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Think-Aloud Protocol as A Method for Exploring and Understanding The Argumentation Skills of Pre-Service Science Teachers

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Abstract

Argumentation is a core component of critical thinking, one of the essential 21st-century skills. However, exploring this skill remains a challenge, often due to limitations in the available assessment methods. This study aims to offer a solution by utilizing the think-aloud protocol to explore and better understand the argumentation skills of Pre-Service Science Teachers (PSTs). A total of 30 PSTs from a state university in Indonesia participated in the research. Data collection and analysis through the think-aloud protocol were conducted in several stages: procedural briefing, implementation, coding and video analysis, and data interpretation. The findings revealed that the think-aloud protocol was effective in providing deeper insights into argumentation skills and yielded more detailed and accurate data across five key components: claims, evidence, reasoning, counterarguments, and rebuttals. On average, the PSTs demonstrated beginner-level argumentation skills, with the strongest performance in the claim component and weaker results in supporting aspects. Specifically, 5 participants were categorized as proficient, 9 as advanced, 6 as intermediate, and 10 as beginners. These results highlight the need for more effective learning strategies that provide PSTs with greater opportunities to practice constructing and critiquing arguments.

Keywords: argumentation; think-aloud protocol; 21st-century skills; pre-service scienve teachers

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INTRODUCTION

Rapid changes in life in the 21st century have made argumentation an important element in various countries' educational standards (Xiao and Kuhn, 2024). Argumentation is one of the vital skills needed by individuals to achieve success in various professional and academic fields (Fan and Chen, 2021; Guo et al., 2023). This skill helps individuals express their reasons in various contexts, such as the learning process, professional activities, and decision-making (Noroozi et al., 2020). In addition, argumentation is also considered a major component of critical thinking (Yilmaz-Na and Sönmez, 2023), which is an important achievement in today's education and learning (Saldıray and Doğanay, 2024). Therefore, developing argumentation

skills in each individual is not only important for their educational progress but also crucial to prepare them to face the complex challenges of an ever-evolving world.

Argumentation is a critical skill in the construction of scientific knowledge (Ho et al., 2019). This skill has become a core competency and a key element in science learning (Osborne et al., 2019). In particular, the elements in the Toulmin Argument Pattern (TAP) (Toulmin, 2003), such as claim, justification, and rebuttal, enable Pre-Service Science Teachers (PSTs) to reflect on and evaluate the extent to which the arguments presented are accurate in explaining the science concepts being learned (Lin, 2023). This makes argumentation a central skill for PSTs, both as learners who develop this skill and as future educators who will later promote this skill in their teaching (Ruwe and Mayweg-Paus, 2023).

Identifying the extent of the quality of argumentation skills possessed by PSTs is an important initial step before developing these skills. The success of this identification process is highly dependent on the method used, which must be able to explore the details of each argument put forward by PSTs as part of their thinking and reasoning process. However, current methods are often less effective in exploring and understanding PSTs' argumentation skills. Therefore, efforts are needed to overcome this obstacle, and the think-aloud protocol is believed to be an effective solution for this purpose.

The think-aloud protocol is a method that involves verbalizing thoughts directly while a person is performing a specific task (Ericsson and Simon, 1993). It is a voluntary activity in which individuals are asked to complete a relevant task, expressing their thoughts aloud while engaging in the task (Bai, 2018; Cowan, 2019). This method has been widely applied in psychology and educational research, providing a unique approach to understanding a person's thought processes when interacting with specific instruments and interventions (Wolcott and Lobczowski, 2021). Think-aloud protocols are a very useful tool for exploring and analyzing thinking strategies, as well as deepening understanding of how cognitive processes operate in learning contexts. Additionally, the think-aloud protocol is a method that can be used to understand the thinking process (Park et al., 2020), metacognitive skills (Jordano and Touron, 2018), self-regulated learning (Heirweg et al., 2019), and writing strategies (Latif, 2019; Rogiers et al., 2020). This statement implies that this method can also be used to explore and understand PSTs' argumentation skills. This is because argumentation is closely related to the thinking process, especially critical thinking (Chen et al., 2024; Fauziah et al., 2024). In addition, argumentation is also related to self-regulated learning and metacognitive awareness (Amini Farsani et al., 2019). Therefore, the use of think-aloud protocols to identify the quality of PSTs' argumentation skills can be a significant innovation and has the potential to produce new findings, especially in the context of argumentation skills assessment.

Think-aloud protocols are considered a valuable tool for gaining a deeper understanding of PSTs' argumentation skills, offering insights that may not be accessible through traditional assessments, such as tests or interviews alone. By allowing researchers to observe and analyze participants' real-time thought processes as they construct arguments, this method provides a unique opportunity to identify the strategies employed and the difficulties encountered during argumentation. Despite its potential, no study to date has specifically employed think-aloud protocols to investigate PSTs' argumentation skills. This highlights a notable gap in the existing literature, especially given the critical role of argumentation in effective science education. Accordingly, the present study seeks to explore and better understand PSTs' argumentation skills through the use of think-aloud protocols, while also evaluating the suitability and effectiveness of this method within this research context.

METHOD

Design

This study applied a qualitative approach to explore and understand PSTs' argumentation skills through the think-aloud protocol (Ericsson and Simon, 1993). Through this method, PSTs

are asked to spontaneously report everything that comes to their mind while working on a task, without interpreting or analyzing their thoughts (Bai, 2018). Thus, this study is expected to provide in-depth insights into how PSTs construct and express their arguments.

We used a think-aloud protocol to capture arguments generated by PSTs' direct thinking while working on a task. To achieve this goal, each PST was given a 30-minute climate change argumentation skills test. Before the test began, they were briefed on the procedure to be followed. During the test, they were asked to verbalize every thought that crossed their mind and were allowed to use facial expressions and body movements. This process was recorded by the researcher, and the obtained videos were then analyzed to explore argumentation skills that include five components: claims, evidence, reasoning, counterarguments, and rebuttals (Erduran et al., 2004; Toulmin, 2003). The collected information was then interpreted to obtain research findings.

Participants

The participants of this study were 30 PSTs from a state university in Indonesia, consisting of 11 males and 19 females. This diverse gender composition is expected to provide interesting insights into the various perspectives and approaches in constructing the arguments they produce. In addition, it is also expected to obtain valuable findings to improve teaching methods and support more effective argumentation learning in the classroom.

Data Collection and Analysis

The process of collecting and analyzing data through the think-aloud protocol was carried out through several stages, namely procedural direction, implementation, coding and video analysis, and data interpretation (Figure 1). Each stage was designed to explore and understand the PSTs' argumentation skills. The results of this analysis are expected to provide deeper insight into the PSTs' ability to argue, as well as provide recommendations for the development of a more effective science education curriculum.

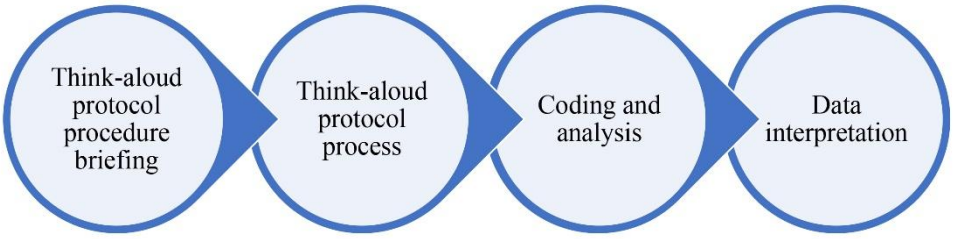

Figure 1. Research design

The initial stage is a briefing to the PSTs regarding the think-aloud protocol procedure. This stage is used to convey information to the PSTs about what they should do during the think-aloud protocol. This aims to ensure that the PSTs clearly understand the steps that must be taken during the think-aloud protocol process.

The second stage is the application of the think-aloud protocol through argumentation tests about climate change. In this stage, PSTs participate in individual think-aloud protocol sessions, which are recorded in video format. They are asked to complete the test while expressing out loud every thought that crosses their mind.

One important issue related to the reactivity of the think-aloud protocol method is the presence of the researcher in the session. Hillocks (1986) and Chamot (2001) argued that the presence of the researcher can influence participants' verbal responses and performance. To minimize this reactivity, the researcher decided not to be in the same room as the PSTs. Alternatively, the researcher observed the PSTs' verbalizations through a glass door and encouraged them to express their thoughts with phrases such as "speak your mind" or "talk it

out" if they did not do so consistently. This approach has been shown to help PSTs express their thoughts more spontaneously and less disruptively.

The third stage is coding and analyzing videos of the think-aloud protocol process. This process aims to determine the quality of PSTs' argumentation skills. The five components of argumentation skills are the basis for coding and analyzing research data, as referred to in Table 1. This analysis process allows researchers to identify and evaluate each argument expressed by PSTs during the think-aloud session.

Table 1. Descriptions of coding categories and subcategories

Coding Categories	Coding Subcategories	Description
Claim	0	No claims were made.
	1	The claims made do not correspond to the context of the problem.
	2	The claims made follow the context of the problem but are unclear or broad and even non-specific.
	3	The claims submitted follow the context of the problem and are stated clearly and specifically.
Evidence	0	No evidence was used.
	1	The evidence used does not follow the context of the problem and does not support the claims.
	2	The evidence used is appropriate to the context of the problem but is still raw data or does not yet show specific support for the claims.
	3	The evidence used is appropriate to the context of the problem and shows specific support for the claims.
Reasoning	0	No reasoning is provided.
	1	The reasoning provided does not explain the relationship between the evidence and the claims.
	2	The reasoning provided has explained the relationship between evidence and claims but has not clearly stated the concepts, principles, laws, or scientific theories used in constructing the reasoning.
	3	The reasoning provided explains the relationship between evidence and claims and clearly states the concepts, principles, laws, or scientific theories used in constructing the reasoning.
Counter-argument	0	No counterarguments were given.
	1	The counterargument given does not directly counter the initial claim.
	2	The counterargument given directly counters the initial claim but is less clear or broad and even non-specific.
	3	The counterargument given directly counters the initial claim and is stated clearly and specifically.
Rebuttal	0	No rebuttal was given.
	1	The rebuttal given does not explain the reasons why the opposing viewpoint is invalid.
	2	The rebuttal provided explains the reasons why the opposing viewpoint is invalid but does not clearly state the concepts, principles, laws, or theories used in constructing the rebuttal.
	3	The rebuttal that has explained the reasons why the opposing viewpoint is invalid and has clearly stated the concepts, principles, laws, or theories used in constructing the rebuttal.

The coding method employed in this study was grounded in established qualitative research literature (Creswell, 2009). To ensure inter-coder reliability, two trained coders independently analyzed the data. In cases where disagreements arose regarding the coding of specific verbal data, a third researcher acted as a mediator to help resolve the discrepancies. The level of agreement between coders was assessed using Cohen's Kappa analysis (Table 2)

(Landis & Koch, 1977; McHugh, 2012). Given the substantial volume of data, the coding process was iterative, demanding, and time-intensive.

To measure qualitative data for comparative purposes, the concept of frequency index used in Fang and Tajvidi (2018) the study was adapted and applied in this study. As a quantitative measure for qualitative data, the frequency index is calculated as the product of the number of PSTs involved in the same mental activity (in a subcategory) and the frequency of occurrence of that mental activity in all transcripts. The higher the frequency index, the more popular (or common) the mental activity is among all PSTs. Thus, this method not only provides a clear picture of PSTs' thinking patterns but also allows researchers to draw broader conclusions about the tendency of argumentation skills in the context of science education.

Table 2. Interpretation of Cohen's Kappa

Value of Kappa	Level of Agreement
< 0.00	Poor
0.00 – 0.20	Slight
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Substantial
0.81 – 1.00	Almost Perfect

The final stage is data interpretation (Table 3). Information collected from the think-aloud protocol, after going through the coding and analysis process, is then interpreted by the researcher to produce research findings, namely revealing the extent of the quality of PSTs' argumentation skills, as well as providing in-depth insights into how they develop and construct arguments in the context of science education. This interpretation will help researchers to understand the patterns and tendencies of argumentation skills possessed by PSTs, as well as provide a basis for developing more effective curricula or teaching strategies.

Table 3. Level of argumentation skills

Score	Level of Argumentation Skills
0.00 – 0.75	Beginner
0.76 – 1.50	Intermediate
1.51 – 2.25	Advanced
2.26 – 3.00	Proficient

Source: Hendratmoko et al. (2023)

RESULTS AND DISCUSSION

The results of the think-aloud protocol revealed some variation in the quality of the PSTs' argumentation skills (see Table 4). However, Cohen's Kappa analysis indicated a very high level of agreement between coders, suggesting that the coding process was both consistent and reliable. The findings also showed that some PSTs were able to construct strong, logical arguments, with claims supported by relevant evidence and a consideration of multiple perspectives. In contrast, others struggled to build coherent arguments, often having difficulty explaining their reasoning clearly.

From a methodological perspective, think-aloud protocols are used to investigate phenomena in a more in-depth and detailed manner (Park et al., 2020). This method allows researchers to obtain richer insights and more accurate and detailed data (Latif, 2019). Through think-aloud protocols, researchers can report and measure the content and frequency of individual skill monitoring more specifically (Jordano and Touron, 2018). Thus, the application of this method not only improves the quality of the data obtained but also enriches our understanding of certain aspects that may be missed in other research methods, such as the distribution of the quality of PSTs' argumentation skills.

The data in Table 4 clearly illustrate the argumentation skills of each PST for each component. These findings confirm that the think-aloud protocol is effective in exploring the quality of PSTs' argumentation skills. This method, as proposed by Latif (2019) and Park et al. (2020), allows researchers to obtain more specific and in-depth data related to individual thinking and reasoning processes. The think-aloud protocol provides a reliable and almost simultaneous report on learning activities, which in turn helps in providing a deeper understanding of how PSTs construct and express their arguments (Cowan, 2019). This is in line with previous findings regarding the ability of this method to explore more complex dimensions in the critical thinking process (Latif, 2019). Thus, the application of the think-aloud protocol has proven effective in offering deeper insights into the argumentation skills of PSTs.

Table 4. Results of data analysis of PSTs argumentation skills

PST	Claim			Evidence			Reasoning			Counterargument			Rebuttal			Kappa Cohen's
	C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3	
1	1	1	-	1	1	-	1	1	-	0	0	-	0	0	-	1.00
2	1	1	-	1	1	-	1	1	-	0	0	-	0	0	-	1.00
3	3	3	-	3	3	-	3	3	-	2	2	-	2	2	-	1.00
4	2	2	-	1	1	-	2	2	-	1	1	-	1	1	-	1.00
5	1	1	-	1	1	-	1	1	-	1	1	-	0	0	-	1.00
6	3	3	-	3	3	-	3	3	-	3	3	-	2	2	-	1.00
7	3	3	-	2	2	-	1	1	-	3	3	-	2	2	-	1.00
8	3	3	-	3	3	-	3	3	-	0	0	-	0	0	-	1.00
9	3	3	-	3	3	-	3	3	-	3	3	-	3	3	-	1.00
10	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	1.00
11	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	1.00
12	3	3	-	2	2	-	3	3	-	0	0	-	0	0	-	1.00
13	3	3	-	3	3	-	3	3	-	3	3	-	3	3	-	1.00
14	2	2	-	1	1	-	1	1	-	2	2	-	2	2	-	1.00
15	3	3	-	3	3	-	3	3	-	3	3	-	0	0	-	1.00
16	3	3	-	1	1	-	0	0	-	2	2	-	1	1	-	1.00
17	0	0	-	0	0	-	0	0	-	1	1	-	1	1	-	1.00
18	1	1	-	0	0	-	0	0	-	1	1	-	0	0	-	1.00
19	3	3	-	2	2	-	3	3	-	2	2	-	1	1	-	1.00
20	1	1	-	0	0	-	0	0	-	0	0	-	0	0	-	1.00
21	3	3	-	3	3	-	3	3	-	0	0	-	0	0	-	1.00
22	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	1.00
23	0	0	-	3	3	-	1	1	-	1	1	-	1	1	-	1.00
24	0	0	-	0	0	-	1	1	-	0	0	-	0	0	-	1.00
25	0	0	-	0	0	-	1	1	-	0	0	-	0	0	-	1.00
26	3	3	-	3	3	-	2	2	-	2	2	-	1	1	-	1.00
27	3	3	-	1	1	-	2	2	-	1	1	-	1	1	-	1.00
28	3	3	-	3	3	-	1	1	-	1	1	-	0	0	-	1.00
29	3	3	-	2	2	-	1	1	-	0	0	-	0	0	-	1.00
30	3	3	-	0	0	-	1	1	-	1	1	-	0	0	-	1.00

To obtain more specific and comprehensive information regarding the argumentation skills of PSTs, the data presented in Table 4 were carefully grouped and analyzed based on each distinct component of argumentation. This step allowed for a deeper understanding of the

individual elements that contribute to the overall argumentation process. By breaking down the data according to the various components, such as claim, evidence, reasoning, counterargument, and rebuttal, we were able to identify patterns and trends that highlight the strengths and weaknesses of the PSTs' argumentation abilities. The results of this detailed grouping and subsequent analysis are visually summarized in Figure 2, which provides a clear and concise overview of how each component was represented across the sample. This analysis not only helps to illuminate the areas in which PSTs excel but also points to specific aspects of argumentation that may require further development and support.

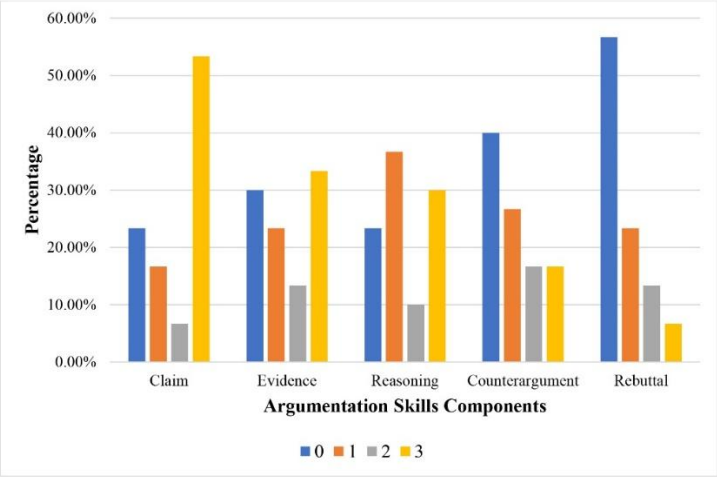

Figure 2. Quality of argumentation skills of PSTs in each component

The achievement of PSTs' argumentation skills in the claim component shows that most have achieved a score of 3 (Figure 2). The results of this study indicate that the majority of PSTs have been able to make clear and specific claims based on the given problem. Where a claim is a statement made by an opinion holder to convince others to accept his view (Hollihan and Baaske, 2022). However, when viewed from the average score, their achievement is at a score of 2, which means that they are not yet fully able to produce good claims. This shows that their skills in constructing claims still need to be improved and require further guidance.

The evidence used by PSTs in their arguments also had varying scores (Table 4). The average score for this component was 1, indicating that in general, PSTs were not yet able to provide evidence that was relevant to the context of the problem. The evidence they used also did not fully support the claims put forward. Compiling effective evidence in arguments has proven to be difficult (Du and List, 2021). The quality of evidence produced by PSTs still needs to be improved. This is because in arguing, it is important to support claims with strong evidence so that the arguments presented can be accepted by others (Kim and Roth, 2018). In addition, evidence that is consistent with the claim will ensure the validity of the conclusion (Correnti et al., 2022). Therefore, developing PSTs' skills in compiling effective evidence should be a primary focus in training, to improve the quality of the arguments they make.

The results on the reasoning component show that PSTs obtained varying scores (Table 4). The average score for this component is 1, which indicates that the reasoning provided is still insufficient to explain the relationship between claims and evidence. PSTs have not been able to build adequate reasoning, which should be able to explain the relationship between claims and evidence and be supported by relevant scientific concepts, principles, laws, or theories. The quality of PSTs' reasoning in building arguments still needs to be improved. This is because the argumentation scheme involves interrelated reasoning patterns and critical questions (Baumtrog, 2021). Reasoning itself refers to providing arguments or justifications for a particular position, which serves to prove the argument put forward (Prochazka et al., 2018). In arguing, individuals are required to develop logical and reasonable reasoning to support their arguments, which can ultimately produce effective argumentation quality in

solving problems (Pimvichai and Buaraphan, 2019). Therefore, strengthening reasoning skills is very important so that PST can build more solid arguments and support the problem-solving process more effectively, this can be achieved through the application of inquiry-based learning (Hendratmoko et al., 2023).

Counterarguments presented by PSTs in their arguments were dominated by a score of 0 (Figure 2). However, the average score for this component was 1, indicating that the counterarguments presented did not directly challenge the initial claim. The results of the think-aloud protocol showed that most PSTs could not even present counterarguments at all. This is following the findings of (Özdemir, 2018), who stated that individuals tend to ignore counterarguments or ignore knowledge that does not support their point of view, and prefer to convey claims from a one-sided perspective. Counterarguments, which are statements that oppose the initial claim, are a high-level argumentation component that should be mastered by every individual (Akbayrak and Namdar, 2019; Anwar and Ali, 2020). However, in the process of developing this component, some PSTs did not seem to make any effort to produce counterarguments (Öztürk and Doğanay, 2019). The quality of PSTs' ability to present counterarguments in their arguments still needs to be improved. Therefore, lecturers need to create situations where each individual is asked to work with other perspectives through counterarguments, as well as consider the right way to refute those perspectives.

The rebuttals produced by PSTs in their arguments were also dominated by a score of 0 (Figure 2). However, on average, this component scored 1, indicating that the rebuttals presented did not sufficiently explain the reasons why the opponent's point of view was considered invalid. In addition, the rebuttals made did not clearly link relevant scientific concepts, principles, laws, or theories in their preparation. This shows that most PSTs still have difficulty in presenting rebuttals in their arguments. Similar to counterarguments, rebuttals are a high-level argumentation component that must be mastered by every individual (Akbayrak and Namdar, 2019; Anwar and Ali, 2020). The quality of PSTs' ability to present rebuttals needs to be improved, considering that this is a very important skill, difficult to learn, and valued in many fields, including politics and science. With rebuttals, arguments become more complex and can improve the overall quality of the arguments produced (Capkinoglu et al., 2020). Therefore, improving PSTs' skills in constructing rebuttals is very important to strengthen their arguments and increase their effectiveness in arguing.

The results of further analysis show that PSTs have varying levels of argumentation skills, ranging from beginner to proficient. This finding is presented in Figure 3, which shows the distribution of argumentation skill levels of each PST.

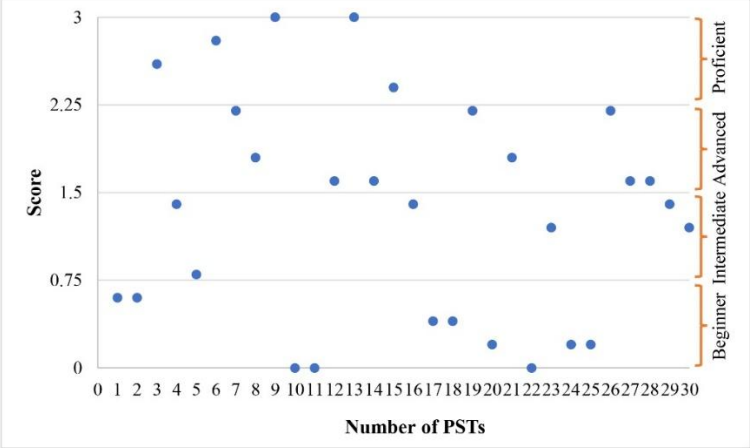

Figure 3. PST argumentation skills level

The data in Figure 3 reveals that 5 people are at the proficient level, 9 at the advanced level, 6 at the intermediate level, and the rest are at the beginner level. This reflects that some PSTs have reached a high level in their argumentation skills, thanks to their ability to build

structured and evidence-based arguments. However, some PSTs are still at a lower level, indicating difficulties connecting their ideas and supporting arguments with strong reasons. This finding emphasizes the importance of evaluating and designing more focused training programs to improve PSTs' argumentation skills. With this step, it is hoped that they will be better prepared to face the challenges in science teaching in the future and contribute to the development of critical thinking among their students.

The quality of PSTs' argumentation skills identified through the think-aloud protocol showed quite a large variation (Figure 3). Most PSTs were at the beginner level, where the arguments they produced tended to be simple claims with weak evidence support. For example, in the context of climate change, the arguments presented by PSTs at this level can be seen in Figure 4. In the argument, although there is evidence that some countries are still able to produce food, the reasons given to support the claim do not consider the long-term impacts or extreme conditions that may occur in the future. This reflects the difficulty in connecting evidence to claims, which in turn reduces the strength and clarity of the message delivered. To overcome this challenge, it is essential to provide more in-depth training on argumentation structure and effective use of evidence. With the right training approach, it is hoped that PSTs can develop to a higher level, producing more structured, convincing, and evidence-based arguments.

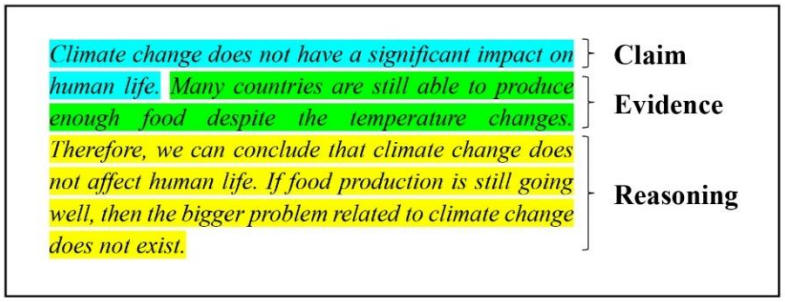

Figure 4. Example of argumentation at the beginner level

Some PSTs are also at the intermediate level. At this level, the arguments made usually consist of claims supported by evidence and little reasoning (Figure 5). Although there is better development compared to the beginner level, there is still room to deepen the analysis and clarify the relationship between claims and evidence. PSTs begin to show skills in exploring counterarguments and explaining the relevance of the evidence used, but often their reasoning is still lacking in detail. With proper guidance, it is hoped that PSTs at this intermediate level can develop further and reach a higher level of argumentation skills. Therefore, learning programs that emphasize improving critical analysis skills and more complex argumentation techniques will be very beneficial, one of which can be applied through the inquiry approach (Hendratmoko et al., 2023).

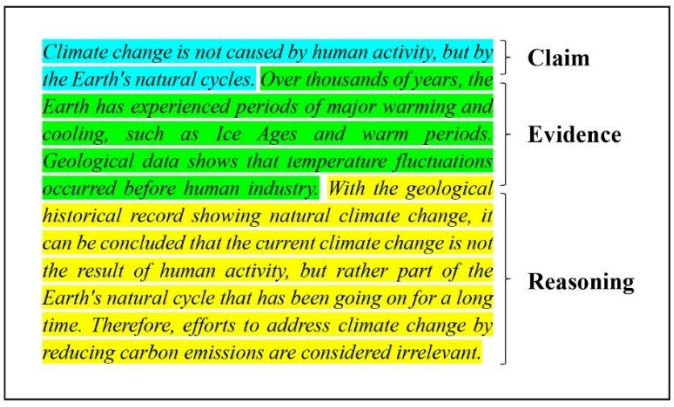

Figure 5. Example of argumentation at the intermediate level

Figure 3 shows that 9 PSTs are at the Advanced level. At this level, the arguments produced already include claims supported by strong evidence and reasoning, although they do not fully include counterarguments and rebuttals (Figure 6). In the argument, although various opinions are presented, the focus is still given to scientific evidence showing that human activities significantly affect climate change and that proactive action is needed to address this problem. PSTs at this level demonstrate good skills in constructing comprehensive and structured arguments, but there is still an opportunity to strengthen their arguments by considering alternative views. The addition of counterargument elements can increase the credibility of the argument and demonstrate a deeper understanding of the topic being discussed. Therefore, advanced training that focuses on rebuttal techniques and critical thinking is needed to help PSTs reach a higher level of argumentation so that they can become more persuasive and effective science teachers in the future.

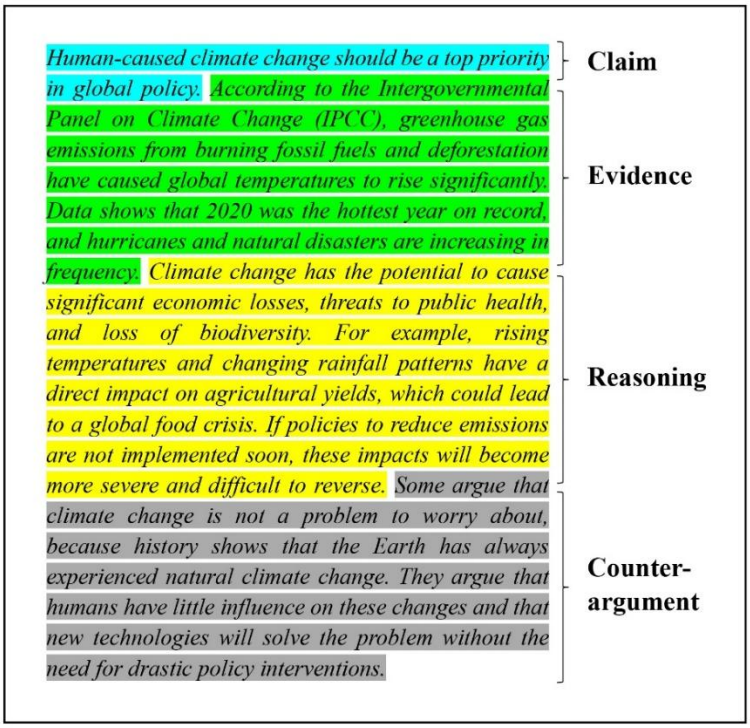

Figure 6. Example of argumentation at the advanced level

A small proportion of PSTs in this study were at the proficient level. Arguments produced at this level reflect optimal argumentation quality, where the claims put forward are supported by strong evidence and reasoning and can present counterarguments and rebuttals (Figure 7). PSTs at this level demonstrate maturity in critical thinking and skills to analyze issues from multiple perspectives. They are not only able to defend their positions but also understand and respond to challenges to the arguments put forward. This shows that they have mastered the argumentation skills needed to engage in complex and in-depth discussions. Therefore, it is important to continue to encourage PSTs at this level to practice and develop their skills further, so that they can become effective science teachers and be able to facilitate meaningful discussions in the classroom. One way to achieve this is by implementing an inquiry-based debate approach (Hendratmoko et al., 2024), which can deepen their understanding of the topic and improve their argumentation skills more actively.

Overall, the average quality of PSTs' argumentation skills revealed through the think-aloud protocol is at the intermediate level. This shows that most PSTs can convey claims well, clearly, and specifically, supported by evidence and a little reasoning. However, they still have difficulty presenting counterarguments and rebuttals. This finding reflects that the quality of argumentation skills possessed by PSTs is still low and requires further development.

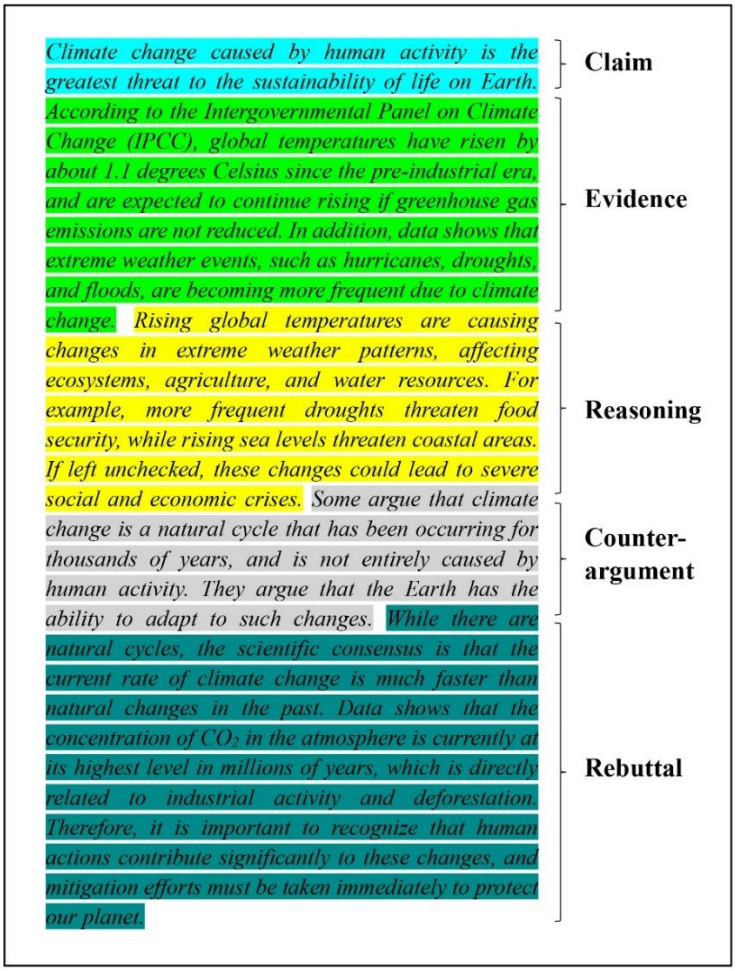

Figure 7. Example of argumentation at the proficient level

The low quality of PSTs' argumentation skills in this study is in line with previous research findings showing that individual argumentation skills are generally still low (Noviyanti et al., 2019). This can be seen from the high achievement of the majority of PSTs only in the claim component, but not in other components. The arguments presented only consist of simple claims, which are sometimes built on an inaccurate understanding of concepts (Wardani et al., 2018). Therefore, it is important to implement more effective learning strategies to improve PSTs' argumentation skills.

Given the importance of argumentation skills for PSTs, efforts to improve the quality of these skills are very crucial. One step that can be taken is to design learning that provides more opportunities for PSTs to build and critique arguments, make claims, and use evidence in the reasoning process through inquiry activities (Mikeska and Howell, 2020). In addition, in the context of argumentation, PSTs gain knowledge through a series of confirmations by presenting the results of investigations and discussing the results through scientific debates (Fakhriyah et al., 2021). Therefore, the integration of learning strategies that focus on critical and collaborative argumentation will greatly contribute to improving the quality of PSTs' argumentation skills in the future, so that they can be more effective in facing challenges in the world of education and teaching science in a more evidence-based and critical way.

CONCLUSION

The findings of this study indicate that the think-aloud protocol is an effective method for exploring and understanding argumentation skills in depth. This method has been proven to be able to produce more accurate and detailed data related to the five main components of argumentation: claims, evidence, reasoning, counterarguments, and rebuttals. Based on the

findings of this protocol, it is known that most PSTs have been able to formulate claims well, but still have difficulty in developing other components. This finding indicates that most PSTs are still at the beginner level in their argumentation skills. Therefore, more intensive and targeted efforts are needed to improve the quality of PSTs' argumentation skills.

RECOMMENDATION

The findings of this study indicate that the average argumentation skills of PSTs are at a beginner level, with the highest achievement in the claim component, but still low in other supporting aspects. These findings highlight the need for further development in compiling evidence and reasoning that support claims, as well as skills in presenting more solid counterarguments and rebuttals. The findings also indicate the need for more effective learning strategies, which provide PSTs with more opportunities to practice constructing and critiquing arguments. In addition, it is also necessary to consider the use of Artificial Intelligence (AI) for automatic feedback on the arguments produced by PSTs. Therefore, further research needs to consider the application of inquiry activities, scientific debates, and the use of AI tools to optimize PSTs' argumentation skills.

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