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High School Students' Scientific Argumentation Skills on Static Fluid

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Abstract

The need to improve students' argumentation skills through phenomenology learning approaches encourages efforts to map scientific argumentation skills. the research aims to determine students' argumentation skills on static fluid. Qualitative research with survey method using questions about static fluid phenomena in everyday life. random sampling obtained 33 students from one of the State High Schools in Malang Regency as samples in the study. Data were analyzed by mapping the level of scientific argumentation skills. The results showed that students' argumentation skills were spread from level 1 to level 4 with the majority at level 2. At this level, students are generally able to provide claims consisting of data and reasoning. This achievement shows that students' scientific argumentation skills are relatively low. Future research can design innovative models and media to improve students' scientific argumentation skills.

Keywords: physics learning, scientific argumentation, static fluid.

INTRODUCTION

Scientific argumentation is an important variable that students' must have. Scientific argumentation is the ability to make claims, refine, and be accompanied by scientific evidence as support (Al-Ajm & Ambusaidi, 2022). In learning, argumentation contains two main activities, namely presenting ideas and refuting ideas (Mikeska & Howell, 2020). The process of integrating scientific argumentation in science education can encourage the creation of a collaborative learning environment through the process of refutation and refinement of ideas so as to improve scientific reasoning and problem solving skills (Fakhriyah et al., 2021; Jumadi et al., 2021).

Many previous studies have been conducted to explain the profile of scientific argumentation skills in physics and its integration process in science learning. Research by (Syerliana et al., 2018) shows that students' scientific argumentation skills are still relatively low with the smallest percentage in the warrant component. The integration of scientific argumentation skills in science learning shows positive results. (Sulisworo & Safitri, 2022) successfully developed online worksheets to improve students' argumentation skills in physics learning. In addition, this study also explained that the worksheets developed were valid and effective in improving students' argumentation skills.

The low level of students' scientific argumentation skills can be influenced by difficulties due to a combination of cognitive and instructional challenges, especially in physics learning contests. Previous research shows students' difficulties in explaining scientific phenomena empirically during learning, which leads to a lack of confidence in scientific argumentation (Novianti et al., 2022). Although the ability to construct arguments requires analysis of relevant scientific concepts, students often struggle with understanding the content itself (Anwar et al., 2021). The complexity of physics concepts, plus the need to integrate multiple representations leads to cognitive overload, hindering the practice of scientific argumentation (Candido et al., 2023; Murphy et al., 2018).

One of the learning alternatives that can be applied to encourage students in scientific argumentation is a phenomenon-based approach. Involvement in real and contextual problems allows students to formulate claims based on evidence and experiments, thus developing their argumentation skills (Amielia et al., 2018). In line with that, the phenomenon-based approach not only encourages critical thinking, but also provides opportunities for collaboration in developing scientific arguments (Pujianto et al., 2023). Presenting phenomena can trigger curiosity and relevance, so students are motivated to develop abilities that support scientific argumentation, such as collecting evidence and compiling appropriate reasons (Naviri et al., 2021).

Good scientific argumentation is a process that includes the formulation of empirical evidence-based claims, the use of logical justifications to support claims, and critical evaluation of alternatives and refutations. According to (Roviati & Widodo, 2019), good scientific argumentation requires key elements, including claims supported by relevant data, a clear relationship between evidence and claims, and strong justification to answer the question or problem posed. In addition, according to (Iordanou, 2022) the application of Toulmin's argumentation pattern which includes claims, data, justification, and refutation helps improve students' critical thinking skills by encouraging evidence-based reflection and evaluation. In addition (Mutmainnah et al., 2025) added that good scientific argumentation also reflects students' ability to integrate concepts and data in a structured manner, which is significantly influenced by their academic ability. Thus, good scientific argumentation not only serves to solve scientific problems, but also to develop analytical, logical, and reflective thinking skills relevant to the education challenges of 21st century.

The urgency of this research lies in the need to improve students' argumentation skills through learning approaches. Scientific argumentation is an important part of science literacy and higher order thinking skills (HOTS), which are indispensable in 21st century learning (Susana et al., 2023). However, previous studies have shown that students' argumentation skills are still at a low level, with difficulties connecting real phenomena into scientific concepts such as Newton's Laws (Siahaan et al., 2020). Phenomenon-based learning approaches, such as Phenomenon-Based Argument-Driven Inquiry (ADI), have been proven effective in improving argumentation and scientific reasoning skills through direct exploration of real phenomena (Mufidah et al., 2020). By integrating real-life phenomena, students are not only invited to understand science concepts in depth but also encouraged to build communication and collaboration skills, which are relevant to the challenges of modern life (D. A. W. Wardani, 2023). Therefore, this research is important to explore and develop learning models that effectively facilitate students in improving their phenomenon-based argumentation skills.

METHODS

Qualitative methods were used in this study. Data was collected through a survey of respondents. The survey method is used to examine a specific sample which aims to test the hypothesis that has been made (Putra & Hidayusa, 2019). Survey research is classified as having two objectives, the first aims to provide a description or explanation of something and the second aims to analyze (Maidiana, 2021). This study aims to provide an overview of students' argumentation skills in explaining the concept of hydrostatic pressure based on phenomenon-based problems. Students convey their ideas accompanied by reinforcing and relevant evidence. The approach taken is phenomenology, A study that seeks to understand people's perceptions, perspectives, and understanding of a particular situation. so that it is not an event that exists outside of the person (Neubauer et al., 2019).

The research was conducted in one of the public high schools in Malang Regency with 33 students as respondents. The sampling technique used random sampling of the population of students who had received hydrostatic pressure material. The survey was conducted for 30 minutes with respondents writing their ideas on a piece of paper. The survey instrument used in the study consisted of one question that was prepared based on the phenomenon of problems related to the concept of hydrostatic pressure. Respondents wrote their ideas in writing in accordance with the rules and components of scientific argumentation that refers to Toulmin's argumentation pattern. Students are given one problem regarding the condition of people diving at a certain depth and students will identify why divers experience pain and ringing in the ears as the depth of diving increases. Students will solve the problem with Toulmin's solution steps of claim, evidence, warrant, support, rebuttal, qualification (Mellenia & Admoko, 2022).

Data analysis in this study uses Toulmin's rubric in the form of levels 1-5 to assess the quality of arguments developed by Toulmin (Mete, 2023).

Table 1. Analytical framework adapted from (Erduran et al., 2004; Mete, 2023)

Level	Describe
1	Arguments consist of simple claims or claims against other claims.
2	Claims and arguments that include data, warrant, or backing
3	A series of claims with weak data, justification, or rebuttal.
4	Identifiable claims that contain rebuttal. May make multiple claims or counterclaims.
5	Arguments consist of comprehensive claims involving more than one rebuttal.

The analysis begins by classifying the answers of each student in each level. The results of the analysis were then depicted in a data diagram to make it easier to communicate the research data. The description of the level of students' scientific argumentation skills is carried out in accordance with the diagram and accompanied by other supporting evidence.

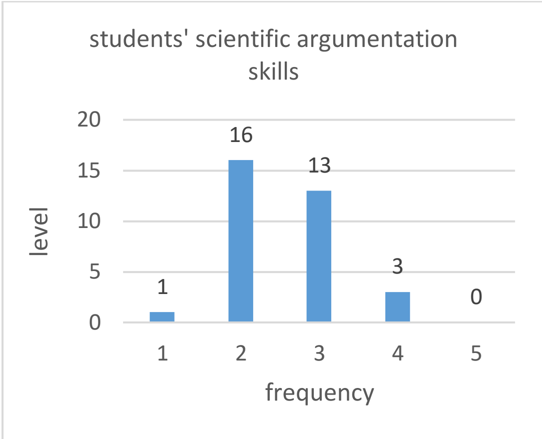

Figure 1: Summary of students' scientific argumentation skills

RESULTS AND DISCUSSION

RESULTS

The research data are students' written answers containing their arguments on the phenomenon of hydrostatic pressure. The question given was "when diving in the sea, divers feel pain in their ears as the depth of sea water increases. Why do you think this happens? Give your argument!". A summary of students' argumentation skills is presented in Figure 2.

Based on Figure 1, the majority of students' argumentation skills are at level 2. At this level, students are generally able to provide claims followed by scientific data and arguments supporting claims. The scientific data that follows the claim is mostly correct and in accordance with the concept. Students at level 2 are grouped into three groups as presented in Table 2 (Mete, 2023).

Table 2. Grouping of level 2 scientific argumentation skills

No	Level	Description	Freq
1	2a	Level of argument supported by false reasons or unscientific data for a claim	2
2	2b	Level of argument consisting of a claim and scientific data or a partially correct explanation	5
3	2c	Level of argument consisting of a claim and scientific data or an explanation that is partially correct.	9

Table 2 explains the grouping of level 2 scientific argumentation skills from 2a to 2c. 2 respondents were at level 2a by making false reasons and data. Other results show that there are 5 respondents making claims and partially correct data grouped at level 2b. Respondents who gave claims accompanied by correct data were grouped at level 2c as many as 9 respondents.

DISCUSSION

The results showed that students' scientific argumentation skills on the concept of hydrostatic pressure were spread from level 1 to level 4 with the majority at level 2. Students can connect claims and data by being described in the scientific reasoning section. There are no students who have scientific argumentation skills at level 5. This indicates that students have not been able to convey a comprehensive argument consisting of claims, data, justification, support, and refutation given properly. Argumentation is said to be good and correct if it includes aspects of claims, data, justification, support, and refutation when discussing the subject (Toulmin, 2003).

Level 1 scientific argumentation

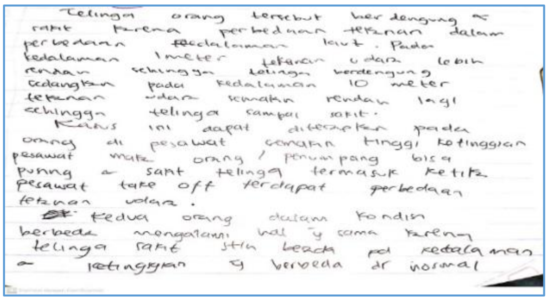
Telinga orang tersebut berdengung & sakit karena perbedaan tekanan dalam perbedaan kedalaman laut. Pada kedalaman 1 meter tekanan udara lebih rendah sehingga telinga berdengung sedangkan pada kedalaman 10 meter tekanan udara semakin rendah lagi sehingga telinga sampai sakit.
Kasus ini dapat diterapkan pada orang di pesawat semakin tinggi ketinggian pesawat maka orang / penumpang bisa punya sakit telinga termasuk ketika pesawat take off terdapat perbedaan tekanan udara.
Kedua orang dalam kondisi berbeda mengalami hal yg sama karena telinga sakit stlh berada pd kedalaman & ketinggian yg berbeda dr normal

Figure 2. Respondents' answers at level 1

Figure 2 is an example of the answers of respondents who have scientific argumentation skills at level 1. At this level, respondents provide simple claims from the given phenomenon. In this case, the respondent made a claim, but the claim was not correct. The respondent stated that the deeper the diver's position in the water, the lower the air pressure. This is incorrect because the factor that affects ringing in the ears is not air pressure, but seawater pressure. Respondents also do not understand that the deeper the position of a point in a liquid, the greater the pressure obtained by the point (Adisna et al., 2020).

Level 2 scientific argumentation

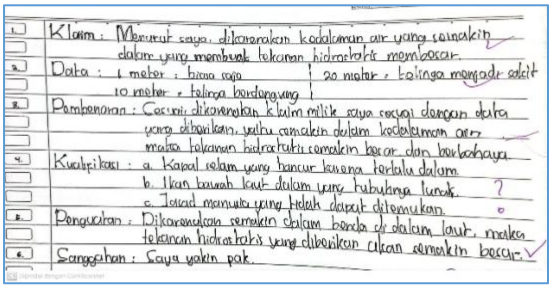
1. Klaim : Menurut saya, dikarenakan kedalaman air yang semakin dalam yang membuat tekanan hidrostatis membesar.
2. Data : 1 meter : biasa saja | 20 meter : telinga menjadi sakit
10 meter : telinga berdengung
3. Pembenaran : Sesuai, dikarenakan klaim milik saya sesuai dengan data yang diberikan, yaitu semakin dalam kedalaman air maka tekanan hidrostatis semakin besar dan berbahaya.
4. Kualifikasi : a. Kapal selam yang hancur karena terlalu dalam.
b. Ikan bawah laut dalam yang tubuhnya lunak.
c. Jasad manusia yang tidak dapat ditemukan.
5. Penguatan : Dikarenakan semakin dalam benda di dalam laut, maka tekanan hidrostatis yang diberikan akan semakin besar.
6. Sanggahan : Saya yakin pak.

Figure 3. Respondents' answers at level 2

Figure 3 shows an example of student argumentation at level 2. Students are able to correctly claim that greater water depth results in greater hydrostatic pressure. The supporting data has also presented the diver's situation from a depth of 1meter to 20 meters. Apart from this, students have not strengthened the reasoning data with the principle of hydrostatic pressure. In accordance with the research of Estianinur et al., 2021) that on the concept of hydrostatic pressure, students still have an incomplete understanding and misconceptions.

Level 3 scientific argumentation

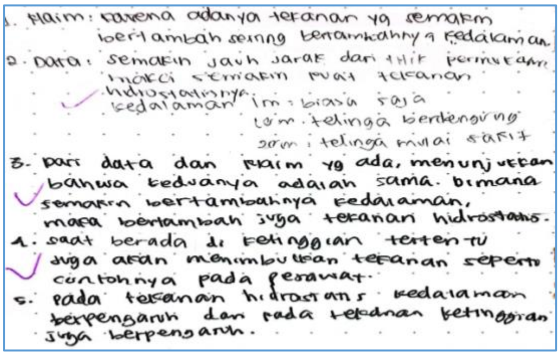
1. Klaim : karena adanya tekanan yg semakin bertambah seiring bertambahnya kedalaman.
2. Data : semakin jauh jarak dari titik permukaan maka semakin kuat tekanan hidrostatisnya.
kedalaman 1m : biasa saja
10m : telinga berdengung
20m : telinga mulai sakit
3. Dari data dan klaim yg ada, menunjukkan bahwa keduanya adalah sama. Dimana semakin bertambahnya kedalaman, maka bertambah juga tekanan hidrostatis.
4. Saat berada di ketinggian tertentu juga akan menimbulkan tekanan seperti contohnya pada pesawat.
5. Pada tekanan hidrostatis kedalaman berpengaruh dan pada tekanan ketinggian juga berpengaruh.

Figure 4. Respondents' answers at level 3

Figure 4 shows an example of student argumentation at level 3. Students are able to provide claims correctly, namely the deeper the depth of a point, the greater the pressure and supported by existing depth data, namely at a depth of 1meter to 20 meters. However, the support provided is still simple. Support is very important to convince the reasoning that has been made based on claims and existing data so that the support can be given the appropriate formula, namely hydrostatic pressure (Khusnayain, 2017).

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Level 4 scientific argumentation

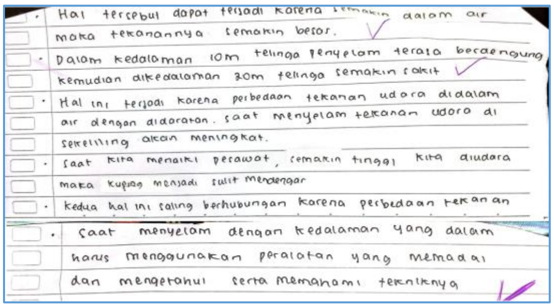

Figure 5. Respondents' answers at level 4

Figure 5 shows an example of student argumentation at level 4. Students can make claims that say that the deeper the water, the greater the pressure, after that it is complemented by depth data, and students are able to connect data and claims so that it becomes reasoning. Here students provide qualifications that are correct by analogizing airplanes, but in terms of refutation it is still not strong because exceptions or clear limits are not given when they can use the concept of hydrostatic pressure and when they cannot Wardani et al., 2018).

The results of the study provide new information that students' scientific argumentation skills are relatively low. Some factors that may affect these results are that the basic concepts are not yet intact. In addition, students tend to memorize concepts without a critical thinking process, so they have not been able to make arguments according to the given topic. The results also strengthen previous research by (Syerliana et al., 2018) which showed similar results. Thus, further research can design innovative learning models and media to improve students' argumentation skills. Teachers can pay special attention to the mastery of students' scientific argumentation considering that it is one of the important variables that students must master in today's development.

CONCLUSION

Research to describe scientific argumentation skills obtained the results that students' argumentation skills based on Toulmin's argumentation patterns are still in the low category with the majority at level 2. These results indicate that students have not been able to connect claims and data properly, and are not equipped with appropriate support, qualifications and refutations. Future research can make efforts to improve scientific argumentation skills through innovative learning models and media. Quality learning media should be interactive and facilitate student discussion. The aim is to develop students' ability to argue both orally and in writing. It is also important to increase the research sample so that the results obtained are more valid and appropriate.

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