Development of a scientific argumentation test instrument for undergraduate argument-based microbiology laboratory

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Abstract. This study aims to develop an instrument that is used to assess scientific argumentation skills of prospective biology teacher students in microbiology practical activities. This research uses research and development methods which consist of define, design, develop and dissemination stages. During define stage, it was determined the argumentation skills that measured and the context of the test. Then, the test items were developed by constructing and revising. The pilot test was administered to be analysed by validity and internal reliability. The result of this study was a set of scientific argumentation test instrument consisting of 5 essay questions, each divided into 4 questions that measure aspects of argumentation, namely claims, data, warrant, and backing. Each question number contains situations and questions related to the existence of microorganisms in daily life based on laboratory activities. The results of expert validation and trials show that the five questions are valid and reliable. Thus, the results of this study recommend the use of this test instrument for research that assesses the skills of scientific argumentation in microbiology lab activities.

1. Introduction
Learning microbiology as a science acts as a "tool" to develop student’s personality with scientific values and attitudes and develops many skills that need to be trained and possessed by a student, as a prospective scientist, one of which is scientific argumentation skills. Arguments are interpreted as the relationship between claims and data through the use of justification and evaluation of knowledge [1]. The term argumentation itself does not only refer to debate, although the debate is one form of argumentation. Argumentation is more intended to be a process of thinking and social interaction in which people construct and criticize arguments [2]. The researchers suggest that argumentation as part of science learning must be encouraged and taught explicitly in the classroom [3]. The research results of Van Lacum, Ossevoort & Goedhart [4], indicate that the participation of students in scientific argumentation can result in a better understanding of scientific concepts and processes. But the opportunity for students to participate in authentic argumentation in science classes is very rare. In addition, little is known about the understanding of prospective science teachers regarding scientific argumentation, their ability to participate in the practice of argumentation, or their ability to use argumentation in the classroom as part of science learning [5].

Inquiry-based microbiology learning in the laboratory is a complex activity that integrates hands-on and minds-on activities, so that laboratory or practicum activities are recommended to be applied in...
student learning in higher education [6]. This is in line with the objectives of school science education according to the National Science Education Standards [7], which is to create educated students who are able to do experiment correctly and are encouraged to know and understand nature using scientific processes and principles that are appropriate in making personal decisions. In addition, through inquiry-based microbiology practical activities, students are expected to be able to use their intellectual abilities in discussion and debate or arguments about the scientific and technological matter and increase their economic productivity through the use of knowledge, understanding and scientific skills possessed in their careers.

The Argument-Based Inquiry Lab Activity Program in microbiology is a practical program designed to provide opportunities for students to practice improving the quality of argumentation while familiarizing themselves with inquiry activities. This program is the result of adaptation, modification, and synthesis of the Argument-Driven Inquiry model developed by Sampson, Grooms & Walker [8] and the Argument-Based Inquiry that uses the Science Writing Heuristic (SWH) approach by Chen, Hand & Park [9]. The program consists of 8 stages, namely 1) introduction of problem and inquiry questions, 2) formulation of initial arguments, 3) designing and conducting of investigations, 4) data analysis and formulation of group arguments, 5) performing class argumentation, 6) creating lab reports, 7) peer-review, and 8) revision of lab reports. The characteristics of this learning model are described as a "guided inquiry" laboratory model that supports the practice of argumentation because students must decide how to collect, analyze and understand the data to construct arguments that provide and justify an answer to the research question through a series of discussions. The limits of the stages of this model are defined by scope and purpose. Each stage is as important as other stages for the success of achieving the desired goals and outcomes of the learning process.

Argumentation can be defined as a series of propositions that are used as reasons to strengthen or reject an opinion or idea (10). While argumentation is a social process in which two people or more build and criticize arguments. The process of scientific argumentation should involve the construction and criticism of scientific arguments, which involve consideration of alternative hypotheses. Argumentation, as part of what needs to be considered in critical thinking skills, is a verbal, social and rational activity that aims to convince reasonable critics of an acceptable view [11,12]. While scientific argumentation is a special case when dialogue is directed at coordinating evidence and theory to improve explanation, model, prediction or evaluation [13].

The structural component of an argument includes claims, data, warrants, backing, rebuttal and qualifier, known as the Toulmin Model [14]. This model has become the basis for evaluating the quality of an argument in terms of the presence or absence of these structural components. Some researchers suggest that the simple checklist of argumentative elements does not accurately reflect the persuasive quality of an argument, rather on an evaluation framework that must pay attention to the combination of elements.

According to the Toulmin model, the first component in each argument is a statement of establishment or standpoint in the form of a conclusion or answer to a given problem, which is referred to as a claim. This claim must be supported by data as evidence. While an explanation of the relationship between data and claims is bridged by warrant. Claims, data and warrant are the basic structure or core of an argument (as can be seen in Figure 1). The backing provides support to explain why the warrant has authority. The rebuttal is a special condition in which data and warrant cannot support claims or do not apply. While qualifier establishes requirements what conditions these arguments to be valid [1,15-18].

Whereas there are some studies presenting the benefits of argumentation in scientific knowledge development, there is still a need for research discovering the assessment of scientific argumentation among students in a wide variety of scientific concepts [19]. In the other hand, Frey et al., [20] have once developed a 36-item test instrument covering the ability to identify claims and qualifiers in a claim, the ability to distinguish among a claim, fact, opinion, and data, the ability to distinguish among authority, logic and theory as possible reasons one accepts a claim, and the ability to identify rebuttals and counter-arguments. However, the test wasn’t designed to assess specific domain of scientific
concept or skills. Some research in the development of assessment specific domain Scientific argumentation had been conducted by some researchers. For example, Lee et al., [21] had developed students' scientific argumentation test associated with uncertain current science. The problem is the tests were designed to measure argumentation skills related to climate change issue.

Regarding microbiology laboratory concepts and skills, we need a specific domain test to fulfill the goal of the activity. So, we decided to conduct this study. Therefore, this article aimed to develop a scientific argumentation test instrument of a microbiology laboratory.

![The Toulmin model for the scientific argumentation framework used in this study](image)

**Figure 1.** The Toulmin model for the scientific argumentation framework used in this study

2. **Methods**
The study used Research and Development (R&D) methods according to Thiagarajan [22] which is known as the 4D model. This method consists of four stages, define, design, develop and disseminate. This paper attempted to describe systematic, factual and accurate information on the development of scientific argumentation test instrument for the undergraduate microbiology laboratory.

2.1. **Defining the skills and contexts to be assessed**
The test instrument aims to measure specific students' scientific argumentation skills in microbiology lab activities. Therefore, the aspect that will be evaluated is the ability of students to express an argument along with its components. Based on the Toulmin model, as seen in Figure 1, the components of the argument consists of claims, data, warrant, backing, rebuttal, and qualifier. While claims, data, and warrant are the core components of an argument, backing, rebuttal and qualifier complete the argument and make the quality of the argument better. In this study, targeted students were new to scientific argumentation in science education, and based on the results of preliminary studies, their argumentative abilities were in a low category [23]. Therefore, this instrument measures only 4 of the 6 components mentioned, namely the claim, data, warrants, and backing. If later a rebuttal and a qualifier appear, will be added as part of the value for the backing.

The scientific context in this study is microbiological concepts involved in the activities of the microbiology lab and their relation to everyday life, both as students of prospective science teachers and as a society in general. There are 5 microbiological topics that are used as the context in this test, namely aseptic work in the microbiology lab, drinking water quality, antimicrobial susceptibility, microbes around us and the role of microbes in fermentation.
2.2. Designing the prototypical Scientific Argumentation Test instrument
The test instrument was aimed to assess specific scientific argumentation skills in the topics of microbiology laboratory and the application in daily life. So, the test designed to be a series of essay questions that gives students the opportunity to give their argument to be assessed whether include all components of an argument structure or logically answer the question and reason.

2.3. Developing & validating the test instrument
The test items have been constructed so that the skills and context appeared. The test was developed in the form of 5 question numbers according to each context for each number. Every question number was given the directions to answer all the aspects of an argument: claim, data, warrants, and backing for each problem asked. Along with the development of test questions, the rubric and assessment are also made. The rubric was with 3 levels of score gradation, the highest scored 3 and the lowest scored 0.

The test instrument was validated by three experts in the field of microbiology, argumentation in science education and biology education. Assessment aspects for the validation of the test construction the included: (1) the suitability of questions with indicators of scientific argumentation skills, (2) the suitability of the questions with the laboratory topics being studied, (3) the accuracy of the content of science in the questions and answer keys, (4) the accuracy of the use of words and terms or language, (5) questions did not lead to multiple interpretations, and (6) suitability and relevance of assessment criteria and scores with questions and answers.

2.4. Disseminating the test among biology education students
A validated test instrument was administered to 33 biology education students of the 5th semester in Cirebon, West Java. The test results were analyzed using the Pearson Product Moment formula. It is a type of correlation test used to determine the empirical validity of a test instrument. Reliability was also analyzed using the Cronbach-Alpha formula [24].

3. Result and Discussion
3.1. Example of Figure (Put subtitle of your research results)
The developed test instrument consisted of 5 items. Example of the indicators and scientific argumentation skills test items are shown in Table 1.

| Indicators of scientific argumentation skills | Test item |
|----------------------------------------------|-----------|
| Context: Microorganisms need media and nutrients for growth. Air or atmosphere does not contain enough nutrients to meet microbial growth. However, the atmosphere contains a number of microbes that can be isolated. Different types and quantities differ from one place to another. Even air is one of the spreaders of microbes that cause several diseases. Problem: How do you think microbes can be in the air? Making accurate claims in accordance with the problem | Make a claim (statement) to answer the above problems. Include data to support claims | Provide evidence or data to support claims that you submit based on the results of daily observations or from other sources. Explain the relationship between data and claims | Describe the relationship between the data and claims that you write. Provide a foundation of how justification (warrant) to support the claim | Describe backing that you can use to support the justification of claims. |

The result of the expert judgment indicated that all of the three experts agree that the test instrument valid and can be used to assess students’ scientific argumentation skills. The expert who validated the instrument consisted of three experts, each of whom was an expert in the field of scientific
argumentation in science education, an expert in the field of biology education, and an expert in the field of microbiology. The results of expert validation showed that overall the feasible questions are used as research instruments with little revision on the questions that are considered lacking. The revision had been made and shown again to the validator before the trial is carried out.

The result of the trial score analysis from students showed that all the test items are valid. The results of item analysis on instrument testing include analysis of validity and reliability as can be seen in Table 2. The results of the analysis of the items indicate that the whole question is valid and can be used as an instrument to retrieve data in research that assesses scientific argumentation skills in a microbiology lab.

| No. question | Correlation | Validity | Reliability | Conclusion |
|--------------|-------------|----------|-------------|------------|
| 1            | 0.606       | Sig.     |             | Question item can be used |
| 2            | 0.601       | Sig.     |             | Question item can be used |
| 3            | 0.722       | Sig.     | 0.71        | Question item can be used |
| 4            | 0.739       | Sig.     |             | Question item can be used |
| 5            | 0.647       | Sig.     |             | Question item can be used |

The scientific argumentation test instrument developed in this study was in accordance with the recommended guidelines for the evaluation of argumentation [1,15-18]. This test instrument also meets the need for an assessment instrument for biology education students who are beginners in scientific argumentation. It is expected that this scientific argumentation test instrument can be used as a preference for future empirical research as well as for teaching purposes assessment focusing on the integration of scientific argumentation and microbiology laboratory.

4. Conclusion

The test instruments that measure scientific argumentation skills in microbiology lab activities have been developed. The results of expert judgment and trial analysis showed that it is valid and reliable, therefore, it can be used to assess students' scientific argumentation skills. The results of this research are highly recommended for research in developing students' scientific argumentation skills during microbiology lab activities in the future.

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