Students’ mathematical argumentation ability in determining arguments or not arguments

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Abstract. Someone who has critical thinking ability can use the exact criteria to evaluate an argument. This engages critical thinking to determine whether a claim or an argument which has been given is correct or not and whether the sentence which has been given is included an argument or not. To determine it, there must be clear evidence and logic explanation. The aim of this study is to investigate the argument in critical thinking ability. The students are asked to determine whether the information which has been given by the researcher is included an argument or not and give the reason. The information that is given by the researcher is in the form of triangle congruent evidence. The subject is the students in mathematics education who consist two people with criteria moderate (female student) and high academic ability (male student). This study is descriptive qualitative research. This result study was the student who had high academic ability was still not able to analyze more detail about an argument so he was called he did not have critical thinking ability. While the student who had moderate academic ability had been able to analyze that the information which was given was included an argument or not and was able to justify it so it could be concluded that she had critical thinking ability. It could decipherable that the student who had high academic ability was not sure understood about an argument.

1. Introduction
In general, critical thinking ability is occupied as important skill and one of major aims in highr education [1]. Critical thinking ability is being higher priority than algorithmic cognitive ability. The current reform of mathematics education in the worlds cover transition from algorithmic cognitive ability to higher cognitive ability, is critical thinking ability [2, 3]. Ennis defines that critical thinking as “reflective thoughts which is logic and focus on decision-making what has to be believed or what has to be done” [4, 5]. Ennis [5] divides critical thinking into two parts; they are critical thinking ability and critical thinking disposition. Critical thinking disposition relates to decision-making whether someone has to do an action which is asked/commanded or not. Critical thinking ability relates to decision-making whether someone has to be believed or not towards an argument. Ennis [4] claims that the people who have critical thinking ability can evaluate its accuracy and reliability various arguments. It is also found by the prior study that evaluation is important part of critical thinking that engages a serial cognitive process which is addressed to know a problem, select a plan of solution, and evaluate. It means that the people who have critical thinking ability can use the exact criteria to evaluate an argument.

In the research, it shows that the students still get difficulties to decide a claim/ an argument and confirm evidence towards a claim/an argument that has been given to them [6, 7, 8]. Baker & Weber
emphasize the importance of improving the ability to analyze an argument about information because an argument can influence someone in decision-making [9]. Because of that, it is needed students’ critical thinking in analyzing information in order not to be misleading. Next, confirming evidence is an important aspect in explaining a reason towards a claim/ an argument [10].

Moon states argument is a core process in critical thinking [6]. Therefore, evaluating argument about information is an important tool that must be developed to rate the students’ critical thinking ability [11]. The students who are able to check and rate an argument/a claim are supporting evidence that they have critical thinking ability. Critical thinking ability can push the students to think independently and solve the problem in daily life context [12]. As’ari said that someone is called having critical thinking ability is the person can determine whether the sentence which has been given is a claim/ an argument or not [7, 8]. Someone who has critical thinking ability must be able to evaluate the information from various information sources. It also involves critical thinking to determine whether a claim/ an argument that has been given correct or wrong [13].

An argument is core component of critical thinking that covers ability to build its argument, approve or no with a claim towards the information that has been listened to [14, 15, 16]. Someone who has critical thinking ability must be able to determine an argument from information that has been given to him/her. It involves critical thinking and skill in determining whether a claim/ an argument that has been given correct or wrong. The students must justify their arguments accompanied by supporting evidences or to argue the argument with contrast examples or un-supporting facts.

Based on the explanation above, the students’ ability in determining arguments are important indicators for the students who think critically. It will be done a study to know how the students’ ability of private colleges in Pasuruan in determining an argument. Particularly, the research problem in this study cover: 1) how do the students use critical thinking ability to know whether the information that has been given is an argument or not?, 2) how do the students justify an argument or not?

2. Method
This study is a descriptive qualitative research. The research subject is the students in mathematical education program in one of private colleges in Pasuruan in force of 2015 that consist of 2 students who are chosen by using purposive sampling technique. The research subjects are taken as respondent and selected based on high and moderate abilities category. The gender for high ability is male student and moderate ability is female student. The instrument that is used is a critical thinking ability test about triangle that is made in the form of evidence matter which refers to critical thinking ability indicator, namely claim/ argument identification.

Interview was done in semi-structures with the questions which focus on how they use their critical thinking ability to know whether the information that has been given by the researcher is an argument or not. Interview is done for 20-30 minutes. The interview result is recorded then it will be transcribed and given code.

3. Result and Discussion
Argument that is intended for in this research is a group of questions which have cause effect relation or in other words the sentence that consist of some statements and conclusions. In this research it aims to investigate about argument in the students’ critical thinking ability. Those need suitable critical thinking that the students who are able to check and asses an argument/ a claim are supporting evidence that they have critical thinking ability. Someone who knows that a sentence/ information which is given to him/her is an argument/ a claim or not is one of indicators of the one who has critical thinking ability [7, 8].
Based on the data analyses of the result and interview to two students, namely subject 1 (S1) and subject 2 (S2) about argument in mathematical critical thinking ability. The study result showed that the student who had high ability in academic was still less critical in interpreting the sentence which had been given by the researcher. For example, for number 1 the subject 1 really answered that the sentence that had been given by the researcher was an argument (see Figure 1), but after being confirmed through interview he was still hesitant whether it was an argument or not. In the beginning he answered an argument, but at the edges after the researcher asked more detail he said that it was not an argument. Figure 1 and Figure 2 was the test result of subject 1 (S1).

From the conversation above, subject 1 had linked to the material content, with the side axiom, the side, the side. Based on the material content, he had understood the material. He also had been able to mention whether the argument valid or not. But he did not link the argument’s validity when it was seen from legal ponen mode, Tollens mode and etc.

The following is the interview result between the researcher and subject 1 (S1)

R : for number 1 you answered an argument. Why?
S1 : because $\overline{AB} = \overline{CD}$, $\overline{AD} = \overline{BC}$, $\overline{AC} = \overline{AC}$ (coincide) so it met side axioms, side, side so $\Delta ABC \cong \Delta CDA$.

R : if one did not fulfill the axiom, for example there was no $\overline{AB} = \overline{CD}$ were you still called it an argument?
S1 : an argument was the form if p, so q, if the p was true, the q was false it meant that the conclusion was false.

R : what did it mean?
S1 : it was true argument but the conclusion was not valid.

From the conversation above, subject 1 had linked to the material content, with the side axiom, the side, the side. Based on the material content, he had understood the material. He also had been able to mention whether the argument valid or not. But he did not link the argument’s validity when it was seen from legal ponen mode, Tollens mode and etc.
S1: there were premises $AB = CD$ as $p$, $AD = BC$ as $q$, $AC = AC$ as $r$. The conclusion $\Delta ABC \cong \Delta CDA$ was as $s$.

The conversation above showed that subject 1 had been able to understand that the argument consisted of some premises and conclusion and was able to mention premises and the conclusion based on the information which had been given by the researcher. But after being traced more detail about the knowledge of argument that he had, he did not distinguished between argument and non-argument. From the conversation between them as if between argument and non-argument were no differences. That was conversation that showed the situation above.

R : how about number 4, why did you answer non-argument?
S1: (keeping silent while thinking) … if the argument in taking the conclusion directly if for number 4 it used logic concept if $p \land q \land r$ so $s$.
R : what did you mean by “directly”?
S1: it meant that if the first and second questions were fulfilled.
R : could you give the example?
S1 : if $AB = CD$, $AD = BC$, $AC = AC$ so $\Delta ABC \cong \Delta CDA$
R : if $p \land q \land r$ so $s$ what did it mean?
S1: if $p$ was $\angle BAC = \angle DCA$, and $q$ was $\overline{AC} = \overline{AC}$ and $r$ was $\angle ACB = \angle CAD$ so $s$ was $\Delta ABC \cong \Delta CDA$
R : so what did it refer between argument and non-argument?
S1 : in my opinion if non-argument could be stated with logic if $p$ so $q$.
R : what did it differ between argument and non-argument?
S1: if the form argument was like number 1 and non-argument was like number 4.
R : was argument that had premise and conclusion?
S1 : there was…
R : where were premises and conclusion?
S1 : premises were $\angle BAC = \angle DCA$, $\overline{AC} = \overline{AC}$ and $\angle ACB = \angle CAD$. The conclusion was $\Delta ABC \cong \Delta CDA$
R : it meant that either argument or non-argument was same had premises and conclusion didn’t it?
S1 : yes …
R : then what was the difference?
S1 : the form argument was like number 1 while non-argument was like number 4…

From test result and interview that were done by the researcher to the subjects 1 showed that subject 1 was less critical in understanding the argument. It was because the student was less understanding about argument. When it was given the information subject 1 still could not mention that the sentence which was given included to argument or not.

Figure 3. Argument (S2)

The following is the test result and interview toward subject 2 (S2), this subject had moderate academic ability. For number 1 subject 2 answered an argument and the answer which was given according to the researcher was correct. It would be displayed the test result of subject 2 about argument in critical thinking ability below. The test result of subject 2 (S2).
The following is the interview result of subject 2 (S2) about argument

R  : for number 1 you answered an argument. Why?
S2  : the argument loaded conclusion, in here there was statement 1 and statement 2 and both statements could be concluded.
R  : which one were the statements?
S2  : if \( \overline{AB} = \overline{CD} \), \( \overline{AD} = \overline{BC} \), \( \overline{AC} = \overline{BD} \) so \( \Delta ABC \cong \Delta CDA \) these were statement 1 \( \overline{AB} = \overline{CD} \), \( \overline{AD} = \overline{BC} \), \( \overline{AC} = \overline{BD} \) these were statement 2 so \( \Delta ABC \cong \Delta CDA \) was the conclusion
R  : did the argument have to load statement and conclusion?
S2  : yes ma’am, for example there was not conclusion it meant that it was not argument.
R  : was the statement same with premise? and then the conclusion?
S2  : in my opinion they were same
R  : could you be explained what premise/statement was?
S2  : premise was …. (while thinking). I did not defined it ma’am, but the example was like number 1 if \( \overline{AB} = \overline{CD} \), \( \overline{AD} = \overline{BC} \), \( \overline{AC} = \overline{BD} \) so \( \Delta ABC \cong \Delta CDA \)
R  : how about conclusion?
S2  : based on the conclusion was taken from some premises/statements then gave the conclusion

From the conversation above subject 2 had been able to understand that the argument had to load a collection of premises and conclusion. If there was not conclusion according to subject 1 it was not an argument. Subject 2 also had been able to mention each premises and the conclusion. The following was the interview result of subject 2 (S2) about non-argument.

R  : for number 4 why did you answer non-argument?
S2  : for number 4 meant that there was certainty ma’am
R  : what kind of certainty did you mean?
S2  : if the statement was using if so meant that there was something determinable for example if \( \angle BAC = \angle DCA \), \( \overline{AC} = \overline{BD} \) so \( \angle ACB = \angle CAD \) so \( \Delta ABC \cong \Delta CDA \). From the statement that had been determinable if this so it had to be this (while pointing question number 4). So there was not any conclusion.
R  : what was an argument in general?
S2  : there was a collection of statements in which from them could be taken a conclusion
R  : how about non-argument?
S2  : it was only a collection of premises without any conclusion

The conversation above showed that the subject 2 classified into someone who had critical thinking ability, it was shown when doing the interview in detail about argument. She could determine whether the argument or not and give clarification the characteristics of argument had to load premises and conclusion while non-argument only loaded premises without conclusion. But she did not link the valid and not valid arguments. She only explained argument and argument; she did not go into the content in detail about the valid and not valid arguments.

Based on the test result and interview result above, there was finding on subject who had high academic ability, in reality he was not able to analyze on information that was given was argument or not. It was contrast with the opinion of Sadler & Fowler [17] that the student with high academic ability can surpass the other students in making justification toward argument. Proved that subject 1 really had high academic ability, but he could not able to analyze the information that was given to him was argument or non-argument. While the student who had moderate academic ability was able to
analyze the information and mention that the information that was given was argument or not and she could give the reason/clarification what it was called argument and non-argument.

Someone who was not able to distinguish whether the information was argument or not that was given to him/her it meant that the person did have critical thinking ability. As it was said by As’ari [7] that if someone is not able to decide whether an information that has been given to him/her is claim/argument or not, or the person cannot distinguish which one premise and the conclusion in an argument, he/she is far from being said having critical thinking ability. The person tends not to have critical thinking ability. It occurred on subject 1.

Students who are able to check and assess an argument/claim, identify and evaluate an argument, and can give supporting evidence, so they do important part of critical thinking. It also occurred on subject 2, she checked and assessed whether the information has been given is argument or not, besides that she also could give opinion why it was called argument or not so she had been able to be concluded that she involved in critical thinking and had critical thinking ability.

The result of the study showed that the student who had high academic ability was not necessarily able to decide argument toward the information that was given to him. Evaluating argument toward the available information is the important equipment to assess the students’ critical thinking ability especially the argument knowledge. It is really needed in order to the students are able to filter the information carefully and not stuck from argument/claim that is said by someone. Critical thinking ability is needed for the students to be successful in the future. Because of that, critical thinking ability has to be applied and developed in core curriculum and teaching and learning process to produce the students who have thinking quality of leadership in the future. Because of that, it is really important to develop skill of students’ critical thinking in all lessons, especially mathematics. Mathematics learning does not only teach the mathematics content.

4. Conclusion
The student who had high academic ability could not able to analyze argument. It could be seen when the researcher gave an information he still could not decide whether the information that had been given was argument or not so it could be said that he did not have critical thinking ability. While the student who had moderate academic ability could decide whether the information had been given by the researcher was argument or not, so she could be said she had critical thinking ability. The student who had high academic ability could not justify or give the reason appropriately why it was called argument or not. While the students who had moderate academic ability, she can and is able to explain and justify about argument or non-argument.

For further study is recommended in order to the researchers investigate more detail about critical thinking by using another indicator, for example by using inferential indicator, other point of view or another critical thinking ability indicator in order to be able to know whether the students classify into high, moderate or low critical thinking ability..

5. Acknowledgments
The researchers would like to express their gratitude to the Indonesian Endowment Fund for Education (LPDP), the Graduate Program of Mathematics Education at The State University of Malang, and STKIP PGRI Pasuruan.

6. References
[1] Douglas E P 2012 Defining and Measuring Critical Thinking in Engineering 56 153–9
[2] Aizikovitsh E and Amit M 2010 Evaluating an infusion approach to the teaching of critical thinking skills through mathematics Procedia - Soc. Behav. Sci. 2 3818–22
[3] Science E 2019 The ability of high school students ’ critical thinking in solving trigonometric problems T he ability of high school students ’ critical thinking in solving trigonometric problems
[4] Ennis R H 1981 Critical Thinking and Subject Specificity : Clarification and Needed Research
[5] Ennis R H 2011 The Nature of Critical Thinking : An Outline of Critical Thinking Dispositions Univ. Illinois 1–8
[6] Moon J Critical Thinking: An Exploration of Theory and Practice  
[7] As’ari A R and Irawan E B 2016 VARIASI KONSTRUK DALAM PEMBELAJARAN MATEMATIKA  
[8] Indrawatiningsih N 2018 Arguments in Critical Thinking Ability 218 12–5  
[9] Norris S P, Phillips L M, Smith M L, Sandra M, Stange D M, Baker J J, Weber A C and Al N E T 2008 Learning to Read Scientific Text : Do Elementary School Commercial Reading Programs Help?  
[10] Ford M 2008 Disciplinary Authority and Accountability in Scientific Practice and Learning  
[11] Lubben F, Sadeck M, Scholtz Z, Braund M, Lubben F, Sadeck M and Scholtz Z Gauging Students’ Untutored Ability in Argumentation about Experimental Data : A South African case study Gauging Students’ Untutored Ability in Argumentation about Experimental Data : A South African case study 37–41  
[12] Jacob S M 2012 Mathematical achievement and critical thinking skills in asynchronous discussion forums Procedia - Soc. Behav. Sci. 31 800–4  
[13] Lin S 2013 Science and non-science undergraduate students’ critical thinking and argumentation performance in reading a science news report  
[14] Nussbaum E M and Edwards O V. 2011 Critical questions and argument stratagems: A framework for enhancing and analyzing students’ reasoning practices J. Learn. Sci. 20 443–88  
[15] Chen Y, Lin J, Chen Y and Chen Y 2014 Science Activities : Classroom Projects and Curriculum Students in Argument : Using Density as an Example Teaching Scient fi c Core Ideas through Immersing Students in Argument : Using Density as an Example 37–41  
[16] Osborne J, Jim M P and Kuhn D 2010 Teaching and Learning Science as Argument  
[17] Sadler T D and Fowler S R 2006 A threshold model of content knowledge transfer for socioscientific argumentation Sci. Educ. 90 986–1004