The contribution of argumentation and critical thinking skills on students' concept understanding in different learning models

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Keywords

Volume 17 | Issue 1

Article 6

2020

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Keywords

argument-driven inquiry, basic biology concepts, conventional

Introduction

Argumentation is an essential aspect of science education that promotes the learning of science content (Keirle & Morgan 2011; Zohar & Nemet 2002). Previous research indicates that students' ability to argue is limited by their specific content knowledge (Means & Voss 1996; Sadler & Fowler 2006). Even though an argument may seem to be based on reliable information, it is still possible to identify its flaws. Argumentation-skills analysis is a part of critical-thinking skills (Halpern 1998). Lai (2011) characterised the ability to identify the ambiguities in an argument as critical-thinking skills. Critical thinking is a way of thinking that has skill and disposition dimensions. The two main characteristics of those who tend to think critically are skepticism and didactic thinking (Yoram 2010). However, few studies discusses the linkage between argumentation skills, critical-thinking skills and the understanding of concepts.

Argumentation can provide a strong foundation for understanding a concept fully and correctly. C. Wu (2017) defines argumentation as the process of strengthening claims through critical-analysis thinking based on evidence and logical reasoning. Persuasive arguments use many relevant and specific justifications to support claims with accurate conceptual evidence. Conversely, weak arguments are indicated by unscientific, inaccurate, and non-specific considerations (Lazarou, Erduran & Sutherland 2017). The principle of logic is the primary tool in argumentation or argumentative discourse for changing the attitudes and opinions of others. The ability to convey information, experience, concepts, principles, or generalisations into discourse is determined by a person's ability with language and their ability to argue (Alqahtani 2016). A person's ability to argue can demonstrate his thinking ability. Therefore, as Kuhn (2012) argues, the use of scientific argument activity can strengthen conceptual understanding, allowing students to acquire new ideas that can broaden knowledge and eliminate misunderstandings. Furthermore, argumentation activities are necessary to develop students' reasoning, metacognitive, communication, and thinking skills, thus increasing their scientific literacy (Lazarou, Erduran & Sutherland 2017).

Science educators argue that arguments contribute to the development of students' critical thinking (Lazarou, Erduran & Sutherland 2017; Rayner & Papakonstantinou 2018). According to Steinberg and Freeley (1986), through argumentation, one tries to show that the statement is true by providing accurate facts as evidence. When they practice argumentation, students' critical thinking skills develop and eventually their rhetorical style becomes more varied. Moreover, Thomas (2011) states that providing critical-thinking exercises through the use dialogue in teaching encourages the development of critical-thinking skills.

Critical thinking skills are associated with high-level cognitive skills, such as analysing, synthesising, and evaluating (Keshta & Seif 2013). Furthermore, learning to think critically is learning about the act of thinking itself. It concerns not the "what" but the "how" of the matter, along with how to accept, judge, weigh and decide something; how one thinks to get the most understanding and meaning (Willingham 2007). Jacob (2012) revealed a significant relationship between critical-thinking skills and conceptual understanding. Students who are skilled in critical thinking have higher cognitive learning outcomes than those who are not, and critical thinking has a significant influence on academic success (Wiles, Allen & Butler 2016). Kadayifci, Atasoy and Akkus (2012) in their study of a chemistry class concluded that there was a close relationship between students' skills (or lack thereof) in arguing with the level of their critical-thinking skills. The learning environment should support students' acquisition of critical-thinking skills as a tool that students use to construct their understanding (Grabinger & Dunlap 2012).

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A number of studies have examined the correlation between understanding concepts and both argumentation skills and critical-thinking skills. The research of Sadler and Fowler (2006) reveals that there is a reciprocal and positive relationship between the process of argumentation, particularly where the arguments are linked to real-world problems and contexts, and students' understanding of concepts. Dawson and Venville (2009) found that those students who received training in argumentation increased their argument skills.

Several studies have shown that argumentation skills, critical-thinking skills, and understanding of concepts can be improved through the application of specific learning models. Demircioğlu and Uçar (2012) found that Argument-Driven Inquiry (ADI) learning models can significantly improve the quality of student arguments. Similarly, Sampson, Grooms and Walker (2011) suggest that ADI affects the way students participate in scientific argumentation: they become more disciplined and produce better quality arguments, especially in written form. Similarly, Nurramadhani, Ms and Rahman (2017) found that the implementation of ADI had a significant impact on students' oral and written arguments. Sampson and Gerbino (2010) found that ADI learning models might improve students' cognitive learning outcomes; in their study, students improved their understanding of concepts of biology. Demircioglu and Ucar (2015) showed that students in a class covering gas concepts who were taught using the ADI instructional model had statistically significant higher scores than a control group.

The ADI model has the potential to improve argumentation skills and develops students' critical-thinking skills particularly when appropriately scaffolded. The results of this study can provide information to educators about how an appropriate learning model focuses on improving the understanding of concepts as well as students' argumentation and critical-thinking skills.

Materials and methods

Research model and research design

This correlational study was conducted to uncover the contribution of argumentation and critical-thinking skills to students' understanding of basic biology concepts in different learning models in the Faculty of Teacher Training and Education, University of Lampung, Indonesia. In this study, argumentation and critical-thinking skills were positioned as predictors, and understanding of concepts was positioned as a criterium. The scope of this study was to determine the effect of the students' argumentation skills, as measured by the Toulmin Argumentation Pattern (TAP) prepared by Osborne et al. (2001), and their critical-thinking skills on students' understanding of concepts. The learning strategies were ADI learning model and conventional model. This study was conducted for a semester in 2015.

Research sample

A total of 120 first-year pre-service teachers who studied in the Mathematics and Science Education Department, University of Lampung, Indonesia, were randomly selected to participate in this study, which examined two basic science courses taught by different methods: conventional teaching and the ADI learning model. The sample consisted of two classes: biology education and chemistry education. First, the classes were tested using a placement test that consisted of multiple-choice questions on the senior high school level related to biological materials. These data were analysed using analysis of variance (ANOVA) with SPSS 21.0 for Windows. The instrument of placement test was validated by expert and empirical validation.

Research instrument and procedure

The students' argumentation skills were measured using an essay test consisting of eight questions. The argumentation test was developed based on the competing theories models by Osborne e colab. (2004). The scoring rubric of argumentation skill was adapted from the Toulmin Argumentation Pattern (TAP) based on the Osborne e colab. (2004) framework, as presented in Table 1.

Table 1. Scoring of argumentation skills based on TAP

Score	Criterion
5	Argumentation consists of arguments that are simple claims versus counterclaims or a claim versus a claim.
4	Argumentation has arguments consisting of a claim versus a claim with either data, warrants, or backings but does not contain any rebuttals.
3	Argumentation has arguments with a series of claims or counterclaims with either data, warrants, or backings with the occasional weak rebuttal.
2	Argumentation shows arguments with a claim with a identifiable rebuttal. An argument may have several claims and counterclaims as well.
1	Argumentation displays an extended argument with more than one rebuttal.

Source: Osborne et al., (2001).

The students' critical-thinking skills in providing elementary clarification, constructing basic support, inferring, providing advanced clarification and organising models and tactics (Ennis, 2011) as well as their understanding of basic biology concepts were evaluated using essay tests. The essay test was developed based on the basic biology competence for a pre-service science teacher regarding the concepts of the structure and function of plants and animals, reproduction of living things, metabolism, Mendel's laws and human inheritance, organisms' interaction with the environment, and evolution. The essay tests were given at the beginning of the study (pre-test) and at the end (post-test).
The instruments used were validated beforehand by expert and empirical validation using the Cronbach's Alpha with a cutoff of 0.7 based on the Nunnally (1978) reliability criteria. Expert validation consisted of content and constructed validity. Content validity is the accuracy of an instrument regarding the content of the instruments, estimated by the curriculum. Construct validity is related to construction or the science concept to be tested, and refers to the appropriateness of the results of the measuring instrument relative to the ability to be measured. Empirical validity was conducted on 61 second-year students of the Mathematics and Science Education Department, University of Lampung, Indonesia. The reliability of the essay test was also examined. Reliability refers to the degree of test scores that are free from measurement error, and is expressed as an index that indicates the extent to which a measuring instrument is trustworthy or reliable.

Data analysis

The data of this study consists of measurements of students' argumentation skills, critical-thinking skills and understanding of basic biology concepts as collected in the pretest and post-test scores using the essay test. All the test items fulfilled the validity. The result of the reliability test showed that the items employed in the essay test had high reliability indices: 0.690 for the argumentation

test, 0.773 for the critical thinking test and 0.832 for the concept-understanding test. The argumentation test was still used even though its validity was below the cutoff, as it was exclusively used in this study setting (Zimbardo and Boyd, 1999). The data of the study were analysed by using multiple regression analysis to examine the correlation between the predictor and the criterium using SPSS 21.0 for Windows.

Result

Argument-Driven Inquiry (ADI) learning model

Tables 2 and 3 summarise the regression analysis of the correlation between students' argumentation and critical-thinking skills on their understanding of basic biology concepts related to the implementation of the ADI model. The results of variance analysis of the correlation between students' argumentation and critical thinking skills on their understanding of basic biology concepts within ADI models showed high significance (sig = 0.000), indicating that the relationship was solid. It wasalso demonstrated by the multiple regression equation: $Y = -4.017 + 0.014X1 + 1.120X2$.

Table 2. Regression coefficient of the correlation between students' argumentation and critical-thinking skills on their understanding of basic biology concepts within ADI models

	Coefficients				
Model	Unstandardised Coefficients		Standardised Coefficients	Sig.	
		Std. Error	Beta		
(Constant)	-4.017	3.873		-1.037	0.304
ADI Argumentation Skills (X1)	0.014	0.025	0.025	0.544	0.588
ADI Critical-Thinking Skills (X2)	1.120	0.054	0.937	20.645	0.000

The correlation (R) between students' argumentation and critical-thinking skills and their understanding of basic biology concepts within the ADI model was significant. The value of R was 0.941 and the R square was 0.886. In brief, the effective contribution of students' argumentation and critical-thinking skills on their understanding of concepts was about 88.6%. Besides the argumentation and critical-thinking skills, the changes in the students' understanding of concepts were also influenced by other undetected factors by about 11.4%. The argumentation-skill parameter provided an effective contribution by as much as 0.6%, while the critical-thinking skill parameter provided an effective contribution of about 88% to students' concept understanding (Table 3).

Table 3. Contribution of students' argumentation and critical-thinking skills on students' understanding of basic biology concepts within ADI models

Variable	RC(%)	EC(%)
X1 (Argumentation Skills)—Y (Concept Understanding)	0.67	0.6
X2 (Critical-Thinking Skills)—Y (Concept Understanding)	99.3	88
X1 (Argumentation Skills) & X2 (Critical-Thinking Skills)—Y (Concept Understanding)	100.00	88.6

Conventional model

Tables 4 and 5 summarise the regression analysis of the correlation between the effects of both argumentation and critical-thinking skills on students' understanding of basic biology concepts related to the implementation of the conventional model. According to the conventional model, the results of variance analysis are highly significant (sig = 0.000). It indicated that the relationship between students' argumentation and critical thinking skills on their understanding of basic biology concepts is solid. It was demonstrated by the multiple regression equation, such as Y = -0.360 + 0.077 X1 + 0.981 X2.

Table 4. Regression coefficient of the correlation between students' argumentation and critical-thinking skills on their understanding of basic biology concepts within ADI models

Model	Coefficients				
	Unstandardised Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-0.360	4.288		-0.084	0.933
Conventional-Argumentation Skills (X1)	0.077	0.049	0.093	1.579	0.120
Conventional-Critical-Thinking Skills (X2)	0.981	0.066	0.874	14.860	0.000

The correlation (R) score between students' argumentation and critical-thinking skills on their understanding of basic biology concepts within the conventional model was 0.904, and the R square was 0.817. This suggests that the effective contribution of students' argumentation and critical-thinking skills to their understanding of basic biology concepts was 81.7%. However, besides argumentation and critical-thinking skills, the changes in the students' understanding of basic biology concepts were also influenced by other undetected factors by about 18.3%. Table 5 shows that the argumentation-skill parameter provided an effective contribution by as much as 0.8%, while the critical-thinking skill parameter provided an effective contribution by as much as 80.9% to students' understanding of basic biology concepts.

Table 5. Contribution of between students' argumentation and critical-thinking skills on their understanding of basic biology concepts within ADI models

Variable	RC(%)	EC(%)
X1 (Argumentation Skills)—Y (Concept Understanding)	0.98	0.80
X2 (Critical-Thinking Skills)—Y (Concept Understanding)	99.02	80.9

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X1 (Argumentation Skills) & X2 (Critical-Thinking Skills)— Y (Concept Understanding)	100.00	81.7

Discussions

The present study shows that there students' argumentation skills and critical-thinking skills strongly contributed to their understanding of basic biology concepts in both the ADI (88.6%) and conventional (81.7%) learning models. Also, the improvement of students' argumentation skills was associated with significant conceptual understanding. A correlational study by Park (2016) suggests that there is a correlation between the quality of students' arguments and their understanding of concepts. In this study, Riemier et al. concluded that the higher quality of student arguments was positively related to their level of structural and conceptual understanding. Dawson and Venville (2009) verified that students who participate in argumentation training increase their argumentation skills.

The variables argumentation skills and understanding of basic biology concepts are interrelated. Sadler and Fowler (2006) examined whether and how students use scientific content knowledge as they create and justify claims relative to contexts centered on biotechnology and society. Science content knowledge can affect the manner in which individuals defend and justify their positions. Students who engage in arguments that are relevant to the real world may increase their conceptual understanding. Therefore, conceptual understanding is essential for students to develop high-quality arguments.

The results also revealed that critical-thinking skills made a very large contribution to students' understanding of concepts. It was observed that an increase in students' critical-thinking skills also increased their understanding of basic biology concepts. This is reinforced by the findings of Frijters, ten Dam and Rijlaarsdam (2008), that the provision of critical-thinking exercises through effective dialogue-based teaching encourages the development of critical-thinking skills, to enhance students' subject-matter knowledge of biology. We agree with Halpern (1998), who points out that critical thinking as cognitive skills and models can improve desired learning outcomes. Critical thinking is purposeful, reasoned, and goal-directed because it involves solving problems, formulating inferences, calculating likelihoods, and making decisions. When people think critically, they evaluate the outcomes of their thought processes and how good a decision is or how well issues are solved.

The two variables of argumentation skills and critical-thinking are interrelated. A correlational study by Kadayifci, Atasoy and Akkus (2012) examined the correlation between students' critical and creative-thinking abilities and their argumentation skills. They examined the number of flaws students identified in an argument related to Boyle's Law as well as their scores on critical thinking. The number of flaws students produced and the quality of their opposing arguments were positively related to how they supported the claims with valid and relevant information. Behrooznia, Hashemi and Mahjoobi (2014) verified that critical-thinking skills were positively correlated with argumentation skills. The ability to think critically can be developed through students' involvement in tasks that require argumentation skills.

Related to ADI and conventional learning models, it appears that there is a strong correlation between predictors simultaneous to the criteria found in ADI models compared to conventional learning models. It may be that students studying using ADI learning models constructed their

knowledge through active involvement in inquiry, argumentation, writing and reviewing so that they could understand concepts, improve critical thinking and argue actively. Arguments displayed high structural and conceptual quality when students were able to use everyday experiences or specific experiences during learning sequences (Park 2016). Zohar and Nemet (2002), Thomas (2011) and Sampson and Gerbino (2010) verified that argument-based learning is crucial to developing students' argumentative skills and habits to build and support their scientific claims through arguments and to evaluate or compare them to the statements or arguments of others.

The results also show the contribution of both predictor argumentation and critical-thinking skills on students' understanding of basic biology. In the two learning models, the contribution of argumentation skills was smaller than that of critical-thinking skills. It may be that the argumentation skills of the Indonesian population cannot be used as a predictor of concept understanding. In other words, a new understanding of concepts does not necessarily appear in the argument directly, but arguments support the improvement of student thinking and help them discover aspects that may be new to them. According to Zhou (2010), arguments may not encourage students to gain a scientific understanding, but may encourage them to learn and use their existing scientific understanding, whereas critical thinking is seen as a factor that strongly influences students' final understanding of concepts other than metacognition, because learning to think critically is learning about the way of thinking itself (Willingham 2007).

The results also show a very strong contribution of critical thinking to students' understanding of basic biology concepts. They prove that the improvement of critical thinking increases students' competency in providing elementary clarification, constructing basic support, inferring, providing advanced clarification and organising models and tactics. The competency as a whole is a high-order thinking-skills parameter. Seker and Kömür's (2008) study of the correlation between students' concept understanding and critical thinking found a significant relationship between understanding of concepts and critical-thinking skills. Learners who think critically have better cognitive learning outcomes than those who do not (Jacob 2012). The results of the current study indicate that increases in students' critical thinking leads to increases of basic biology concept understanding and cognitive learning outcomes.

Furthermore, the low contribution of argumentation skills to students' understanding of basic biology concepts shown in this study might be caused by the use of an inappropriate measurement instrument for argumentation skills. In this study, students' argumentation skills were only measured using an essay test that they completed themselves. Golfashani (2003) explained that related to an education study, data was generally obtained using a set of instruments addressed to the students; thus when there was an intervention during the data-collection process, the data obtained might also be different from the real condition. This supports the findings of previous studies, such as those conducted by Kuhn (2012), although much of the previous research focuses on only one aspect of argumentation skills, such as written argumentation skills or oral argumentation. Therefore, a more comprehensive model for assessing argumentation is needed.

The higher contribution of critical-thinking skills to students' understanding of basic biology concepts compared to the contribution of argumentation skills might also be caused by the administration of critical-thinking skills measurement integrated into the measurement of students' understanding of concepts carried out by the essay test. This finding is in line with those of Seker and Kömür (2008), who reported that the critical-thinking skills variable had a large contribution to students' understanding of concepts measured using an essay test. This suggests that the administration of the essay test tends to be more accurate for measuring critical-thinking skills.

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Kusuma et al. (2017) state that the essay test is very highly appropriate for measuring learners' higher-order thinking skills. Barnett and Francis (2012) added that higher-order thinking questions could encourage students to think deeply about the subject matter.

Based on the findings of this study the researchers realized that the test used was an inaccurate measure for assessing argumentation skills. It would require a teacher's creativity to design another measurement tool capable of accurately recording the argumentation-skill variable. Therefore, one possible form of measurement is the Argumentative Assessment by Standpoint, Scaffolding, and Coding (AASSC) model. Kuhn (2012) stated that the AASSC model assessment could act as a performance assessment and is also part of the assessment for learning. This model has the criteria that is a standpoint, the coding system, and scaffolding. The students' argumentation skills, as measured using the AASSC model, showed good progress in the discourse of written argumentation and oral argumentation.

Conclusion

The main purpose of this study was to explore the correlation between students' understanding of concepts and both argumentation skills and critical-thinking skills through the argument-driven learning model. Moreover, we sought to identify the contribution of each factor. The major finding of the study was that the correlation between students' understanding of basic biology concepts and both their argumentation and critical thinking skills is very high (RADI = 0.886; RConventional= 0.817). Moreover, the contribution of students' argumentation skills to their understanding of basic biology concepts (ADI = 0.6%; Conventional = 0.8%) was lower than the contribution of their critical-thinking skills (ADI = 88%; Conventional = 80.9%. It can be concluded that students in the ADI group and the conventional group experienced the development of critical-thinking skills to the same extent. Therefore, in addition to the use of appropriate measuring instruments, teachers also need to implement an appropriate learning model.

The existence of a positive relationship between critical thinking and argumentation skills in improving students' understanding of basic biology concepts is inseparable from the effective use of learning models.   , The steps of the ADI learning model can be used to help students develop their intellectual potential, understanding of concepts, and critical-thinking skills at a higher level in the real world. The learning scenarios in the ADI model include the activities of designing and carrying out investigations, arguing, writing and reviewing. In inquiry activities, students work in collaborative groups to develop, apply methods (for example: systematic experimentation or observation) and answer the research problems. The argumentation activity begins with students compiling the written arguments consisting of explanations supported by evidence, and the reasons for the choice of evidence in the media such as blackboards, then discussed together. Then, groups of students are given the opportunity to share their arguments with the other groups and criticise other people's work to determine the most valid or acceptable explanation. The target writing activity is the creation of an investigative report written by individual students. Reports describe the purpose of the investigation, the methods used, and good and reasoned arguments. The reviewing activity is conducted by students to assess quality and produce valuable feedback for them. Furthermore, the revision of the investigation report based on the review results is a step to improve the writing skills, argumentation skills, and understanding of student material. The series of learning activities with ADI is a means of training students' critical-thinking skills. Therefore, the use of the ADI model can enable students to improve their critical-thinking skills while increasing cognitive learning outcomes and understanding concepts.

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The learning model should not only be focused on students' understanding of concepts, but also be able to enhance students' critical-thinking skills and argumentation activities. Both are significant predictors of learning. The lecturers should consider how to support students' argumentation and critical-thinking skills, which are significant predictors of successful learning in the 21st century, through the application of appropriate learning models. This is because the argumentation and critical thinking skills.

However, there are certain inevitable limitations in this study. First, the study was conducted with a small population; therefore, the generalisability of the findings is limited. To generalise the results of the study, it would be useful to conduct the study with large groups. Second, the study was conducted for six months, which may be a short time to observe improvements in students' ability to construct arguments. Other researchers conducted longer studies that included more argumentation activities. Last, the study was conducted by the author herself, who is very experienced in argumentation, potentially adding a certain degree of subjectivity. Further studies may consider conducting this type of experimental research with in-service teachers and bigger populations over long periods of time.

Acknowledgements

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