# Argumentation Skill Assessment for Diagnosing Students' Understanding of Factual, Conceptual, Procedural, and Metacognitive Knowledge_ Characteristics of Initial Needs

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**Submission date:** 27-Mar-2023 05:09AM (UTC+0700)
**Submission ID:** 2047149079
**File name:** PROOFREAD_AHMAD_WALID.docx (478.29K)
**Word count:** 6969
**Character count:** 42901

JPII 5 (2) (2016) 247-255

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

# Argumentation Skill Assessment for Diagnosing Students' Understanding of Factual, Conceptual, Procedural, and Metacognitive Knowledge: Characteristics of Initial Needs

**DOI:**

Accepted:... .Approved: ... . Published: ...

**This study aims to synthesize the characteristics of the initial needs for argumentative skills assessment instruments to diagnose students' understanding of factual, conceptual, procedural, and metacognitive knowledge. This study used a quasi-experimental method. The technique used was quantitative descriptive research. The research subjects were taken from 50 students who used argumentative patterns in problem-solving on aquatic ecology material so that they were synthesized using argumentation skill indicators. This research was quantitative, with instrument construct design criteria in the cognitive domain based on the taxonomy of science education. The data in the study were collected through several tests to determine argumentation skills. Supporting data were obtained through questionnaires to be analyzed regarding content and learning tools. The data analysis technique calculated the average score of the test questions with criteria according to the skills of argumentation and analysis in terms of content and learning tools. The result of this research is a matrix of rigid test areas with the achievement of indicators of a neatly arranged argumentation skill questionnaire and the results of content analysis and learning tools that support the argumentation instrument.**

**Keywords: Assessment instrument, argumentation skill, cognitive ability**

## INTRODUCTION

The world is currently experiencing a period of globalization, and there is intense competition for qualified human resources (HR). Everyone must study and think in the 21st century, putting special emphasis on growing their intellectual capacity to respond to modern developments and changes. The end result of 21st-century learning is the development of life and career skills, including the capacity for information synthesis, teamwork, wide and complex management, and environmental and social responsibility (Aldowah et al., 2019; Tikva & Tambouris, 2021). The ability to identify, locate, and view all information using technology and media is referred to as having skills in technology, media, and information. This allows information to be meaningful. One of the abilities that every person must possess in this century is the argumentation skill.

Argumentation skills support understanding cognitive processes in the development of scientific information (Cavagnetto & Hand, 2012; Viyanti et al., 2016; Yılmaz-özcan & Tabak, 2019). Students with excellent and complex argumentations will better understand the concept (Claro et al., 2012). Students' scientific argumentation can help them gain a greater grasp of scientific concepts and processes, allowing them to comprehend scientific phenomena in everyday life (Allen-Zhu, 2017; Nie et al., 2015; Osborne et al., 2016; Sampson & Blanchard, 2012). To understand qualified concepts and cognitive abilities, we can look at the ways and results of an educator formulating an assessment ( Ching et al., 2021; Goepfert et al., 2019; Klein et al., 2019; ).

Assessment is a general term that covers the entire procedure used to obtain information about students' learning outcomes (observations, ratings, and paper and pencil testing) and assesses the learning process (Beidas et al., 2022; Janssens et al., 2022). According to Almendingen et al. (2021), assessment is an action or a process to determine the value of something. In assessment, three main terms must be understood and interrelated: decisions, considerations, and interpreting the information obtained as the final assessment result. Information is the raw material needed to make judgments (Vrindt et al., 2022). The term assessment assesses the process, progress, and students' learning outcomes (Molina Saorín et al., 2014; Urcola-Pardo et al., 2017). Thus, it can be concluded that assessment is the proper term for assessing student learning processes.

Osborne et al. (2016) elaborate lecturers' difficulties assessing the correct argument. Science knowledge taught in class is sometimes regarded solid and unarguable by students. Toulmin's (2003) argumentation scheme consists of 1) claim as the center of the argument; 2) claim supporting data; 3) warrant, the relationship between data and claim; 4) backing, quality, and type of reason; 5) qualifiers, statements giving properties, limits, or clear conditions that are part of the claim; 6) rebuttal, identify exceptions to claims or alternative claims. The Toulmin model offers a method for analyzing and critiquing arguments so that each argument component can be tested and assessed for its strength. The co-orientational approach is built based on the Toulmin model, which is added with three elements: the co-orientation process, the argument situation, and the argument relationship. This argumentation scheme can identify aspects of the argument that will be assessed and can assess the justification of an argument in addition to the structure of the argument itself. Each component in this schema works together and explains how they adapt the arguments to different situations and contexts.

Based on the preliminary study results analyzing the Semester Learning Plan (RPS) developed by the lecturers, the development of the Ecology course learning plan sub-ecosystem material has not emphasized argumentation skills. Assessment only refers to outstanding ability either in theory or in practice. Preliminary studies also use the instrument of argumentation skills at the Science Education Study Program of UIN Fatmawati Sukarno Bengkulu, showing that the claim is 72%, the data is 54%, the warrant is 38%, the backing is 66%, and the qualifier aspect is 49%. Based on Toulmin's argumentation paradigm, the argumentation quality study reveals a deficiency in empowering students' argumentation skills in learning. This statement is supported by Viyanti et al. (2016), who state that students' argumentation skills are still low in all aspects of students' argumentative thinking indicators in learning. Students are not trained to argue scientifically (Wahdan et al., 2017).

Argumentation skills can be trained by giving questions or tests in the assessment process (Wikara et al., 2022). Designing argument-oriented test questions prioritizes the core activities of science practice which are the need for tests that help students express knowledge other than content to form an analytical framework for determining and examining arguments (Iordanou, 2022). The relationship between concepts and teacher performance in the classroom cannot be separated from the integration of argumentation skills in evaluation (Problema & Falacias, n.d.). It aligns with

epistemological aspects, a perspective in appreciating criticism and arguing as an effort to build scientific knowledge (Wang, 2021). Students are guided in explaining and proving science by the instrument design for testing students' argumentation skills on ecosystem materials.

According to Wahdan et al. (2017), students' conceptual knowledge is good if they can answer problems by explaining and verifying science based on data. Questions and assessment techniques are used not only to evaluate the teaching and learning process, but also as part of a sequence of activities to enhance quality, performance, or productivity in program implementation (Mardapi & Herawan, 2018; Sukardi et al., 2015). Amornchaia et al. (2015) also state that analytical reasoning skills are practiced in virtual classrooms with performance tasks.

Performance task activities focusing on arguments are designed based on logical errors generated by scenarios and related evidence. The results of another analysis conducted by Belland et al. (2017) regarding argumentation skills combined with computer-based scaffolding are very effective in improving cognitive learning from pretest to posttest; these strengths are consistent across level measures, educational populations, and STEM disciplines. Furthermore, a valuable skill in critical thinking and argumentation is the ability to spot mistakes, such as misleading arguments, which are common in argumentative discourse and can be deceitful, manipulative, or lead to (wrong moves) in the conversation. Despite the significance of thinking skills, argumentation academics who focus on argument quality have not conducted empirical research on fallacies. Due to a lack of resources to deal with fallacious argumentation, a scalable strategy to data collecting and annotation is required, and serious game methodology provides an interesting yet untapped alternative to the original (Habernal et al., 2017). Despite the early development of spoken argumentation, written argumentation is sluggish to develop, indifferent to opposing viewpoints, and often of poor quality. Some assessment pattern findings and high-quality argumentation questions are expected throughout the curriculum and required in an increasingly competitive workplace that demands sophisticated communication abilities (Ferretti & Graham, 2019).

Acar (2018) finds that the development of pre-service science teachers' argumentation skills and conceptual knowledge, the relationship between argumentation skills and conceptual knowledge, and the relationship between argumentation and conceptual knowledge gains for pre-service science teachers at the initial level of conceptual knowledge in the undergraduate program where argumentation skills are incorporated into the science curriculum. His findings align with Patton and White (2015), who discuss the relationship between argumentation skills and conceptual abilities. It is found that most of the counterarguments and rebuttal skills are successfully developed. In addition, different trends of changing argumentation skills are identified as having scientific misconceptions and conceptions. Luginbühl and Müller-Feldmeth (2022) show oral argumentation skills compared to written argumentation to reconstruct various levels of oral argumentation skills with processes and styles beyond the structural aspect in the narrow sense of forming oral argumentation to a higher level. Argumentation skills can be achieved if the integration skills established during formal school education can facilitate the integration of all knowledge (Hacıeminoğlu & Yıldız, 2022). Other supporting research focuses on how to construct arguments and apply concept knowledge, both of which are strongly related to evaluating claims, confirming claims with evidence, and justifying the relevance of evidence to claims through reasoning. However, prior study indicates that while generating arguments, students struggle with distinguishing between argument components, applying conceptual knowledge, and constructing multivariate arguments. Scaffolding can help students focus on the expected structure of the argument and activate the necessary conceptual knowledge, which can help them overcome this problem. When students enter the classroom with varying levels of prior knowledge, support must be personalized to their specific requirements (Lieber et al., 2022)

This study aims to synthesize the characteristics of the initial needs of an argumentative skills assessment instrument to diagnose the students' understanding of factual, conceptual, procedural, and metacognitive knowledge. Assessment instruments are needed to improve students' understanding of argumentation skills factually, conceptually, procedurally, and metacognitively to support achievement in evaluating the learning process. The criteria for argumentation skills in this study is that students can work on questions that are expected to improve the quality of data and research results to strengthen arguments. It can be seen from the questions given by educators. The results of this study are characteristics that must exist in making argumentation skills questions. These characteristics are contained in the framework of indicators and rubrics made from the analysis of the preliminary results.

## METHODS

This study used a quasi-experimental method (Thyer, 2012). This research was based on the description of phenomena or events captured by the researcher with the existing facts by making several observations of the subject to be studied before treating the subject. The research subjects were taken from 50 students who used argumentative patterns in solving problems in aquatic ecology material so that they were synthesized using indicators of argumentation ability. This research was quantitative with the design criteria of the instrument construct in the cognitive domain based on the taxonomy of educational sciences. The techniques used in quantitative descriptive research were testing, measuring, and hypotheses based on mathematical and statistical calculations. (Bao et al., 2002). The data in the study were collected through several tests to determine argumentation skills. Supporting data were obtained through questionnaires to be analyzed regarding content and learning tools. The data analysis technique calculated the average score of the test questions with criteria according to the skills of argumentation and analysis in terms of content and learning tools.

In this study, an argumentation skill assessment instrument was developed as an argumentation test to measure students' skills in reasoning in the form of multiple-choice arguments. The criteria for developing instrument constructs in the cognitive domain were based on the taxonomy of science education (Amalia & Susilaningsih, 2014). The argumentation test area development matrix on the claim component can be seen in Table 1.

**Table 1.** Section of the Test Area Development Matrix

| Components | Aspects | Taxonomy of Science Education | Indicators of Argumentation Skill in operational verbs |
|---|---|---|---|
| *Claim*<br><br>Definition: a statement about things that can be judged right or wrong | Claim Based on Facts<br><br>Claim Based on Definitions<br><br>Claim Based on Cause-and-Effect Relationships | Domain: knowing and understanding (knowledge) | **Identify**<br>**Classify**<br>**Interpret**<br>**Explain**<br>**Understand**<br>**Predict**<br>**Show**<br>**Express**<br>**Explain** |

This research is a preliminary study to see the profile of students' reasoning. The instrument used in this study was nine multiple-choice questions with reasons. An important concept tested in this test is the ecosystem of aquatic ecology, adapted from several ecological topics in the world in several reputable newspapers. Three analyses were used in this study: subject matter analysis, content analysis, and analysis of teaching tools so that a profile of the characteristics of argumentative assessment can be found entirely (Figure 1).


**Figure 1.** Matrix Chart for Making Argumentative Question Instruments

The research was conducted at three universities: UIN Fatmawati Sukarno Bengkulu, UIN Raden Fatah Palembang, and UIN Raden Intan Lampung. Subject matter analysis was taken from several rivers in Bengkulu City. The sample of this research was all questions related to ecosystem material in the ecology course. Data analysis was done by identifying the appropriate question indicators following the criteria. In addition to questionnaire analysis, the questions and content of data collection in this research are to conduct simple direct research to obtain quantitative results. The data analysis technique used patterns, formulas, and achievement

indicators that supported obtaining new information.

## RESULTS AND DISCUSSION

This research begins with preliminary study activities, which include needs analysis, which aims to find out the problems that occur on campus so that they can be solved through product development results. The results of the needs analysis obtained by the researchers were collected based on the analysis of the results of the questionnaire distribution as a supporting data collection instrument. Questionnaires support argumentation skills data, especially regarding students' self-confidence to express their argumentation skills in solving problems. The questionnaire is based on achievement indicators of argumentation skills consisting of claims, data, warrants, backing, qualifiers, and rebuttals. The scope of the results of the students' self-confidence in arguing is presented in Table 2.

**Table 2.** Achievement of Indicators of Student Argumentation Confidence Questionnaire

| Indicators | Indicator Achievement (%) | | | Average |
|---|---|---|---|---|
| | PT A | PT B | PT C | |
| **Claim** | 82,08 | 83,33 | 81,33 | 82,25 |
| **Data** | 81,25 | 81,89 | 82,67 | 81,94 |
| **Warrant** | 81,67 | 81,78 | 86,67 | 83,37 |
| **Backing** | 80,42 | 82,89 | 81,33 | 81,55 |
| **Qualifiers** | 81,67 | 81,33 | 81,78 | 81,59 |
| **Rebuttal** | 82,50 | 82,22 | 81,33 | 82,02 |

Source: Analysis of argumentation skills questionnaire

The result data in Table 1 show that the self-confidence of the students expressing their argumentation skills in the Southern Sumatra High School is categorized as "good," with the highest score on the warrant (83.37%) and the lowest on the backing and rebuttal (81.55%). These results illustrate that overall, the students at higher education in South Sumatra already have good self-confidence in expressing their argumentation skills for the claim, data, warrant, backing, qualifiers, and rebuttal indicators.

After the questionnaire data was processed and synthesized, it was continued by analyzing and synthesizing the questions. Question analysis data used by lecturers in this study aims to determine the percentage of the aspect of argumentation skills in questions. The questions analyzed include daily test questions, quizzes, mid-semester tests, final-semester tests, and lecturer handbooks of the aquatic ecosystem, as presented in Table 3.

**Table 3.** Percentage of Argumentation Skill Indicators in Questions

| Indicators | ∑Question | Total Questions | Percentage |
|---|---|---|---|
| Claim | 37 | 47 | 78,73 |
| Data | 10 | 47 | 21,27 |
| Warrant | 0 | 47 | 0 |
| Backing | 0 | 47 | 0 |
| Qualifiers | 0 | 47 | 0 |
| Rebuttal | 0 | 47 | 0 |

Source: Lecturer question bank for ecosystem material

The data on the percentage of using the argumentation skill indicator in the questions used in class in Table 4.2, on average, only reveals claim (78.73%) and data (21.27%), where the claim dominates the most. Based on these, it can be said that lecturers in higher education in South Sumatra need an assessment instrument to develop argumentation skills. This is the basis for researchers to look at knowledge both factually, conceptually procedural and metacognition so that questionnaires and collaborative rubrics are formed from argumentation skills combined with cognitive dimensions.

Content analysis on this data was taken to know the actual data in the field. It was adjusted to the reviews, documentation, and observations to compare theory and conditions in the field. The data were obtained by conducting direct research related to aquatic ecology. In this case, the researchers compare very natural and polluted waters. The results of the observations are in Table 4.

**Table 4.** Water Ecology Data Based on Observation Parameters

| Aspects | Components | River Type | |
|---|---|---|---|
| | | Natural Water | Polluted Water |
| **Science Education** | Water Temperature (0 C) | 25,42 | 30,51 |
| | Air Humidity (%) | 62,28 | 54,35 |
| | Current speed (m/s) | 0, 46 | 0,23 |
| | Conductivity (us/cm) | 192,61 | 194,43 |
| **Chemistry** | PH | 7,27 | 6,21 |
| | DO | 9,25 | 2,19 |

| | | | |
|---|---|---|---|
| **Biology** | Turbidity (NTU) | 4,7 | 37.23 |
| | Community Benthos | Rarefied | Dense |
| | Periphyton | Available | Available |
| | Riverside Structure and Texture | - Shrubs, herbs, and plant litter<br>- Moist | - Trees, shrubs, herbs, and plant litter<br>- Moist |

The river temperature obtained is 25.42ºC and 30.51ºC, while the standard water quality temperature is 24.89 to 31.89ºC. The water temperature in the river shows good parameters. According to water quality standards, the oxygen content in the river is 9.25 mg/l and 2.19 mg/l. It shows the high diffusion of air from the surface of the water and the abundance of phytoplankton. This phytoplankton carries out much photosynthesis during the day, producing a lot of dissolved oxygen (Nybakken, 1998).

According to water quality standards, the pH value is 6-9, while the river has a pH of 7.27 and 6.21. It shows that the pH of river water has a suitable H+ concentration to support the life of aquatic organisms. The following parameter is turbidity or water turbidity. Based on the measurement results, the turbidity obtained is 4.7 NTU and 37.23 NTU. However, according to the water quality standard, the water turbidity should be less than 5 NTU. It shows that the turbidity of unspoiled river water is still very clear and cloudy in polluted rivers.

In biology, the diversity of benthos attached to the surface of rocks, wood, and others is very diverse. Figure 2 is a graph of the Benthos Diversity Index from the Shannon-Wiener index.

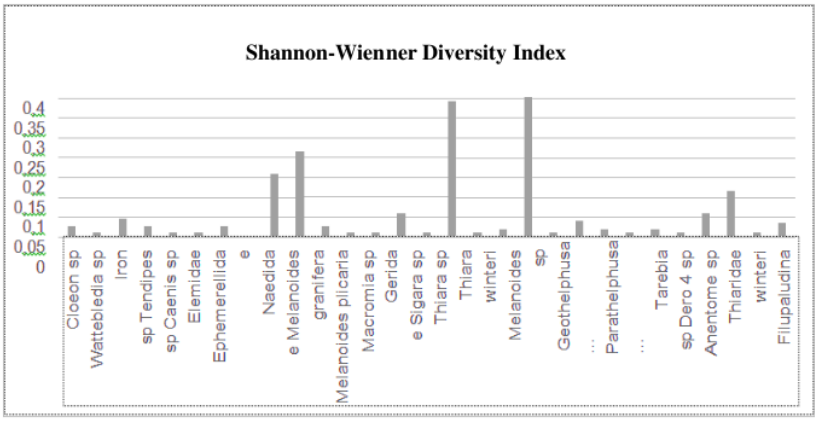


**Figure 2.** The Shannon-Wiener Diversity Index

Figure 1 shows that the level of benthos diversity in the two rivers as sampling sites is moderate. Moreover, Simpson's Dominance Index measurements find that no pi2 is close to 1, so no species dominates.

In addition to content analysis, analysis is also carried out on learning device data in the form of RPS at 3 Universities for ecosystem materials. RPS can be used in order to support the process of teaching and learning activities to emphasize the argumentation skills of students. After being analyzed with learning achievement indicators, it is found that 1) the development of RPS in the Ecology course of ecosystem material does not emphasize argumentation skills (when viewed from indicators); 2) the development of the RPS has not harmonized derivative functions of RPS components following KKNI guidelines; 3) the development of the RPS only emphasizes the factual and conceptual cognitive dimensions (according to KKO), not procedural and metacognitive dimensions; 4) from the results of interviews via telephone, there has been no formation of a course consortium or clump either at the campus or regional level which discusses firmly and in detail related to the preparation of the Ecology course learning plan, and 5) assessment only refers to the definitive ability either in theory or in practice.

Product design is interpreted by making product planning and development of argumentation skill assessment instruments for ecosystem learning. In general, the product draft of the argumentation skills assessment instrument contains the background, philosophical foundations, and a general description of the guidelines for the preparation of the argumentation skill assessment instrument for ecosystem learning. The steps include formulating test objectives, formulating test areas, outlining test material, determining learning outcomes, and compiling question content outlines.

The argumentation skill assessment instrument for Aquatic Ecology learning produced by the researcher is an Argumentation Skill Assessment Instrument, which is equipped with examples of problems in the form of multiple-choice questions on Aquatic Ecology material, problem-solving rubrics, and scoring guidelines. The assessment instrument developed can identify the structure of students' argumentation, the quality of students' argumentation production, and the pattern of students' thinking processes. The argumentation skill instrument can allegedly train

higher-order thinking skills (Wikara et al., 2022). This statement is supported by the opinion of Habernal et al. (2017), Iordanou (2022), and Wang (2021) that higher-order thinking skills cannot be separated from disclosing reasons by identifying, evaluating, and providing reasons.

The argumentation skill assessment instrument for Aquatic Ecology material that was developed refers to several theories, such as Toulmin's (1983) argumentation scheme, content analysis by Walton (2012), argumentation production analysis by Schwartz (2014), Perelman and Olbrechts-Tyteca (1969), and Jackson and Jacobs (1980). The assessment instrument for developing argumentation skills has been applied to a set of ecological argumentation skills assessments concerning the developed rubric. The argumentation skill assessment instrument for aquatic ecology learning has been validated in a good category. It can measure students' argumentation skills, which are carried out in stages from the easiest to the most challenging level of argumentation skill. It is supported by Iordanou et al. (2019), who state that argumentation skills will increase along with the right and gradual process. Moreover, at each stage, the achievement indicator can easily show that the level of argumentation skill is achieved (Re et al., 2019).

Argumentation skills need to be trained in students. These skills are essential to make students succeed in explaining, deciding, demonstrating, and producing problem-solving in the context of knowledge and experience (Meral et al., 2022; Lieber et al., 2022). Argumentation skills must be measured using a good and valid assessment instrument (Ping & Osman, 2019). Educators have not measured argumentation skills, and a sound assessment system on campus is still very much needed. Thus, it is necessary to develop an instrument for assessing argumentation skills for aquatic ecology learning in order to measure students' argumentation skills in the form of reasoned multiple-choice questions and to measure the quality of the object, skill, attribute, or behavior to express the quantity of the object, skill, attribute, or behavior being measured. Ping and Osman (2019) strongly recommend and pay special attention to explaining the test's type, form, and content. It is proven that students' argumentation skills grow when the test, combined with multiple-choice questions and essays, is carried out. It is also following Matsumoto-Royo et al. (2022) that the evaluation results are displayed as valuable information, so the more significant the knowledge possessed, the greater the level of argumentation skill, dedication to learning, and improved final grades. Another study finds a significant relationship between several factors, which shows an increase in argumentation ability when it is associated with an exam as an evaluation tool, as an answer that combines literal response questions and the ability to express opinions (Al Musawi et al., 2022).

The stages of analysis of the argumentation skills assessment instrument for aquatic ecology learning are structured to make it easier for lecturers to develop assessment instruments for material achievements related to argumentation skills (Komljenovic, 2022; Priemer et al., 2020). The argumentation skill assessment instrument for aquatic ecology learning developed combines the concepts of argument theory: the argumentation scheme of Toulmin (1983), Walton (2012), argumentative production analysis by Schwartz (2014), Perelman and Olbrechts-Tyteca (1969), and Jackson and Jacobs (1980). The purpose of combining theorizing arguments is to make it easier to design rubrics and scoring based on the categories implied by each theory and use each scheme to code students' argumentation (Douglas et al., 2020; Xie & Derakhshan, 2021), argumentation skills based on initial needs of questionnaires, questions, or content (Aditomo & Klieme, 2020).

## CONCLUSION

The conclusion of this study presents the characteristics of the initial need for the argumentation skill instrument to diagnose students' understanding of factual, conceptual, procedural, and metacognitive knowledge. A detailed analysis has been carried out following the indicators of instrument development. This study's results are expected to be used as material in the learning process so that the resulting instrument can measure argumentation skills and be seen in cognitive aspects; factual, conceptual, procedural, and metacognitive. It is also hoped that in the future, it will be necessary to develop a validated product that is more complex while still prioritizing the characteristics in each development of new knowledge.

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