Differences in Scientific Argumentation Skills of Preservice Physics Teachers in Written and Oral Contexts: A Case Study of Video-Based Microteaching Learning

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Received: 28th May 2024; **Accepted**: 28th June 2024; **Published**: 30th June 2024
DOI: https://dx.doi.org/10.29303/jpft.v10i1.7277

Abstract - *This study aims to analyze the profile of scientific argumentation skills of preservice physics teachers in the context of written case studies and oral presentations through video-based microteaching learning. Data was collected from 15 preservice physics teachers participating in a microteaching course. Qualitative analysis of argumentation components (claim, reason, evidence, rebuttal, conclusion) revealed significant differences in argumentation skills between the two contexts. In written case studies, students demonstrated a relatively good ability to present evidence. However, they needed to improve in formulating claims and reasons. Meanwhile, in oral presentations, there was a significant increase in all components of argumentation, particularly claims, reasons, rebuttals, and conclusions. These findings have important implications for developing more effective microteaching learning to improve the scientific argumentation skills of preservice physics teachers.*

Keywords: *Scientific Argumentation; Preservice Physics Teacher; Microteaching; Case Study; Video-Based Learning*

INTRODUCTION

Scientific argumentation is essential in education, especially for prospective physics teachers (Faize et al., 2017). This skill encompasses a deep understanding of physics concepts and the ability to communicate that knowledge logically, coherently, and persuasively. Physics teachers proficient in scientific argumentation can guide students to think critically, analyze evidence, and build a deep understanding of physical phenomena. This ability aligns with science education goals, emphasizing content mastery and developing higher-order thinking skills (Osborne, 2010).

The ability to argue scientifically is essential in physics learning because physics is a scientific discipline built on evidence and logical reasoning (Boettcher & Meisert, 2011). In the learning process, students are expected to memorize formulas and concepts and understand how these concepts are derived from empirical evidence and how they can be applied to explain natural phenomena. Scientific argumentation allows students to participate in the learning process actively, questioning assumptions, evaluating evidence, and building a deeper understanding of physics (Jimenez-Aleixandre & Erduran, 2007).

In addition, scientific argumentation skills are also essential in everyday life. In an increasingly complex and information-filled society, evaluating claims, analyzing evidence, and making decisions based on solid reasons becomes increasingly essential. Physics teachers with good scientific argumentation skills can equip students to become critical, analytical citizens and make decisions based on accurate and relevant information (Driver et al., 2000).

However, various studies indicate that the scientific argumentation skills of prospective teachers still need to be improved (Sampson & Gerbino, 2010). Several factors can cause the low ability of this. First, an in-depth understanding of physics concepts can help build solid and logical arguments. Second, the lack of experience in scientific argumentation can make it difficult for students to identify and apply the appropriate argument structure (Simonneaux, 2007). Third, learning methods that focus on memorization and less encourage critical thinking can hinder the development of argumentation skills. Finally, the lack of constructive feedback from lecturers or colleagues can make students unaware of errors or weaknesses in their arguments.

To address this challenge, a more effective learning approach is needed to develop the scientific argumentation skills of preservice physics teachers. Video-based microteaching learning is a promising approach. In this learning, students can observe good scientific argumentation models from instructional videos, practice designing and delivering their arguments, and receive valuable feedback from lecturers and colleagues (Fischer & Neumann, 2012).

The importance of scientific argumentation skills for prospective physics teachers cannot be denied because it significantly impacts the quality of learning and student development. This ability allows teachers to improve students' conceptual understanding by presenting clear and logical scientific arguments, linking physics concepts with real-world phenomena (Wenning, 2007). More than that, teachers can develop students' critical thinking skills by encouraging them to analyze evidence, evaluate claims, and build their arguments (Erduran & Jimenez-Aleixandre, 2007). Learning that involves scientific argumentation also creates an active and interactive learning environment, increasing student motivation and engagement through constructive discussions and debates (Osborne et al., 2004). Ultimately, the argumentation skills instilled by the teacher will equip students to become critical, analytical citizens and able to make evidence-based decisions in the face of challenges in the complex information age (Driver et al., 2000).

Therefore, this study aims to describe the profile of scientific argumentation of prospective physics education teacher students through an analysis of their answers to case studies given after they watched instructional videos related to microteaching. By understanding the profile of students' arguments, helpful information is likely to be obtained to design more effective learning interventions in improving their scientific argumentation skills.

RESEARCH METHODS

This research involved 15 preservice physics teachers enrolled in a microteaching course. The students' argumentation skills were measured in two ways: through a qualitative analysis of case study responses and an assessment of their microteaching presentations. During the course sessions, participants were asked to watch two instructional videos, "Building a Foundation for Success: Effective Lesson Plan Strategies" and "Activate Learning, Improve Performance: Exploring Active Teaching Techniques." After watching each video, participants were given three case studies relevant to the video's topic. They were asked to choose one case study from each video and provide a written response describing how they would solve the case as a physics teacher.

In addition, participants also conducted microteaching presentations where they practiced the teaching skills they had learned (Fischer & Neumann, 2012). These presentations were assessed using an argumentation rubric that included claims, reasons, evidence, rebuttals, and conclusions. After the presentations, participants also engaged in a question-and-answer session with the lecturer and peers who acted as students. The questions in this session aimed to directly test the students' argumentation skills and explore their understanding of relevant physics concepts.

The case study responses and transcripts of the question-and-answer sessions were analyzed qualitatively (Creswell et al., 2017; Miles et al., 2014) using an argumentation framework (Toulmin, 2003; Van Eemeren et al., 2002; Osborne, 2010; Zohar & Nemet, 2002) to identify the components of scientific argumentation that emerged. These components include:

- **Claim:** The main statement or position taken by the student.
- **Reason:** The explanation or reasoning that supports the claim.
- **Evidence:** Data, facts, or examples used to strengthen the reasoning.
- **Rebuttal:** Acknowledgment and refutation of possible objections or alternative views.
- **Conclusion:** Reaffirmation of the claim based on the reasoning and evidence presented.

The analysis was conducted by identifying the presence and quality of each argumentation component in the case study responses and transcripts of the question-and-answer sessions. The proportion of use of each argumentation component was calculated for each case and compared between cases to see significant differences. Further analysis was also conducted, where several examples of case study answers and presentation data representing the patterns found were also presented. These examples were chosen to illustrate how students formulate and articulate their scientific arguments, both in writing and verbally, and to provide an overview of the variation in argumentation skills among them.

RESULTS AND DISCUSSION

Results

This section presents the results of an analysis of the scientific argumentation skills of preservice physics teachers who participated in a microteaching course. Argumentation skills were measured through two types of assessments: a qualitative analysis of case study responses and an assessment of microteaching presentations that included a question-and-answer session (Creswell, 2017; Miles et al., 2014). The qualitative analysis was conducted by identifying the presence of each argumentation component (claim, reason, evidence, rebuttal, and conclusion) in the case study responses and transcripts of the question-and-answer sessions and identifying common patterns in language use and sentence structure. The microteaching presentation assessment used an argumentation rubric that included the same components. Scores from both assessment types were combined to provide a more comprehensive picture of students' argumentation skills. An overview of student argumentation achievement for each session and type of measurement is shown in Figure 1. In addition to Figure 1, which presents general achievements, the description of students' argumentation skills was also analyzed on the acquisition of scores for each argumentation component, obtained from case study answers (Figure 2) and presentations and question-and-answer sessions (Figure 3). This allows us to see in more detail the strengths and weaknesses of students in each aspect of scientific argumentation.

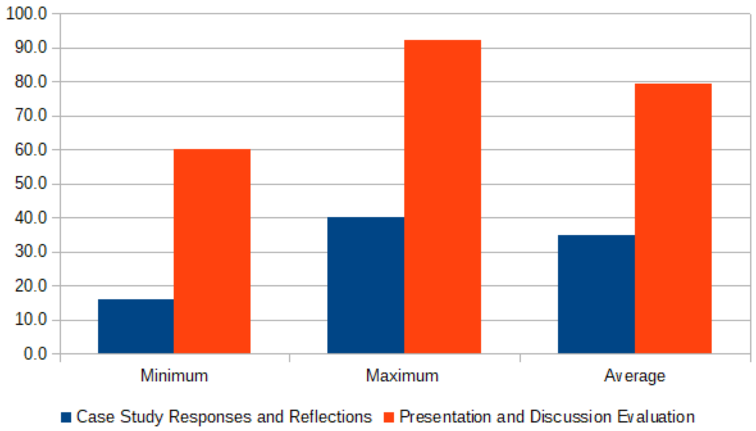

Figure 1. Overview of Argumentation Ability Data for Both Sessions

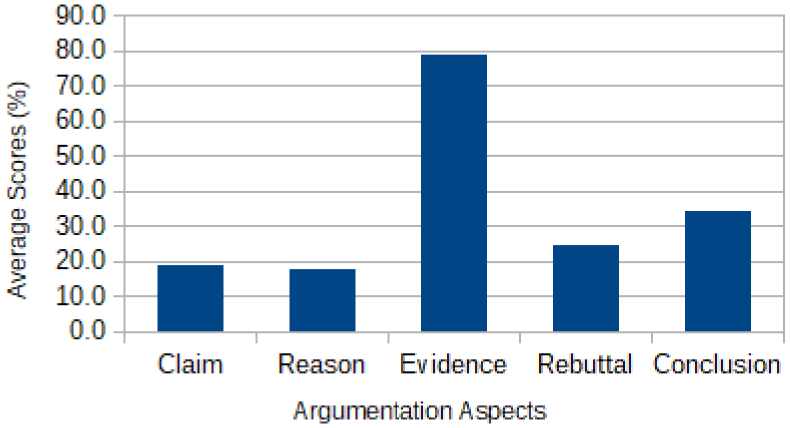

Figure 2. Comparison of Average Scores for Each Argumentation Aspect from Case Studies

Figure 2 shows that in case studies, students had the highest scores on the evidence component, indicating that they could provide relevant evidence or examples to support their arguments. However, their scores on the claim and reason components were relatively low, indicating that they must improve their writing skills, especially in formulating explicit claims and providing solid reasons.

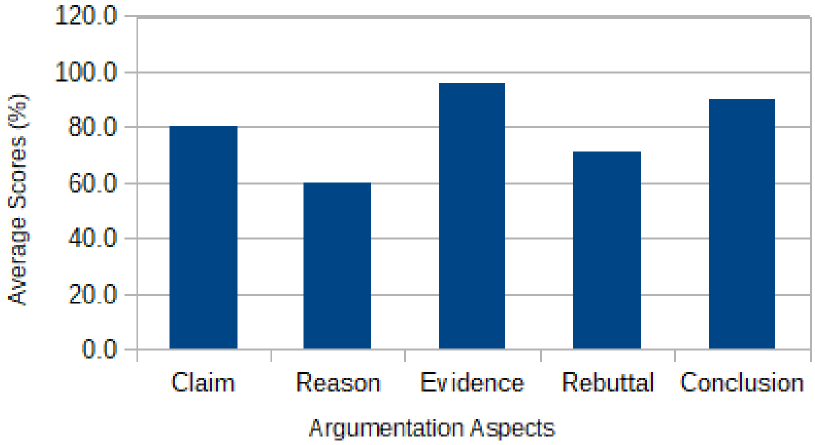

Figure 3. Comparison of Average Scores for Each Argumentation Aspect from Presentation and Q&A Sessions.

Figure 3 shows that in presentations and question-and-answer sessions, students also had the highest scores on the evidence component. However, their scores on the reason and rebuttal components still need to be improved. This indicates that they must improve their ability to formulate complete and structured arguments in writing and verbally.

In addition to the data in Figures 2 and 3, a qualitative analysis was conducted on student responses for each argumentation component. The analysis results show that students' argumentation skills, especially on specific components, still need improvement. This can be seen from the low proportion of argument components, such as claims and reasons, in the two case studies chosen by students.

Table 1. Results of Qualitative Analysis on Argumentation Skills from Case Study Responses

No	Argumentation Component	Description	Information
1	Claim	Significantly, only some students explicitly stated their claims or opinions. This indicates that they need more practice in formulating clear and structured arguments.	Low Proportion of Claims
2	Reason	Only a tiny proportion of students provided clear reasons to support their claims. This could indicate that they have not fully understood the concepts taught or are not yet accustomed to linking theory with practice.	Low Proportion of Reasons
3	Evidence	Most students could provide relevant evidence or examples to support their arguments. This shows that they understand the learning material well but must develop the ability to construct more comprehensive arguments.	Fairly Strong Evidence
4	Rebuttal	Very few students included rebuttals in their arguments. This could mean they have yet to be used to considering alternative perspectives or understanding the importance of addressing potential objections to their arguments.	Rebuttals Rarely Appear
5	Conclusion	Only a tiny proportion of students provided clear conclusions. This may indicate that they need more practice summarizing their arguments and reaffirming their claims based on the evidence presented.	Inconsistent Conclusions

According to the video, a qualitative analysis was conducted on student responses for each case study. The following shows the results of data analysis of student responses to case questions related to video 1 with the theme "Building a Foundation for Success: Effective Lesson Plan Strategies".

Table 2. Results of Response Analysis Related to Video 1 Case Study Theme.

No	Variable Analyzed	Analysis Results
1	Most Chosen Case	Case 2 was the most frequently chosen case by students. This case discusses how to identify the learning needs of students who need help understanding basic physics concepts and design effective learning strategies.
2	Patterns and Similarities in Answers	Case 2: Students tend to use words like "I", "will", "students", "and", "physics concepts", "learning needs", and "understand". This shows that they are focusing on the actions they will take as teachers to help struggling students.

No	Variable Analyzed	Analysis Results
		Case 1: Students use words like "students", "learning", "level of understanding", and "differentiation". This shows that they are trying to design a learning plan that accommodates differences in student abilities.
3	Argumentation Indicators	Case 2: The high proportion of evidence indicates that students can provide concrete examples or steps. However, the proportion of claims and reasons could be higher, indicating that they could express opinions more and provide clear reasons.
		Case 1: The average proportion of claims, reasons, evidence, rebuttals, and conclusions shows a more even distribution. However, there is still room for improvement in strengthening claims and reasons.

Based on Table 2, overall, students show a good understanding of the concepts in the material, especially in providing evidence and examples. However, they must improve their ability to formulate explicit claims and provide strong reasons to support their arguments.

Based on the analysis of student response data on case questions in video 2 with the theme "Activate Learning, Improve Performance: Exploring Active Teaching Techniques", the data in Table 3 was obtained as follows.

Table 3. Results of Response Analysis Related to Video 2 Case Study Theme.

No	Variable Analyzed	Analysis Results
1	Most Chosen Case	Case 1 was the most frequently chosen case by students. This case discusses how to increase the interest and understanding of students less interested in Physics.
2	Patterns and Similarities in Answers	Case 1: Students tend to use words like "students", "physics", "experiments", "demonstrations", "interest", and "understanding". This shows they focus on active teaching techniques to increase student interest and understanding.
		Case 3: Students use words like "energy", "work", "students", "discussion", and "project". This shows they are trying to implement active teaching techniques such as group discussions and problem-based projects to help students understand concepts.
3	Argumentation Indicators	Case 1: A high proportion of evidence indicates that students can provide concrete examples or steps. The proportion of reasons and conclusions is lower, indicating that they sometimes provide reasons or conclusions but only sometimes. The proportion of claims and rebuttals indicates that they do not state or consider rebuttals.
		Case 3: The high proportion of evidence indicates that students can provide concrete examples or steps. The proportion of claims, reasons, rebuttals, and conclusions is still low, indicating that they cannot state claims, provide reasons, consider rebuttals, or provide conclusions.

Table 3 shows that generally students show a good understanding of active teaching techniques, especially in providing evidence and examples. However, they must improve their ability to formulate clear and structured arguments, including claims, reasons, and conclusions. The most common response pattern is to provide a list of steps or strategies without relating them to supporting theory or research. This condition indicates that students may need more practice applying theory to practice and providing solid justifications for their choices.

Discussions

This research reveals significant differences in the scientific argumentation skills of preservice physics teachers between written case study contexts and oral presentations. In written case studies, students demonstrate a relatively good ability to provide evidence (78.7%) but need to improve in terms of claims (18.7%) and reasons (17.3%). This indicates that students tend to focus more on presenting practical solutions than explaining the reasoning behind those solutions. In addition, rebuttal (24.7%) and conclusion (34%) skills also need to be improved.

Meanwhile, in presentations and question-and-answer sessions, there was a significant increase in all components of argumentation, especially in claims (80%), reasons (60%), rebuttals (71.4%), and conclusions (90%). These results show that students can better verbally articulate and defend their arguments when allowed to explain and interact directly with the audience. These differences can be caused by several factors, such as the opportunity to clarify and strengthen arguments during the question-and-answer session and the motivation to perform better in front of lecturers and colleagues (Forsythe et al., 2022).

The study results show that preservice physics teachers are more skilled in presenting evidence and conclusions than formulating reasons and rebuttals, especially in presentations and question-and-answer sessions. Several factors can cause this. First, the time-limited presentation and question-and-answer format may encourage students to focus on delivering solutions and conclusions rather than developing comprehensive arguments (Forsythe et al., 2022). Second, the presentation assessment rubric may emphasize students' ability to explain solutions and draw conclusions more than their ability to provide in-depth reasoning and consider rebuttals. Additionally, the lack of experience and practice in scientific argumentation can be a factor causing students to have difficulty in providing appropriate and logical reasons, as well as considering rebuttals or alternative views (Cetin, 2014; Darmaji et al., 2022). A lack of deep understanding of physics concepts can also hinder providing strong and logical reasoning.

Overall, the results of this study indicate that preservice physics teachers have good potential in developing their scientific argumentation skills. Their ability to provide evidence in case studies and presentations demonstrates adequate conceptual understanding (Cetin, 2014). However, the ability to formulate clear and logical claims and reasons, especially in written case studies, still needs improvement. This result is in line with research by Sampson & Gerbino (2010) which shows the difficulty of prospective teacher students in formulating explicit claims and providing adequate reasons. Several factors that may cause this include a lack of deep conceptual understanding, argumentation practice, or learning methods that are less effective in encouraging critical thinking.

Qualitative analysis of case study answers and transcripts of question-and-answer sessions also reveals several patterns of argumentation that emerge among preservice physics teachers. Some students use personal experience-based arguments, using personal experiences or concrete examples from everyday life as evidence to support their arguments (Boettcher & Meisert, 2011). This result shows that they can connect theory with practice but must be encouraged to use more scientific and credible evidence, such as research results or relevant theories. In addition, some students tend to use authority-based arguments, namely citing expert opinions or other authoritative sources as the main reason to support their claims. Although this can strengthen the argument, students must also develop the ability to think critically and evaluate evidence independently (Jimenez-Aleixandre & Erduran, 2007). Finally, some students need better-structured arguments with unclear and interrelated claims, reasons, and evidence. This condition can be caused by a lack of understanding of the structure of scientific argumentation or a lack of practice in formulating arguments (Simonneaux, 2007).

The significant difference between students' ability to provide evidence and their ability to formulate claims and reasons has essential implications for microteaching learning. This ability shows the need for learning to focus on developing students' ability to formulate explicit claims, provide strong reasons, and link evidence with claims logically. Learning strategies such as Problem-Based Learning (PBL) can be applied to improve critical thinking and problem-solving skills, which are the basis of scientific argumentation (Gunawan et al., 2019; Gunawan et al., 2020). In addition, scientific discussions and debates can provide opportunities for students to practice argumentation (Jimenez-Aleixandre & Erduran, 2007), while structured feedback from lecturers will help them improve weaknesses in claims and reasons (Olson et al., 2016). With more attention to developing scientific argumentation skills, preservice physics teachers are expected to be better prepared to face learning challenges in the modern era.

The use of video in microteaching learning has a significant role in developing the scientific argumentation skills of preservice physics teachers. Learning videos not only functions as a good model of scientific argumentation, both in delivering material and in discussions or debates (Brückmann et al., 2007), but also increases student engagement and motivation through the presentation of more exciting and relevant material (Olson et al., 2016). Furthermore, videos can also be used to facilitate collaborative discussions, allowing students to deepen their understanding of physics concepts and learn from different perspectives (Tiberghien & Sensevy, 2012). Microteaching becomes a safe and controlled argumentation training ground where students can design and deliver their arguments and get constructive feedback to improve the quality of their arguments. Video recordings of microteaching presentations also serve as a tool of analysis and reflection for students to identify strengths and weaknesses in their arguments (Roth, 2009). Thus, integrating video in microteaching learning can optimize the development of preservice physics teachers' scientific argumentation skills.

CONCLUSIONS

This research reveals a significant difference in the scientific argumentation skills of preservice physics teachers between written case studies and oral presentations. Students demonstrate a better ability to present evidence and concrete examples, particularly in oral presentations where they can interact and clarify their arguments. However, formulating explicit claims and reasons needs improvement, especially in written case studies. These findings indicate the potential of students to develop scientific argumentation skills, mainly through structured and interactive video-based microteaching learning, along with comprehensive feedback. Strengthening the aspects of claims and reasons can be a primary focus for improving future learning.

Further research is needed to examine the effectiveness of specific learning interventions in enhancing the scientific argumentation skills of preservice physics teachers. Additionally, exploring other factors that might influence these abilities, such as the level of understanding of physics concepts, experience in microteaching, and student learning styles, is recommended.

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