Analysis of the Aiken Index in the Development of Scientific Argumentation Written Test on Fluid Mechanics Course

Diniya Diniya[1,2,] * Muslim Muslim[1], Dadi Rusdiana[1], Niki Dian Permana[2], Riza Andriani[3], Amma Sufarman[4], Mentari Darma Putri[5], Neni Hermita[6] and Fitri Nuraeni[7]

[1] Science Education Study Program, Universitas Pendidikan Indonesia, Bandun, Indonesia
[2] Program Studi Tadris IPA, Universitas Islam Negeri Sultan Syarif Kasim Riau, Pekanbaru, Indonesia
[3] Physics Education Study Program, Universitas Malikussaleh, Lhokseumawe, Indonesia
[4] Physics Education Study Program, Universitas Intens Muhammadiyah Kolaka Utara, Kolaka Utara, Indonesia
[5] Physics Education Study Program, Universitas Samudera, Langsa, Indonesia
[6] Primary School Teacher Education Study Program, Universitas Riau, Pekanbaru, Indonesia
[7] Primary School Teacher Education Study Program, Universitas Pendidikan Indonesia, Purwakarta Campus, Purwakarta, Indonesia
diniya@uin-suska.ac.id

Abstract. Scientific communication skill is one of the important assessments in 21st-century learning, including in science learning. In this regard, one form of scientific communication is familiarly known as scientific argumentation. Scientific argumentation skills can be trained since high schools to the university level. The current research is concerned with the development of scientific argumentation test. The development research of Plomp model is used. This project is limited to the design stage and the validity of the test instrument. The scientific argumentation instrument was developed through five essay questions. Problems are formulated with fluid mechanics topic. Five experts in the field of fluid mechanics carried out proof of the validity of scientific argumentation instruments and continued with calculations using the Aiken V index formula. The validation results disclosed that all five items were valid with an average Aiken index of 0.87. Questions that have been validated are ready to be tested.

Keywords: Fluid Mechanics Course, Scientific Argumentation Skills, Test Instrument Development.

Introduction

The technology and science have developed very rapidly in the 21st century. Life in the 21st century is synonymous with the need for skills. There are many 21st century skills that people required to master due to current and future challenges [1]. Thus, today's learning is expected to provide learning that goes beyond subject content and can prepare learners to succeed in the 21st century. Educators and learners shall recognize how

F. Khoerunnisa et al. (eds.), *Proceedings of the 9th Mathematics, Science, and Computer Science Education International Seminar (MSCEIS 2023)*, Advances in Social Science, Education and Humanities Research 860,
https://doi.org/10.2991/978-2-38476-283-5_22

to use knowledge and skills simultaneously through mastering critical thinking, applying knowledge to new situations, analyzing information, understanding new ideas, communicating, collaborating, solving problems, making decisions and so forth. This makes education experts never stop finding new paths in the world of education thus learning becomes effective, and students can practice these formulated skills [2-3].

In recent years, there has been an increased emphasis on incorporating scientific argumentation into science education practices. Various studies have reported that engaging in the process of argumentation leads to increased understanding of scientific content knowledge. More recently, the need to engage students in argumentation is formally addressed in national generation science standards. Specifically, the K-12 Science Education Framework, along with the upcoming Next Generation Science Standards (NGSS), specifies "engaging argument from evidence" as one of the eight essential science practices and a necessary skill in the 21st century that shall continue to be practiced in prospective science teachers as well as teachers. One of the skills that has received important attention in science learning is communication skill [4-5]. One type of communication skill can convey arguments with factual data.

Communication and collaboration skills can be demonstrated through learners' argumentation skills [6]. Modern reforms in science education emphasize context, activities, and scientific conversations. Scientific conversations in the form of argumentation are very important because they are considered capable of enhancing understanding and changing understanding of science in line with the statement [7]. Researchers also concluded that providing scientific data will help learners overcome the difficulties they experience in arguing about scientific topics. Scientific argumentation is one of the criteria used to assess learners and has been emphasized in the National Science Education Standards. Berland and Hammer also cited that scientific argumentation has been increasingly recognized as a notable practice in science education because it allows learners to actively engage in creating ideas and questions through a process that produces similarities to scientific practices. Such formulated argumentation is the key mediator for accessing knowledge [8]. Therefore, a prospective science teacher shall possess argumentation skills and thus it can be delivered to students.

Communication and collaboration skills can be demonstrated through learners' argumentation skills [6]. Modern reforms in science education emphasize context, activities, and scientific conversations. Scientific conversations in the form of argumentation are especially important because they are considered capable on improving understanding and changing understanding of science in line with the statement [7]. The researchers also concluded that providing scientific data will help learners overcome the difficulties they experience in arguing about scientific topics. Scientific argumentation is one of the criteria used to assess learners and has been emphasized in the National Science Education Standards. Berland and Hammer also mention that in recent years, scientific argumentation has been increasingly recognized as an important practice in science education because it allows learners to actively engage in creating ideas and questions through a process that produces similarities to scientific practices. This argumentation is a key mediator for accessing knowledge [8]. Therefore, a prospective science teacher must also have argumentation skills so that later it can be trained to students.

Argumentation is based on facts and complex reasoning [9]. Argumentation involves scientific reasoning to draw conclusions from the available information and statements conveyed based on existing facts [10]. Explanations in argumentation are then verified, communicated, debated, and modified [11]. Argumentation ability is an ability that involves cognitive processes that enable students to solve problems [12]. Argumentation is a way to develop thinking skills in general because this ability includes activities to propose and criticize a problem [13]. Competent educators can develop and encourage learners to argue well [14]. Through argumentation activities, learners can understand the process of acquiring knowledge concepts that are being learned [15]. It is not only students who must have the ability to argue, but prospective teachers also need to master argumentation skills. Students or prospective teachers are required not only to be able to convey what they have obtained, but also to have the ability to channel their knowledge [16].

Educators usually feel unsatisfied regarding the level of quality of students' argumentation [17-18]. An instrumental view of argumentation is needed to develop questions for the assessment of argumentation skills. There are several models for developing questions for the assessment of argumentation skills, one of which is Toulmin's Argument Pattern model. Developments in the Application of Toulmin's Argument Pattern for Studying Science Discourse states that the application of Toulmin's Argumentation Model can be a reference in analyzing argumentation. The basis for the development of the Toulmin's Argument Pattern (TAP) model test instrument consists of claim, data, warrant, backing, qualifier, and rebuttal [19]. Students can argue based on claims, data, evidence, and support [20].

Several experts have also examined argumentation skills in students and teachers. Based on the findings [16, 21] that some of the students have not been competent in writing science argumentation as seen from the inclusion of evidence and support that can guarantee the truth of the chosen claim. The development of argumentation skills test instruments in physics can be applied to impulse and momentum materials. According to the results of research [22-23] that the types of errors made by students in solving problems on impulse and momentum material are errors in working strategies, thinking errors related to the applicability of the law of conservation of momentum, and conceptual errors.

A study on improving communication skills in prospective teachers through HOT Lab on the topic of Electrical Circuits found that there was a significant improvement. In particular, the improvement of communication skills in the aspect of information representation that applies HOT Lab is high while those that apply verification labs are at a low level. Individual communication skills were not affected by gender. However, the verbal aspect of information representation is more dominant in female prospective teachers while the mathematical and graphical aspects of information representation are more dominant in male prospective teachers [4]. Another study showed that learning using a laboratory inquiry model based on analogy mapping was able to assist in training students' argumentation skills [3]. Findings about argumentation skills in prospective teachers using the MIKiR approach during the covid-19 pandemic concluded that it can train the scientific argumentation skills of prospective science teachers. The interaction and communication steps in the MIKiR approach are very helpful in practicing the scientific argumentation skills of prospective science teachers [24].

Another study which analyzed the argumentation skills of students obtained the average argumentation skills at level 1-2 [25]. The results of this study can be used as a basis for planning the learning process. Activities that involve student argumentation need to be improved to develop the ability to understand concepts and argumentation skills. Research [26] found that prospective teacher students were involved and motivated in meaningful nanoscience and nanotechnology learning experiences and prospective teacher students' argumentation skills had emerged and developed well during the learning process, namely being able to provide claims and data, and several warrants, qualifiers, and rebuttals to the arguments they gave. As well, a study developed related to argumentation questions on impulse and momentum material [27]. The results showed that five test items were declared valid and classified as highly reliable. With these results, the test instrument developed can be used to measure argumentation skills on impulse and momentum material. Research [28], namely developing written scientific argumentation questions on the topic of the role of Microbiology in the health sector in the Microbiology course. The question was declared valid and suitable for use.

Research [29] discovered several interesting findings on students' abilities as follows: in making moderate claims (56.59%), providing evidence were very weak (18.35%), and making explanations were also very weak (14.21%). The results implied that learning strategies were necessary to improve scientific argumentation skills. Research [30] found that educators should provide time for students to engage in scientific inquiry and argumentation and to achieve a deep understanding of the core ideas presented.

Based on the background delivered in this line of research, it can be stated that no one has developed a scientific argumentation instrument question on fluid mechanics. Hence, the current research has received considerable attention to be conducted with the aim of developing a scientific argumentation test using Toulmin's Argument Pattern (TAP) model.

2 Methods

Conducted thruogh the Development and Research, the current research was conducted in the odd semester of the 2022-2023 academic year. Research and development or Research and Development (R&D) is a series of processes or steps to develop a new product or improve existing products [31]. In this paper, Research and Development is a research method used to produce certain products and test the effectiveness of these products. The development model used is the Plomp model. This model was proposed by Plomp in 1997 [32]. Plomp stated that in development research a research design is needed. "We characterized educational design in short as a method within which one is working in a systematic way toward the solving of 'make' problems". This briefly indicates that characterizing educational design as a method within which one is working in a systematic way toward solving the problems. Plomp's model consists of preliminary investigation phase, design phase, realization/construction phase, test, evaluation and revision phase, and implementation. In this study, the development was only carried out up to the test, evaluation and revision phase because the implementation phase requires a long process and time. In general, the Plomp's model can beillustrated as in Fig. 1.

Fig. 1. Research and Development Design according to Plomp.

In the initial investigation phase, researchers collected data or information in the field and identified related problems. This data collection serves to strengthen the background of the problem, research objectives, and benefits. Data collection was carried out by studying documentation related to research articles that have examined the development of argumentation questions and it was found that there was still no research that developed scientific argumentation questions on the topic of fluid mechanics. At this stage, the curriculum in the Tadris Science Study Program at UIN Suska Riau was also analyzed. It was found that there was a Mechanics course and the questions had never been developed in the form of scientific argumentation.

At the design stage, researchers chose the sub-topic that shall be developed into a scientific argumentation test instrument. The selection of sub-topics is also adjusted to the learning outcomes in the Mechanics course. The subtopics chosen were Archimedes' law, Bernoulli's law, Hydrostatic pressure, dynamic fluid, and harmonic oscillator. Each question is also related to the context that exists in everyday life. The following is a lattice of argumentation questions presented in the study.

Table 1. Sub-topic and the number of questions on each topic

Sub-Main Material	Number of Sub-Question
Archimedes' Principle in Phytoplankton	1
Bernoulli Principle on Air Plane	2
Hydrostatic Pressure	3
Fluid Dynamics in Blood Vessels	4
Harmonic Oscillators in Anti-Earthquake Buildings	5

After choosing the topic, the researcher started to conduct the questions design. The questions were designed in the form of essay questions. The questions consisted of five items. The questions were designed using scientific argumentation indicators according to Toulmin. Researchers only limit 4 indicators, namely claim, data, warrant and backing. Moreover, it is to conduct the next stage, namely the realization phase. This realization phase is a follow-up to the design phase. In this regard, the manufacture of products and instruments needed is carried out. The result of this realization phase is questions on a written scientific argumentation instrument. The learning product resulting from this phase is prototype I. Furthermore, the researchers conduct the test, evaluation, and revision phase. At this stage, validation is carried out to experts or also called validity construction. The selected experts are lecturers who teach Physics or Science content in 5 different universities with 5 years of service. The distribution of experts who became validators can be seen in the Table 2.

Table 2. Validator

No	Validator	University
1	NDP	UIN Suska Riau
2	RA	Universitas Malikussaleh
3	MDP	Universitas Samudera
4	AS	Institut Teknologi dan Sains Muhammadiyah Kolaka Utara
5	FN	Universitas Pendidikan Indonesia

Expert testing is conducted with respondents who are experts in designing models or products. The validation test of the test instrument focuses on the construction aspect which consists of the accuracy of the formulation of questions, instructions for handling questions, accuracy of the use of images, and accuracy of questions arranged based on the difficulty level of the questions. Expert validation activities are carried out in order to provide an assessment of the initial product and suggest revisions for improvement. To obtain validity data from the learning instruments developed, validators were given an assessment questionnaire sheet and test instruments that were prepared to determine aspects of question construction, suitability of substance, and language. Furthermore, the assessment results from the validators were analyzed to determine the level of validity. At the end of this research, the resulting product is a written argumentation ability test instrument for the Mechanics course.

3 Results

The results on the current research are in form of experts' validation. Experts' validation test is conducted by the chosen experts in the Table 3.

Table 3. Validity Test Results in the Material Context

Number	Validator					V-Aiken Index	Note
	1	2	3	4	5		
1	4	4	4	4	4		
2	3	4	3	3	4	0,89	Very high
3	2	4	4	4	4		

Based on the above table, in the material aspect, the value of V Aiken's index is 0.89. Applying the criteria for the v Aiken index with a 5% significance of 0.80, the material aspect is considered valid.

Table 4. Validity Test Results in the Construction Context

Number	Validator					V-Aiken Index	Note
	1	2	3	4	5		
2	3	4	3	3	4	0,9	Very high
3	2	4	4	4	4		
2	3	4	3	3	4		
3	2	4	4	4	4		

Based on the above table, in the construction context, the value of V Aiken's index is 0.90. Applying the criteria for the v Aiken index with a 5% significance of 0.80, the material aspect is considered valid.

Table 5. Validity Test Results in the Construction Context

Number	Validator					V-Aiken Index	Note
	1	2	3	4	5		
8	3	3	4	4	4	0,92	Very high
9	3	4	4	4	4		
10	3	4	4	4	4		
11	3	4	4	4	4		
12	3	4	4	4	4		

Based on the above table, in the language aspect, the value of V Aiken's index is 0.92. Applying the criteria for the v Aiken index with a 5% significance of 0.80, the material aspect is considered valid.

The design of argumentation questions for the subtopic of Archimedes' Law on Phytoplankton has several revisions. The revisions include providing a more relevant clue other than the density of water and the density of seawater to find the magnitude of the buoyancy force on phytoplankton. Other validators also provided revision suggestions, namely clarifying how to calculate the amount of buoyancy force on phytoplankton, measuring the volume of phytoplankton immersed in water. The validator also gave a revision suggestion that there should be a picture of the phytoplankton to be measured, so that the surface area and height can be measured.

On the subtopic of Bernoulli's Principle on Airplanes, the validator advised that there are too many questions in one question, meaning there will be many claims, data, justification, and support. Just focus on 2 or 3 questions according to the subject matter. The validator suggested that the questions be split into 2-3 questions that are still related to Bernoulli's Law. Other validators also suggested clarifying the air direction or wind speed. This means against the direction of the air (wind speed) on the wing or gravity and refers to the previous question, which questions why an airplane with a large mass can fly. Because if it is against the direction of the wind speed where can students find out. And therefore, additional information is needed because the wind direction in the air changes and the plane flies on a trajectory marked by radar, which is why planes when in the air do not collide with each other. and if this question leads to wind direction. The wording of the question is better if it is changed whether when the plane flies in the air, the plane moves in the direction of the wind or not.

On the Hydrostatic Pressure subtopic, the validator did not provide any suggestions for improvement. Furthermore, on the topic of Dynamic Fluid in Blood Vessels, the validator suggested that the pictures in the questions should be combined with pictures of fluid flow in physics concepts, not just pictures of healthy blood flow and unhealthy blood flow. Other validators also suggested that the questions on this subtopic do not seem to support meeting the 4 (four) aspects of argumentation (claims, data, justification and supporting arguments) if only linking to the concept of fluid, the possibility of student answers is a claim about high blood pressure, justification and support based on theory. There is no data. In this regard, the data will only appear if students alternate to elaborate answers using modeling on pipes on the concepts of continuity and Bernoulli.

On the subtopic of Harmonic Oscillators in Anti-Earthquake Buildings, the validator gave a suggestion to add a sketch of an anti-earthquake building in the question. Other validators also stated that the questions on the subtopic were also like the questions in subtopic 4, namely the data was not listed in the questions presented.

The limitations of this study are the limited number of questions developed. The argumentation indicators developed are also still limited to only 4 indicators. It is recommended that future research can develop all indicators of scientific argumentation. Future research can also examine the ability of scientific argumentation.

4 Conclusion

Based on results obtained in this line of study, it can be argued that the validation test through experts' judgment, the written argumentation test on Fluid Mechanics demonstrated that those three aspects of assessment (material, construction, and language) possess a very high validation value. There is also emerging evidence that the questions are appropriate to use. To more comprehend the current project, this paper suggests to test the argumentation instrument for further researchers.

References

1. Joynes, C., Rossignoli, S., Amonoo-Kuofi, E. F.: 21st Century Skills: evidence of issues in definition, demand, and delivery for development contexts. Institute of Development Studies, 1-77 (2019).
2. Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., Osher, D.: Implications for educational practice of the science of learning and development. Applied developmental science **24**(2), 97-140 (2020).
3. Diniya, D Rusdiana, D.: Improving Students' Argumentation by Providing Analogical Mapping-Based Through Lab Inquiry for Science Class. IOP Conference Series: Materials Science and Engineering **288** (1), 012053 (2018).

4. Malik, A., Ruswandi, U., Setiawan, A., Suhandi, A., Permanasari, A.: How to Improve Creative Thinking Skills of PreService Physics Teachers? In 2nd International Conference on Sociology Education (ICSE 2017), 1063– 1067 (2018).
5. Sapriadil, S., Setiawan, A., Suhandi, A., Malik, A., Safitri, D., Lisdiani, S. A. S., Hermita, N.: Effect of higher order thinking virtual laboratory (HOTVL) in electric circuit on students' creative thinking skills. Journal of Physics: Conference Series **1204**(1), 012025 (2019).
6. Alexaindre, J. Rodriguez, A.B.: Doing the Lesson or Doing Science: Argument in High School Genetics. John Wiley & Sons, Inc (2000).
7. Moon, K., Brewer, T. D., Januchowski-Hartley, S. R., Adams, V. M., Blackman, D. A.: A guideline to improve qualitative social science publishing in ecology and conservation journals. Ecology and society **21**(3), (2016).
8. Berland, L.K. Hammer, D. Framing for Scientific Argumentation. Journal of Research in Science Teaching **49**, 68-94 (2012).
9. Herring, J. How to Argue: Powerfully, Persuasively, positively. FT Press, Upper Saddle River (2012).
10. Pallant, A., Lee, H. S.: Constructing scientific arguments using evidence from dynamic computational climate models. Journal of Science Education and Technology **24**, 378-395 (2015).
11. Probosari, R. M., Sajidan, S., Suranto, S., Prayitno, B. A.: Integrating reading as evidence to enhance argumentation in scientific reading-based inquiry: A design-based research in biology classroom. Jurnal Pendidikan IPA Indonesia **11**(1), 171-184 (2022).
12. Rosita, C. D.: Kemampuan penalaran dan komunikasi matematis: Apa, mengapa, dan bagaimana ditingkatkan pada mahasiswa. **Euclid** 1(1), (2014).
13. Cáceres, M., Nussbaum, M., Marroquín, M., Gleisner, S., Marquínez, J. T.: Building Arguments: Key to Collaborative Scaffolding. InteractiveLearning Environments **26**(3), 355–371 (2018).
14. Jennings, P. A., Greenberg, M. T.: The prosocial classroom: Teacher social and emotional competence in relation to student and classroom outcomes. Review of educational research **79**(1), 491-525 (2009).
15. Pitorini, D. E., Suciati, S., Ariyanto, J.: Kemampuan argumentasi siswa: Perbandingan model pembelajaran inkuiri terbimbing dan inkuiri terbimbing dipadu dialog Socrates. Jurnal Inovasi Pendidikan IPA **6**(1), 26-38 (2020).
16. Suhandi, A.: Pengembangan perangkat pembelajaran fisika sekolah untuk meningkatkan pemahaman konsep dan kemampuan berargumentasi calon guru fisika. Jurnal Pendidikan Fisika Indonesia, **8**(2), (2012).
17. Kontos, P., Miller, K. L., Mitchell, G. J., Stirling-Twist, J.: Presence redefined: The reciprocal nature of engagement between elder-clowns and persons with dementia. Dementia **16**(1), 46-66 (2017).
18. Noroozi, O., Hatami, J., Bayat, A., Van Ginkel, S., Biemans, H. J., Mulder, M.: Students' online argumentative peer feedback, essay writing, and content learning: Does gender matter? Interactive Learning Environments **28**(6), 698-712 (2020).
19. Viyanti, V., Cari, C., Sunarno, W., Prasetyo, Z. K.: Analisis tes argumentasi materi terapung dan tenggelam. Jurnal Pendidikan Fisika Dan Keilmuan (JPFK) **2**(2), 88 (2016).
20. Ginanjar, W. S., Utari, S., Muslim, M.: Penerapan model argument-driven inquiry dalam pembelajaran IPA untuk meningkatkan kemampuan argumentasi ilmiah siswa SMP. Jurnal Pengajaran MIPA **20**(1), 32-37 (2015).

21. Kaniawati, I., Suhandi, A.: Penerapan model pembelajaran pembangkit argumen menggunakan metode saintifik untuk meningkatkan kemampuan kognitif dan keterampilan berargumentasi siswa. Jurnal Pendidikan Fisika Indonesia **10**(2), 104-116 (2014).
22. Karim, S., Saepuzaman, D., Sriyansyah, S. P.: Diagnosis kesulitan belajar mahasiswa dalam memahami konsep momentum. Jurnal Penelitian & Pengembangan Pendidikan Fisika **1**(1), 85-90 (2015).
23. Rhahim, E., Tandililing, E.: Hubungan keterampilan matematika dengan kemampuan menyelesaikan soal fisika terhadap miskonsepsi siswa pada impuls momentum. Jurnal Pendidikan dan Pembelajaran Khatulistiwa (JPPK) **4**(9), (2015).
24. Diniya, D., Ilhami, A., Mahartika, I., Prakash, O.: Kemampuan argumentasi ilmiah calon guru IPA melalui pendekatan mikir selama pandemi COVID-19. Journal of natural science and integration **4**(1), 141-148 (2021).
25. Sari, W. K., Nada, E. I.: Analisis kemampuan argumentasi ilmiah mahasiswa pendidikan kimia pada pembelajaran daring. In: NCOINS: National Conference of Islamic Natural Science, pp. 1-10, (2021).
26. Amalia, R., Rahmawati, Y., Budi, S.: Pengembangan keterampilan argumentasi calon guru kimia melalui pendekatan socio critical and problem oriented. Jurnal Tadris Kimiya **1**, 91-104 (2019).
27. Putri, F. D.: Pengembangan Instrumen Tes Kemampuan Berargumentasi Pada Materi Impuls dan Momentum. Khazanah Pendidikan **14**(1), (2020).
28. Berlian, L., Taufik, A. N., Iman, A.: Pengembangan instrumen tes argumentasi tulisan yang berorientasi e-learning untuk melatih keterampilan argumentasi mahasiswa. Bio Educatio **6**(2), 378677 (2021).
29. Zaroh, I., Muntholib, M., Joharmawan, R.: Implementasi Instrumen Asesmen Argumentasi Ilmiah Materi Laju Reaksi. Orbital: Jurnal Pendidikan Kimia **6**(1), 78-90 (2022).
30. Chen, Y. C., Benus, M. J., Hernandez, J.: Managing uncertainty in scientific argumentation. Science Education **103**(5), 1235-1276 (2019).
31. Purwasih, D., Wilujeng, I., Misbah, M., Zakwandi, R., Rahmat, A. D.: Multi-rater analysis for learning instruction webbed models based on local potential "Pulau Kembang" validation: An innovative means to assess product quality. In: AIP Conference Proceedings (Vol. 3058, No. 1). AIP Publishing (2024).
32. Plomp, T., Nieveen, N.: An Introduction to Educational Design Research, Netherlands Institute for Curriculum Development (SLO), Enschede-Netherlands (2010)