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Student conceptual and epistemic quality improvement argumentation with scaffolding on argument-driven inquiry

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Abstract: This study aimed to compare the quality of students' argumentation based on conceptual and epistemic aspects between learnings that implemented argument-driven inquiry (ADI) and argument-driven inquiry with scaffolding (ADIS) models. The data were collected through dialogic argumentation observation and audio-visual recordings. The data then were analyzed qualitatively. The research was carried out in a first-year Mathematics and Science Education Department, Lampung University. The population of the study was all students of the Mathematics and Science Education Department, which was divided into 4 study programs. The 148 pre-service science teachers, which consisted of 67 participants in the ADI group and 81participants in the ADIS group, were selected as the samples for the study. The results show that an ADIS model is inclined to have a higher potency in enhancing the achievement of students in terms of their quality of argumentation. It is believed that the ADIS model has appropriate learning stages needed by students so that it enhances their contribution for science teachers and lecturers to implement the ADI learning model.

Keywords: *argument-driven inquiry, argumentation quality, dialogic argumentation, epistemic, scaffolding*

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INTRODUCTION

Argumentation is the main purpose of science education since it involves students in complex scientific practices to construct and verify knowledge claims. An argumentation process is used to analyze information on a specific topic and the analysis result is communicated to other people. Hence, an argumentation practice is an important part of knowledge construction in science education.

An argumentation is seen as an important part of the process of science learning due to three reasons, they are scientists use argumentation to develop and improve scientific knowledge, people use argumentation in many scientific debates, and students need argumentation to support their understanding (Aufschnaiter, Erduran, Osborne, & Simon, 2007, p. 377) An argumentation as the structural element of science language is the key in learning science and communicating scientifically. Marttunen (1994, p. 175) claims that an individual, who can perform an argumentation, can instruct and choose reasons that support the given claims, explain a condition where an argument is invalid, and evaluate a counter-counter-argument on the research findings by Hasnunidah and Susilo (2014, p. 649) it is revealed that students' socio-cultural perspective in argumentation does not completely

develop yet, especially in Basic Biology lectures in Mathematics and Science Education of Faculty of Mathematics and Science of Lampung University. The lower the students' argumentative discourse affects the lower argumentation quality. The students are difficult to show data or evidence and defend the problems. The causal relationship explanation to a particular phenomenon given to the students is not coherent and the developed evidence is less supported and irrelevant. A very thoughtful effort needs to do to develop the students' socio-cultural perspective in argumentation through an appropriate learning model to improve the students' argumentation skills.

Students who take part in scientific argumentation might strengthen their skill development for the 21st century (Clark, et al., 2009, p. 4). The necessary ability to possess scientific argumentation is an ability to investigate and accept or reject the relationship between ideas and theoretical ideas in an explanation, or an ability to create a relationship between evidence and theory in an argument which is considered an important aspect of scientific literacy. Scientific argumentation plays a key role in the development, evaluation, and validation of scientific knowledge and is the core point that causes science to differ from other subjects (Driver, Newton, & Osborne, 2000, p. 287; Bricker & Bell, 2008, p. 473) Learning which involves students in an argumentation does not merely provide an opportunity to construct scientific ideas but also provides chances for the students to enhance their understanding of science as well (Duschl & Osbone, 2002, p. 41). Students' competence in scientific explanation needs to be developed in the classroom through strategies or learning models that support the development of competence in scientific literacy (Intan, Rahayu, & Fauziatul, 2019, p. 54).

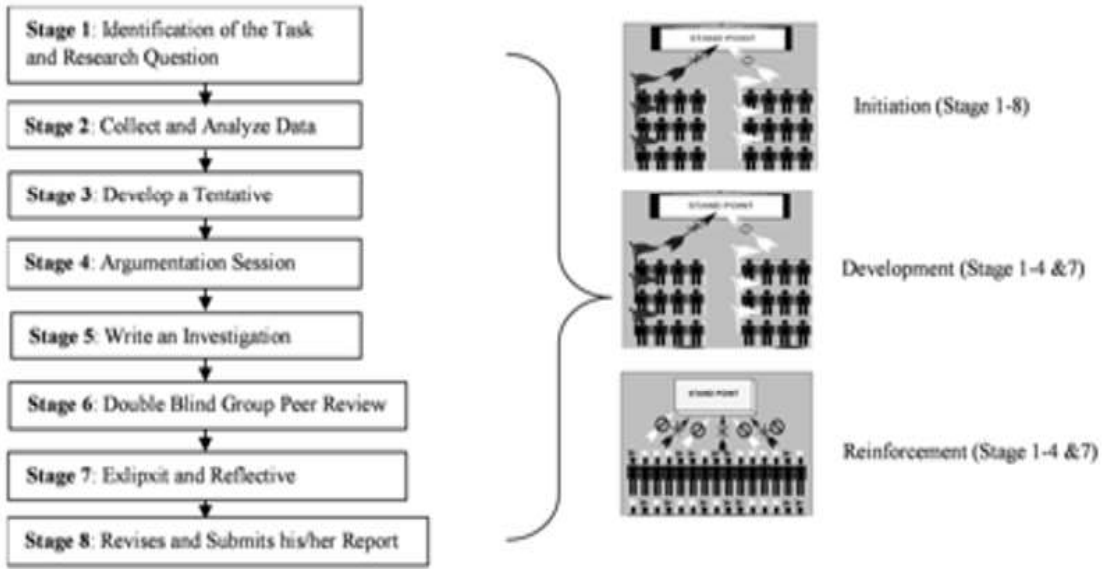
The ADI model is believed to be able to facilitate biology lecturers to inure students to develop their critical thinking, participate actively in argumentation discourses, and improve the argumentation quality. A study by Oh and Jonassen (2007, p. 105) reveals that a group of students who experience scaffolding argumentation can provide more data in an argumentation discourse. One alternative to improve students' thinking processes is scaffolding (Prayitno, Nurjana, & Khasanah, 2017, p. 51). Scaffolding, which is implemented step by step in learning, facilitates students developing scientific argumentation which consists of a claim, evidence, and reasoning (McNeill, Lizotte, Krajcik, & Marx, 2004, p. 15). Therefore, the implementation of scaffolding in an ADI model can make this model more effective in improving the students' argumentation quality (Hasnunidah, Susilo, Irawati, & Sutomo, 2015, p. 1185). The scaffolding which is implemented in this study has a specific characteristic called standpoint which functions as an initial point of argumentation development and stages that consist of initiation, development, and reinforcement

METHOD

The research was carried out in a first-year Mathematics and Science Education Department in the Faculty of Teacher Training and Education of Lampung University, Sumatera, Indonesia. The course was conducted in two-hour sessions each week and consisted of fifteen experiments related to basic biology concepts and principles. Courses were taught according to the ADI and ADIS models for fifteen weeks. After the course, the students' argumentation quality based on conceptual and epistemic aspects skills was measured. The learning which implemented an ADI model consisted of 8 stages based on Sampson and Gleim (2009, p. 465) and Sampson, Grooms, and Walker (2011, p. 217). Meanwhile, the learning

which implemented an ADIS model in the initiation stage emphasized the development of the class' standpoint and consisted of 8 stages (Hasnunidah, Susilo, Irawati, & Sutomo, 2015, p. 1185). The development stage was emphasized in the development of the group's standpoint and consisted of 5 stages. The reinforcement stage also consisted of 5 stages which emphasized the development of individual standpoints. The learning procedure with the ADI and ADIS model is shown in Figure 1.

Figure 1
Stages of the argument-driven inquiry with scaffolding learning model



The population of the study was all students of the Mathematics and Science Education Department, which is divided into 4 study programs: biology education, chemistry education, physics education, and mathematics education, all of which involve basic biology as a subject. The 148 pre-service science teachers, which consisted of 67 participants in the ADI group and 81participants in the ADIS group, were selected as the samples for the study. The samples consisted of 134 females and 14 males and were chosen by random sampling technique from each study program. The students participated in 10 topics that employed an argument-driven inquiry (ADI) learning model and 15 topics which implemented an argument-driven inquiry and scaffolding (ADIS) learning model.

The teaching material applied in the study covers the structure and function of plants and animals, living things' reproduction, metabolism, Mendel's law and human nature inheritance, an organism's interaction with the environment, and evolution. The data were obtained by using students' dialogic observation sheets and audio-visual recordings and were followed by lecture transcriptions. The students' argumentation quality in this study was analyzed based on its conceptual and epistemic aspects by using a rubric adapted from Sandoval and Millwood's (2005, p. 23) framework as presented in Table 1-2. The conceptual quality of an argument was evaluated based on the student's ability to state a causal claim

for a theoretical framework of a specific domain and to support the claim by using available data. The epistemic quality was measured based on the student's ability to quote appropriate data to support a particular claim, write a causal explanation for a phenomenon, and organize appropriate rhetorical references when referencing the data (Sandoval & Millwood, 2005, p. 23*)*.

Table 1
The rubric of the argumentation quality analysis on conceptual and epistemic aspects

Quality Aspects	Descriptor	Criteria
Conceptual	I	Students can state a causal claim with a specific theoretical framework individually
	II	Students can guarantee claims with available data individually
Epistemic	III	Students can quote appropriate data to support a claim individually
	IV	Students can write a logical explanation of a phenomenon individually
	V	Students can organize appropriate references during data finding individually

Table 2
The percentage level of group member

Level of Group Members	Percentage (%)
Level 1	0 – 20
Level 2	21-40
Level 3	41-59
Level 4	60-79
Level 5	80-100

The data of the study were in the form of argumentative discourses categorized based on the level which was tested statistically by using independent sample t-tests with a significant value of 5%. Before the data analysis s conducted by using MANCOVA, the assumption tests were done, including normality testing using one-sample Kolmogorov-Smirnov Test and homogeneity testing using Levene's test, the equality of error variance.

FINDINGS AND DISCUSSION

The data used in this study were obtained from the argumentative discourses. The results of the normality testing and homogeneity testing showed that the data were normally distributed and almost all the variances were homogeneous. The result of the independent sample t-test showed significant differences in the level of argumentation quality mean for the epistemic aspect (1, 2, and 3) between ADI and ADIS learning models. Whereas the mean of the argumentation quality level for the conceptual aspect (1 and 2) is not significantly different

between the ADI and ADIS classes. Based on the comparison results of the argumentative quality for the two categories, it is found that the conceptual aspect has a higher-level mean compared to the epistemic aspect, both for ADI and ADIS learning models (conceptual = 4.38; epistemic = 2.97). However, the ADIS learning model has a higher-level mean than the ADI learning models for the conceptual aspect (ADIS = 4.60; ADI = 4.15) and the epistemic aspect (ADIS = 3.60; ADI = 2.33). All the normality testing, homogeneity testing, and independent sample t-test results are presented in Table 3.

Table 3
Similarity test of the argumentation quality level means of the students between ADI and ADIS classes on conceptual and epistemic aspects

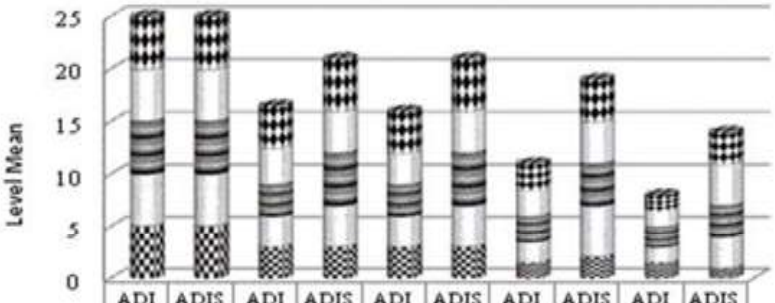
Aspects	Normality Testing[1)]		Homogeneity Testing[2)]		The Independent Sample T-Test[3)]		
	Mean ±Sd	Sig.	F	Sig.	t	df	Sig. (2-tailed)
Conceptual 1	5.00 ± 0.00	1.00	0.10	0.10	1.00	8	1.00
	5.00 ± 0.00	1.00					
Conceptual 2	3.30 ± 0.45	0.78	1.74	0.22	-2.12	8	0.07
	4.20 ± 0.84	0.52					
Epistemic 1	3.20 ± 0.45	1.06	1.97	0.19	-2.54	8	0.04
	2.40 ± 0.84	0.95					
Epistemic 2	2.20 ± 0.45	0.78	1.10	0.33	-3.02	8	0.02
	3.80 ± 1.10	0.83					
Epistemic 3	1.60 ± 0.22	1.06	2.75	0.14	-2.40	8	0.04
	2.80 ± 1.10	0.83					

Note: 1) = *Kolmogorof-Smienov* test (Normal: Sig. > 0.05); 2)= *Levene's* test (Homogeneous: Sig. > 0.05); 3)= *Independent sample T test* (Sig. difference < 0.05)

The students' argumentation quality concerning the epistemic aspect is at level 1 (0–20%) to level 5 (80–100%), while for the conceptual aspect, it is at level 4 (60–76%). The descriptor I illustrates the highest level, while V denotes the lowest level; the closer data is presented in Figure 2. From the graphic, the students in the ADIS class were able to reach level 5 for descriptor III in metabolism, organisms' interaction with the environment, and evolution materials, as well as level 5 for descriptor IV in reproduction material. It indicates that the students in the ADIS class have a higher ability to quote appropriate data to support claims and to write a logical explanation for a particular phenomenon compared to the students in the ADI class. It also identified another pattern—a significant improvement was found in the means for the argumentation quality level for the epistemic aspect in learning in the ADIS class, for descriptors II, IV, and V, and yet this is not found in the ADI class.

The findings of the study reveal that the implementation of scaffolding in an argument-driven inquiry (ADIS) model in a basic biology course is more effective in improving students' argumentation quality compared to an ADI model. It is believed that that standpoint, as the initial point in the development of argumentation and stages (initiation, development, and reinforcement), is effective as scaffolding for the students to improve their argumentation

Figure 2.
The argumentation quality level means on conceptual and epistemic



	ADI I	ADIS I	ADI II	ADIS II	ADI III	ADIS III	ADI IV	ADIS IV	ADI V	ADIS V
Organism's Interaction to Environment and Evolution	5	5	4	5	4	5	2,5	4	1,5	3
Mendel Law and Human Nature Inheritance	5	5	3,5	4	3	4	2,5	4	1,5	4
Metabolism	5	5	3	5	3	5	2,5	4	2	3
Living Things Reproduction	5	5	3	4	3	4	2	5	1,5	3
The Structure and Function of plantations and animals	5	5	3	3	3	3	1,5	2	1,5	1

quality. According to Eemeren, Grootendorst, and Henkemans, (2002, p. 167), a standpoint or starting point plays an important role in initiating a certain classical dialectic, especially in the practice of argumentation. Ferretti, Lewis, Andrews-Weckerly, (2002, p. 577), state that a standpoint is a functional element of argumentation. The ADIS model utilized a standpoint as an initial point of the development of argumentation-based topics given at each stage. In the initiation stage, the students are promoted to an argumentation discourse through an argumentative model which uses a directed claim so that it is easier for students to state a claim.

In the development stage, the students are given the chance to develop a group claim if it will support or refute the standpoint. In the reinforcement stage, the students can involve their individual by presenting it in a broader argumentation discourse. The result of the study shows that a standpoint can stimulate students to develop argumentation discourses. Regarding the standpoint, students are expected to develop their own claims and comp them with strong justification and backing. McNeill, Lizotte, Krajcik, and Marx (2004, p. 15) state that scaffolding that is used step by step during learning might facilitate students developing a scientific explanation that consists of claims, data or evidence, and reasoning.

Several retypes of research on argumentation in learning have been trying to develop students' argumentation skills through the implementation of scaffolding; some of these utilize online-based multimedia facilities. Clark and Sampson (2007, p. 253) used an online personally-seeded discussions program. The students used online facilities to develop principles to describe the obtained data. The students were placed in discussion groups consisting of members who had different principles so that each student could consider and criticize others' principles. This study showed the effectiveness of this program as the scaffolding of scientific argumentation in an online forum. Oh and Jonassen (2007, p. 95)

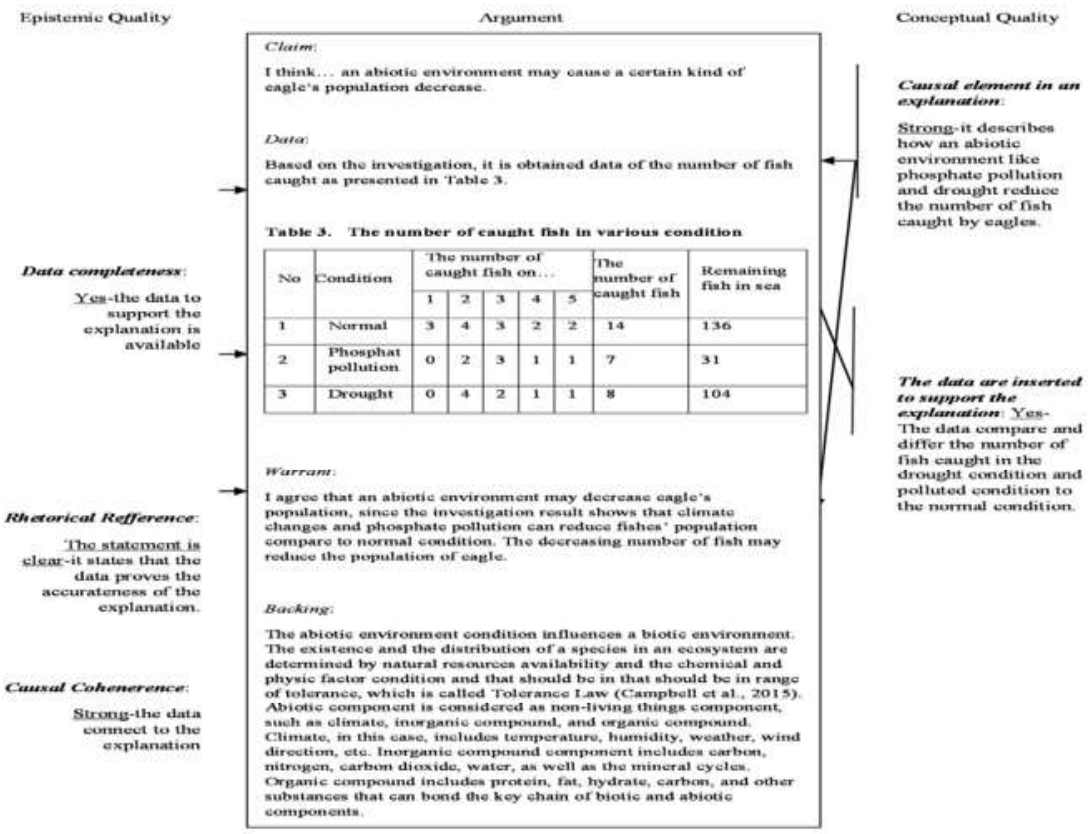
studied the implementation of argument scaffolding in an online forum which facilitates students developing coherent argumentations during the answering process. The result of the study showed that the argumentation scaffolding during an answer session in group discussion activities can improve the production of coherent argumentation. Related to the role of scaffolding in learning, Stone (1998, p. 344) argues that scaffolding might facilitate students reaching higher levels of comprehension in the proximal development zone. Scaffolding can adjust the learning so that it might be more appropriate for students by changing some complex and difficult assignments to become easier to access, manage, and suitable to the students' proximal development zone (Rogoff, 1990, p. 684; Hmelo-Silver, Duncan, & Chinn, 2007, p. 99). Concerning this study, scaffolding that is implemented in the ADI model might develop the students' argumentation skill step by step, so it is not temporary. Scaffolding is also adjusted from time to time and inconstantly in terms of its development in class, group, and individual levels by utilizing a standpoint that is in line with the given topic material. This way gives the students more responsibility for their learning. Furthermore, the stages of initiation, development, and reinforcement add some characteristics to scaffolding as a stage's direction to the students whenever they comprehend competence. Thus, through scaffolding, lecturers can obtain explanations and evidence of the students in understanding new knowledge. Students have an interest in building an understanding of scientific concepts related to the concepts taught by lecturers (Syuhendri, Andriani, & Saparini, 2019, p. 264).

The implementation of an ADI model without scaffolding in learning brings to light that the student's ability to organize data and justification backing (descriptor of epistemic aspect) is still low. The argumentation quality concerning the epistemic aspect, especially for descriptors IV and V, is at levels 1–2. It shows that the greatest difficulty faced by students in argumentation is developing data, justification, and backing especially when they must face other claims from the opposite groups. This is verified by the results of the analysis of the discussion transcriptions which reveal that very few students were able to provide appropriate data to guarantee their claims and provide a coherent causal explanation of a certain phenomenon, as well as to organize appropriate rhetorical references when expressing data. According to Roychoudhury (2007, p. 25) students often underestimate and ignore the evidence in reaffirming a misunderstanding. Students often do not use enough suitable evidence and evidence to justify the argument that they produce (Bell & Linn, 2000, p. 797).

The low level of argumentation quality, especially for descriptor V (epistemic aspect), shows that most students had trouble in organizing appropriate references to develop backing to support claims or counterclaims. From the analysis results of the discussion transcriptions, it is known that there are very few students who were able to develop backing based on references. An example of an argument presented in the students' argumentation scheme and based on the lecture transcriptions which were evaluated using Sandoval and Millwood's (2005, p. 23) framework is presented in Figure 3.

The researchers think that this argument is considered good due to both conceptual and epistemic aspects. The argument can explain a causal element that is needed to elucidate the claim. For example, in terms of support, the students use important and complete data from their investigation to support the ideas, provide supporting data, and provide sufficient data to guarantee the claim. Besides, the rhetorical references, which are used to connect the claim and the data, explain how data can support a claim. In terms of backing, the students

Figure 3
The example of students' argument which is evaluated with Sandoval and Millwood framework.



were able to use their understanding related to the interaction between biotic and abiotic factors which consists of the main principles of organisms' interactions with the environment based on a specific theory; the theory refers to Campbell, Mitchell, and Reece (2015, p. 122) statement related to tolerance law in an environment.

This study verifies Sandoval and Millwood's (2005, p. 33) study in terms of the importance of learning how to defend the students' claims. For example, Sandoval and Millwood analyze some senior high school students' arguments that show that many students were able to use their understanding of natural selection to provide an argument to explain a consistent natural phenomenon by using the main principles of natural selection. Yet, the students heavily depended on a part of the data in supporting a claim. As a result, the students often ignore other data from other sources to guarantee the claim.

According to Sampson and Clark (2008, p. 447), besides its focus on the data, Sandoval and Millwood's framework also evaluates the content. Sandoval et al's framework offers a certain strength to decide if a student can provide an argument that explains a certain phenomenon by using a certain theory, such as natural selection. Sandoval et al.'s framework evaluated the content of an argument in terms of the strength of the explanation in a particular

subject. As is stated by Sampson and Gerbino (2010, p. 427), the quality of a scientific argument depends on the subject (whether it is biology or physics), field (such as cellular biology or evolutionary biology), and place (such as biophysics, the structure of cellular biology, or the development of cellular biology).

CONCLUSION

Based on the above discussion, an ADIS model is inclined to have a higher potency in enhancing the achievement of students in terms of their quality of argumentation. It is believed that the ADIS model has appropriate learning stages needed by students so that it enhances their contribution for science teachers and lecturers to implement the ADI learning model with involve solving scaffolding in the classroom to develop the argumentation quality of the students.

Epistemically, there are significant differences in the level of argumentation quality means between ADI models and ADIS models. On the other hand, the mean of the argumentation quality of the student related to the conceptual aspect is higher than that of the epistemic aspect both in ADI and ADIS models. However, the level mean for the ADIS model is higher than that t of the ADI model in terms of the conceptual aspect.

The implementation of scaffolding in an ADI model framework shows that the students have a greater ability to quote data to support claims and to write a logical explanation of a particular phenomenon compared to the implementation of an ADI model without scaffolding. Besides, the implementation of scaffolding in an ADI model can improve the mean for the argumentation quality level for the epistemic aspect, especially for descriptors II, IV, and V, compared to the implementation of an ADI model without scaffolding. The improvement of the argumentation quality concerning the epistemic aspect shows that standpoints as initiate points in the development of the argumentation and stages (initiation, development, and reinforcement) are an effective means for students to develop their argumentation skills.

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