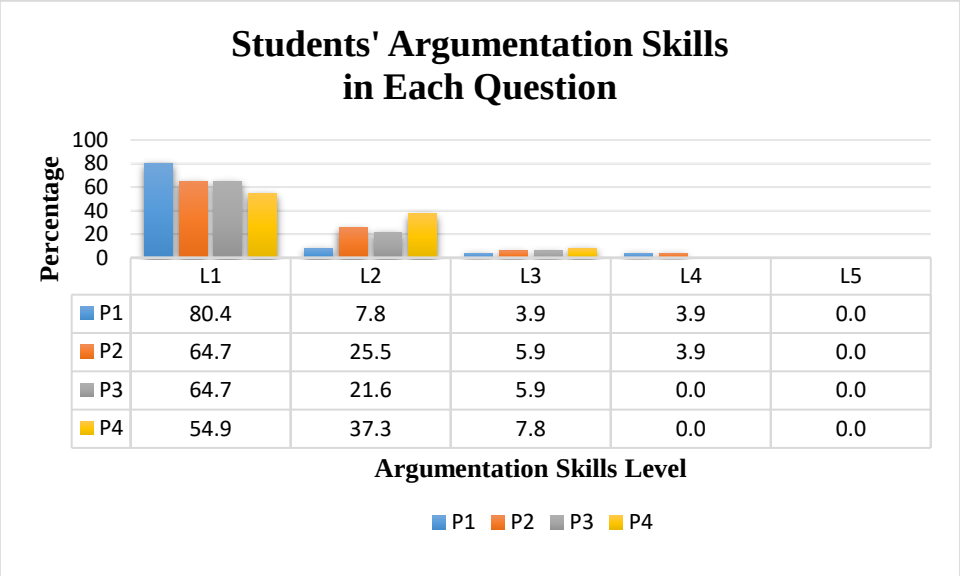

Figure 1. Students' Argumentation Skills in Each Question

Description:
P = Question
L = Argumentation Skills Level

Based on Figure 1, it can be seen that the majority of students' argumentation skills in questions 1 to 4 have level 1 argumentation skills with a percentage of 80.4%, 64.7%, 64.7%, and 54.9%. This shows that students' argumentation skills are still limited to *claiming* the problem but not providing *data* and reasons as well as evidence/facts. Students tend to just repeat the claims that already exist in the problems that have been given. Meanwhile, the lowest percentage for the argumentation level of the four questions was level 5. This means that students' answers have not been able to find rebuttals or qualifications to explain the facts and data from the problem. One possible cause is the students' lack of experience in practicing structured argumentation before, either in the form of scientific discussions, analytical essays, or other critical thinking exercises. Teacher-centered learning often puts students in a passive role, reducing their opportunities to engage in analytical thinking and argumentation (Kumar & Basnyat, 2024).

The learning process in the classroom so far tends to focus on memorizing facts or single answers, so students are not accustomed to expressing opinions that are built on the structure

of claims, data, and justifications. Traditional teaching methods only emphasize memorization, where students passively absorb information without engaging in critical thinking or argumentation (Williams et al., 2024). Another factor is the lack of stimulus of open-ended and challenging problems to develop advanced argumentation. Therefore, it is important to design lessons that are more explicit in training students' argumentation skills.

Quality of Students' Argumentation Skills based on TAP

Based on Figure 2 below, argumentation skills based on TAP, *claim is* included in the highest component with 66.2%. This is followed by the *data* component with 23%, *warrant* 5.9%, *backing* 2%, and *rebuttal* 0%. This shows the weakness of students' argumentation who only provide claims in the answers to argumentative essay questions. Weaknesses in argumentation can have serious implications for students' success in academics and future professional careers and thus require special attention (Hsu et al., 2015).

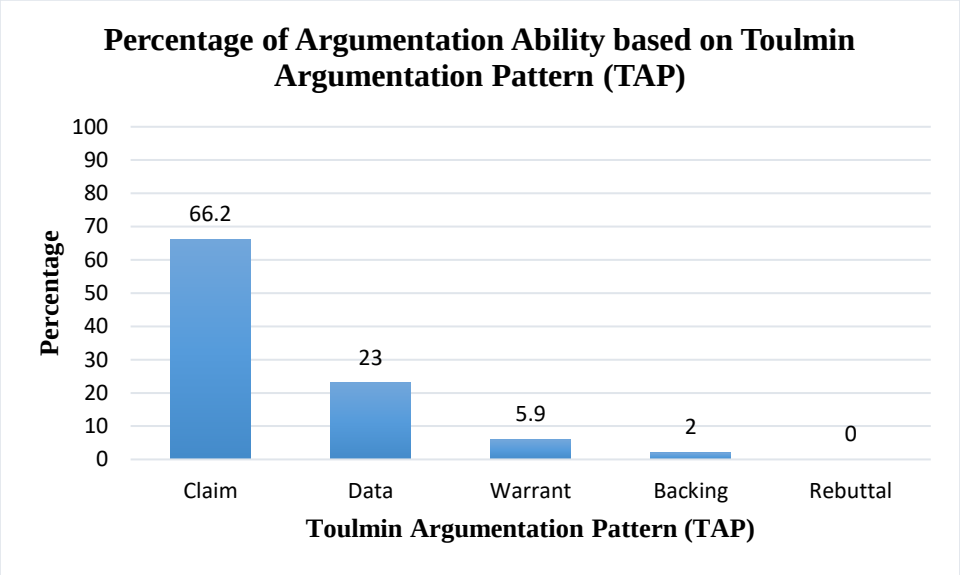

Figure 2. Students' *Argumentation* Skills based on *Toulmin Argumentation Pattern* (TAP)

Based on Figure 2 above, argumentation skills based on TAP, *claim is* included in the highest component with 66.2%. This is followed by the *data* component with 23%, *warrant* 5.9%, *backing* 2%, and *rebuttal* 0%. This shows the weakness of students' argumentation who only provide claims in the answers to argumentative essay questions. Weaknesses in argumentation can have serious implications for students' success academia and future professional careers and thus require special attention (Hsu et al., 2015).Debate has been shown to be an effective approach to improving argumentation skills, including the ability to generate and improve refutations (Yang et al., 2022). In addition to debates, case studies can enhance critical thinking skills involved in complex real-world problems, so students learn to evaluate evidence, consider multiple perspectives, and develop arguments that have rebuttals (Bernstein, 2024).

Students' Argumentation Skills Level

The percentage results of each level of argumentation can be seen in Figure 3. The argumentation quality instrument has 5 levels starting from level 1 is a reason-based argument (*claim*). Level 2 is the reason given and must provide data (*evidence/grounds*) that support the statement. Level 3 is an argumentation containing a series of reasons (*claim*), data (*evidence/grounds*) that support the statement and a few *warrants*. Level 4 presents an argument that has a *claim*, *evidence/grounds*, a few *warrants* and *backing* information with one clear refutation. Level 5 argumentation presents a *claim*, supporting data evidence/grounds),

expanded with more than one *warrants* and warrants and *backing* information with one clear refutation (*qualifier and rebuttal*).

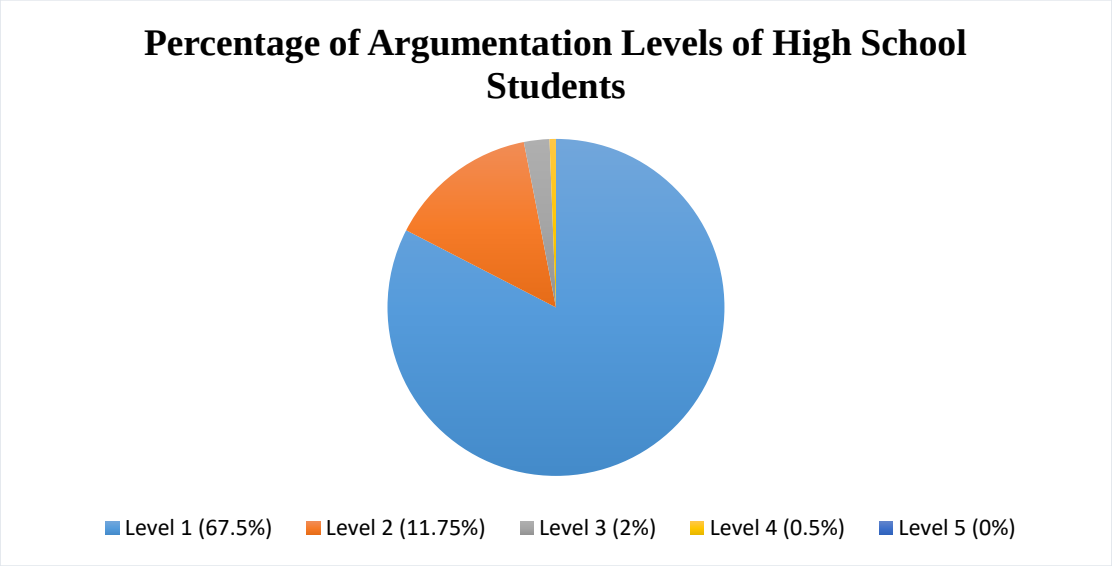

Figure 3. Percentage Diagram of Students' Argumentation Skills Levels

Students' argumentation skills using *claims*, level 1 as much as (67.5%), supported by *data/evidence*, level 2 as much as (11.75%), *warrants*, level 3 as much as (2%), *backing*, level 4 as much as (0.5%), while the appearance of *qualifiers* and *rebuttal*, level 5 as much as (0%). These results show that the average percentage of students is still at level 1 and level 2, no more than 5% of students are at the expected level for level 1 to level 3. In line with Hasmaningsih et al., (2022), the average student's argumentation ability is still at level 2 with a percentage of 74.9% and Härmä et al.. (2021)'s research shows that most students develop arguments that are justified and claims. Students only provide arguments that contain two basic elements of argument structure, *claims* and *data*, so they hardly include structures such as *warrants*, *backing*, *qualifiers* and *rebuttals* which can make arguments less persuasive and reduce the quality of writing (Paek & Kang, 2017). The following are the answers of respondents (students) in various levels of argumentation skills, as seen in Table 4.

Table 4. Respondents' Answers

Respondent Code	Argumentation Level	Answer
P1 : Sebuah pabrik tekstil di kota X membuang limbah cairnya secara langsung ke sungai tanpa pengolahan terlebih dahulu. Limbah tersebut mengandung zat pewarna dan bahan kimia berbahaya yang dapat mengancam kelangsungan hidup baik bagi masyarakat di sekitar daerah sungai dan ekosistem sungai itu sendiri. Setujukah kamu dengan tindakan pabrik tekstil tersebut? Berikan alasannya!		
S9	L1	*Tidak setuju,* ***karena seharusnya limbah cair tersebut diolah dulu agar aman bagi masyarakat maupun ekosistem (claim)***
S18	L2	*Sangat tidak setuju.* ***Karena akibat yang dihasilkan dari membuang limbah cair secara langsung ke sungai tanpa pengolahan terlebih dahulu tentu mengancam pencemaran lingkungan, (claim)*** *dan dapat berakibat fatal pada ekosistem sungai yang dicemari limbah tersebut.* ***Bersumber dari Gramedia.com (data)*** *jika sungai tercemar maka sumber daya air warga sekitar pabrik akan tercemar juga sehingga mengganggu kehidupan dan kesehatan masyarakat.*
S20	L3	*Tidak setuju,* ***karena dengan pembuangan limbah yang mengandung zat berbahaya ke sungai dapat merusak dan mengganggu ekosistem (claim)*** *yang ada di sungai serta dapat membahayakan bagi masyarakat yang tinggal di sekitar sungai* ***dimana mayoritas dari penduduk sekitar sungai tersebut pasti akan menggunakan air sungai (warrant)*** *dan menjalankan aktivitasnya di sekitar sungai tersebut sehingga jika air*

Respondent Code	Argumentation Level	Answer
S10	L4	*tersebut digunakan maka akan sangat mengganggu keberlangsungan hidup* ***(kompasiana.com) (data).*** *Tidak, saya tidak setuju dengan tindakan pabrik tekstil tersebut.* ***Membuang limbah cair yang mengandung zat pewarna dan bahan kimia berbahaya langsung ke sungai tanpa pengolahan terlebih dahulu (claim)*** *dapat memiliki konsekuensi yang sangat buruk bagi masyarakat dan ekosistem Sungai* ***(mertani.co.id) (data). Limbah cair tersebut dapat mencemari air Sungai (warrant),*** *yang dapat* ***mempengaruhi kualitas air (backing) dan membuatnya tidak aman untuk dikonsumsi oleh manusia dan hewan.***
P2. Hutan kelapa sawit merupakan salah satu aspek penting dalam perekonomian Indonesia. Minyak kelapa sawit merupakan sumber minyak nabati yang penting untuk memenuhi kebutuhan pangan bagi masyarakat. Akan tetapi, industri kelapa sawit dapat juga menimbulkan dampak negatif diantaranya deforestasi (pembukaan lahan untuk perkebunan kelapa sawit) yang dapat berakibat pada hilangnya habitat flora dan fauna, serta pencemaran lingkungan dengan penggunaan pupuk dan pestisida berlebihan dalam perkebunan kelapa sawit dapat mencemari air dan tanah, serta membahayakan kesehatan manusia dan lingkungan. Setujukah kamu dengan tindakan deforestasi? Berikan alasannya!		
S6	L1	*Tidak setuju,* ***karena habitat flora dan fauna akan terganggu, dapat mencemari lingkungan dan tidak baik bagi kesehatan Masyarakat (claim)***
S10	L2	*Tidak setuju,* ***karena deforestasi untuk pembukaan lahan perkebunan kelapa sawit dapat memiliki dampak negatif pada lingkungan*** *dan keanekaragaman hayati (claim).* ***Hilangnya habitat alami dapat berdampak pada populasi satwa liar dan keseimbangan ekosistem (Mitragama.com) (data).***
S18	L3	*Kurang setuju.* ***Karena dengan tindakan deforestasi maka membuat flora dan fauna kehilangan habitatnya (borneohijaulestari.com) (claim & data).*** *Akan* ***tetapi jika tindakan deforestasi dilakukan pada wilayah yang memang tidak stabil (habitat atau ekosistemnya) (warrant) maka*** *mungkin pembukaan lahan untuk kelapa sawit bisa dilakukan dengan tetap memperhatikan keadaan lingkungan dan makhluk hidup disekitarnya.*
S19	L4	*Kurang setuju.* ***Pembukaan lahan sawit memang bagus untuk menumbuhkan perekonomian Indonesia (claim), namun jika*** *pembukaan dan perluasan lahan sampai berdampak pada keberlangsungan hidup masyarakat* ***(Rimbakita.com) (data)*** *seperti penggusuran tanah maka hal itu menurut saya tidak patut untuk dibenarkan,* ***karena masyarakat akan sangat kesusahan (warrant). Namun jika pihak dari kegiatan pembukaan perluasan lahan sawit bersedia dan mampu untuk memberikan jaminan terhadap kelangsungan hidup masyarakat maka bisa untuk dipertimbangkan lagi (backing).***

Description:
P = Question
S= Students
L = Student Argumentation Level

The majority of students' answers still repeat the question statement given as a *claim* in their reasoning or argumentation. The percentage of the claim aspect is in the high category because students only provide *claims* that already exist in the questions given (Anita et al., 2021). The quality of argumentation skills at level 1 only contains one claim, students do not elaborate strong reasons to support the claims they make with data, warrant, or backing. Such answers can be said that students answer with low-quality arguments (Wardani et al., 2018).

The researcher concluded that the factors for the low argumentation skills of students seen from the results of the respondents' answers were the lack of seriousness in working on the questions given because filling in the answers using *Google form* and the lack of space or

habituation for students in providing opinions or arguments. Argumentation skills should be introduced at the elementary and secondary school levels to improve understanding and critical thinking (Kyei-Nuamah, 2024). Structured teaching is needed to train and improve students' argumentation skills. Teachers have an important role in creating an environment that encourages critical thinking and argumentation through discussions and learning activities (Stanford et al., 2016).

Improving students' argumentation skills in today's digital learning era demands the integration of critical thinking strategies with the use of interactive media and technology. Utilizing digital platforms such as online discussion forums, collaborative presentation apps and interactive videos allows students to present claims, data and reasoning in a more open and structured manner. Using "*digital argument-map writing*" helps students build a complete argumentation structure step by step so that they can produce better argumentative essays with the structure as a framework (Liu et al., 2017). *Game-based learning* also positively affects argumentation skills (Noroozi & Dehghanzadeh, 2021).

The *Google Groups* application showed an increase in students' ability to integrate different perspectives in their argumentation. This is crucial for developing dialogic argumentation internally which is important for reasoning, critical thinking, and perspective taking (Mcnaughton et al., 2019).Collaborative online platforms, such as ShiMo, combined with *argument mapping* and ChatGPT can improve students' critical thinking by encouraging more refutation and structured argumentation Chen et al., (2025). Technology-based approaches to learning not only focus on the end result, but also encourage reflective, constructive and data-driven thinking processes.

Several studies have shown various learning methods and models that can improve argumentation skills. One of the learning methods that can be used to improve argumentation skills is debate. The potential of debate in classroom learning can improve argumentation skills motivated by various theoretical perspectives. One theoretical perspective comes from dialogue argumentation related to daily social practices. Dialogue argumentation is considered an important pathway for developing individual argument reasoning (Kuhn, 2018). Dialogue argumentation engages students in social negotiation which allows them to gain insight into the strengths/weaknesses of their arguments which can then improve them (Y. C. Chen et al., 2016).

According to Nurfadillah et al., (2023) *the project-based learning* model is also effective in improving students' argumentation skills because they are actively involved in reasoning through group discussions The implementation of classroom action research using a learning cycle that focuses on *teacher's questioning techniques* can improve students' argumentation skills with the original level value of level 1 increasing to level 3 (Kristianti et al., 2018). Classroom action research with a focus on *Think Pair Share* using *levels of inquiry* conducted over three cycles resulted in an increase in students' argumentation skills (Fatmawati & Ramli, 2018).

Argumentation skills are one of the essential components of STEM education that promotes critical thinking, problem solving, and communication skills (Filippidis, 2022). In particular, argumentation-supported STEM education can positively contribute to student success in the science curriculum (Ha et al., 2023). Integrating argumentation into STEM education is an opportunity for students to engage in activities such as debates, discussions, and presentations, where they can practice building and defending their arguments (Mathis et al., 2022). Teachers play an important role in facilitating these activities, providing guidance and feedback, and creating a supportive learning environment. Effective implementation of argumentation in STEM education requires that teachers receive training and professional development to facilitate productive and meaningful argumentation experiences for students (Zorwick & Wade, 2016).

This study has several limitations. *First*, the focus of the study was limited to 51 grade X students in high school. *Second*, this study has not compared argumentation skills in all or some high schools so the results of the study cannot be generalized. *Third*, this research is limited to the test results of essay questions that refer to environmental change material. *Fourth*, the longitudinal study observation method was not applied in this study so that the development or changes in students' argumentation skills could not be monitored over time. This limitation is the basis for further research that is more comprehensive and generalizable.

CONCLUSION

The argumentation Skills of high school students in the *claim* component is included in the highest component with 66.2%, followed by the *data* component at 23%, *warrant* 5.9%, *backing* 2%, and *rebuttal* 0%. The average argumentation Skills of students is still at levels 1-2, the skills of students' argumentation using *claims*, level 1 as much as (67.5%), supported by *evidence*, level 2 as much as (11.75%). Furthermore, *warrants* are level 3 as much as (2%), *backing* is level 4 as much as (0.5%), while the appearance of a *qualifier* or *rebuttal* is level 5 as much as (0%). Students with very low argumentation skills need special attention to be improved. The results of this study show that most students have not reached a high level of argumentation ability. This indicates the need for integration of TAP into the learning process, especially in subjects that require scientific reasoning such as Biology. For example, teachers can apply learning strategies such as debates and provlem-based learning models based on TAP as an effort to improve students' argumentation skills. Further empowerment, especially in the indicators of *data (evidence/grounds)*, *warrants*, *backing*, and *qualifier* or *rebuttal* is highly expected so that it can reach the percentage level 3-5.

RECOMMENDATION

Future research is expected to use longitudinal study observation methods that are more effective in tracking the development of argumentation skills over time so that research is not only limited to the results of filling out essay questions by students in assessing students' argumentation skills. This research is expected to provide a more comprehensive understanding of students' argumentation skills and improve the quality of Indonesian education in the 21st century.

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