

**THE ANALYSIS OF STUDENTS' CRITICAL THINKING SKILLS ON
BIOLOGY SUBJECT**

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Abstract

This study aimed to investigate the differences between: 1) low-ability students' critical thinking skills and high-ability students' critical thinking skills, 2) male students' critical thinking skills and female students' critical thinking skills. This research was a survey conducted in some public Senior High Schools (SMAs) in Batu, East Java, Indonesia. An essay test which examined students' critical thinking skills in biology was distributed to 245 participants. The results of the test were analyzed using a critical thinking skills rubric. Data analysis was performed using ANOVA technique. Research findings showed that 1) high-ability students' critical thinking skills were higher than low-ability students' critical thinking skills, and 2) female students' scores on the critical thinking test were higher than male students' scores. These results suggest that it is necessary to implement learning strategies which can promote students' critical thinking skills in the biology classroom.

Key words: Critical Thinking Skills, Different Academic Abilities, Gender

Introduction

The development of science and knowledge in the 21st century has established a sense of urgency among learners, especially to acquire certain skills that are required in career fields. These skills might include critical thinking skills, problem-solving skills, communication skills, collaboration skills, creativity and innovation (Greenstein, 2012). A student is expected to be an individual who is able to ask, argue, do research, draw proper conclusion from an observation result, think scientifically, criticize, know the way to get knowledge, be creative, make decision, be responsible, express him/herself, and think critically (Aktamis & Yenice, 2010). However, critical thinking skills are considered the most important skill to help students think logically, make a decision and solve a problem in the classroom (Vijayaratnam, 2009).

To think critically means to think rationally in order to determine what to believe or what to do (Ennis, 2013). This includes self-correcting, context awareness, and intellectual empowerment (Lipman, 2003). Critical thinking is an analysis, evaluation, conclusion drawing, deductive and inductive reasoning process (Facione & Facione, 1994). It aims at producing an interpretation, analysis, evaluation and conclusion as well as explanation of a concept, methodology, criteriology, evidence and contextual consideration (Facione, 2013).

A student who thinks critically will have a reasoning skill, and will be able to make an inference, a decision, and formulate a problem (Finken & Ennis, 1993). S/he will also be able to collect and justify relevant information, use abstract ideas, have an open mind, and communicate effectively with other people (Duron et al., 2006). The characteristics of a critical thinker explained by Ennis can be used by the teacher as an indicator in evaluating the level of students' critical thinking skills (Ennis, 2001).

Critical thinking skills are related to academic ability (Dehghani et al., 2011). Students with a higher level of academic ability may perform better in processing and organizing information, making an inference, browsing, exploring knowledge based on their experiences (King et al., 1990). Some studies have showed that students' academic ability has an effect on their critical thinking skills. Students with higher academic ability develop better critical thinking skills than those with lower academic ability. Taghva et al., (2014), reported a significant correlation between students' critical thinking skills and their academic abilities.

In addition, it is also believed that gender and critical thinking skills are correlated (Aliakbari & Sadeghdaghighi, 2011; Harish, 2015). Gender is simply categorized into male or female. The relationship between gender and critical thinking skills has been revealed by some studies such as following.

Facione et al.,(1995) have studied the influence of gender on critical thinking skills and found that females were more open and mature in thinking while males were more analytic. Furthermore, Azin & Tabrizi (2016) state that male and female students will

have a different way to explore their critical thinking skills when they are faced with a particular problem.

Critical thinking is a skill that should be developed, practiced and integrated into a school curriculum in order to get students engaged in an active learning (Peter, 2012; Visande, 2014; Zubaidah, 2016). Critical thinking skills are an essential part of formal education. Critical thinking skills are the key to success in the world today where new knowledge develops rapidly (Marin & Halpern, 2011). Critical thinking is a method or a way of thinking aiming at maximizing outcomes. Critical thinking requires students to analyze information before drawing a conclusion (Choy & Cheah, 2009).

A teacher needs to provide guidance for students to develop their critical thinking skills (Choy & Cheah, 2009). A teacher also needs to help students to be an effective critical thinker (Rezai, 2011). Critical thinking skills needed in learning process emphasizes on the student centered learning. The teacher should take into account learning method that can empower students' critical thinking skills (Duron et al., 2006). The teacher can use a test to observe the improvement of the students' critical thinking skills.

Students need critical thinking skills to analyze a scientific issue (Chiras, 2015). These skills can be developed by giving the students real world problems to solve. Their critical thinking competencies will be improved this way because they have an opportunity to argue why the solutions are effective (Frijters et al., 2008).

Some experts have developed instruments to assess students' critical thinking skills. The forms of the test are various including multiple choice, essay, and a project test (Zubaidah et al., 2015). Tasks or tests can help promote students' critical thinking skills (Tiruneh, et al., 2014) if they contain specific indicators and elements of critical thinking (Shim & Walczak, 2012). The present research, for example, employed a test which included five indicators of critical thinking. They are 1) focus, 2) reasoning and supporting reason, 3) conventions, 4) organization, and 5) integration (Finken & Ennis, 1993).

Based on the explanation above, it is obvious that critical thinking constitutes one of important factors that might determine students' success in learning. Therefore, research on students' critical thinking skills level may provide an insight to both learning theory and practice at schools. In addition to that, the results of the research can also help teachers prepare appropriate feedback to students' work.

Method

Research Design

This research was a survey research which aimed to investigate the level of students' critical thinking skills. The survey model described a situation which happened in the past or is happening at the moment as a reality (Karasar, 2006).

Research Participants

Research participants came from 23 senior high schools (SMAs) located in Batu, East Java, Indonesia. The students were categorized into low-ability students and high-ability students based on the minimum passing level national exam (MPL) criteria. Purposive sampling technique was employed to select the subjects. As a result, public senior high school (SMAN) 1 was chosen to represent the high-ability students. Meanwhile, SMA Islam and SMA Muhammadiyah Batu were selected to represent the low-ability students. There were 245 students participating in this study; they were 155 students from the high academic ability group (48 male students and 107 female students) and 90 students from the low academic ability group (36 male students and 54 female students).

Research Procedures

A biology test was conducted to collect data on students' critical thinking skills. This test covered topics such as environment management, food additives, skeletal system disorders, and senses system disorders. This essay test was developed based on five items suggested by Finken & Ennis (1993). Prior to the test, this instrument was evaluated in terms of its content and construct validity (Fraenkel & Wallen, 2006). The results of the validity and reliability test are presented in Table 1 and Table 2.

Table 1
The Results of Instrument Validity Test

Items	Pearson correlation	Sig. (2-tailed)	Remarks
Number 1	.82	.327	Not valid
Number 2	.176	.343	Not valid
Number 3	.343	.059	Not valid
Number 4	.003	.987	valid
Number 5	.138	.460	Not valid
Number 6	.206	.267	Not valid
Number 7	.064	.730	valid
Number 8	.114	.540	valid
Number 9	.040	.830	valid
Number 10	.405	.809	valid

Table 2

Instrument Reliability	
Cronbach's Alpha	N of Items
.622	10

Table 2 shows that the alpha value of the instrument reliability is 0.622.

Followings are two instances of the essay test items:

1. Sitting position can affect the backbone shape. Some people view that sitting position should be proper to keep the bone healthy. However, some others do not care about it; they are more concerned with their comfort. Do you agree with both arguments? Explain why!
2. According to a study, Indonesia produces garbage about 2.5 in a day. If the number is accumulated there will be a huge midden. Everyone has their own different way in solving the midden problem. Some people burn their garbage because the ashes can be used as a plant fertilizer. Do you agree with the idea of burning garbage? Explain your answer!

The students were asked to answer the questions and provide reasons why they picked the answers. Their responses were then analyzed using the critical thinking rubric which was first developed by Finken & Ennis (1993) and later modified by Zubaidah, et al., (2015). The validity and reliability of the rubric have been confirmed beforehand. Critical thinking descriptors covered focus, reasoning (reason or idea), organization (way of thinking), convention (grammar) and integration of the students' answers. Meanwhile, criteria used for determining students' critical thinking level referred to those modified from Finken & Ennis. These critical thinking skills categories fall into (1) not apparent or not well developed (score 0-2), and (2) start to develop or well-developed (score 3-5).

In addition to that, two ways ANOVA was employed to investigate the difference between the high-ability students and the low-ability students in terms of the level of their critical thinking skills. It was also used to examine the difference between male and female students' critical thinking skills.

Findings

The results of the ANOVA test are summarized in Table 3.

Table 3
The results of the ANOVA test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	2298.672 ^a	3	766.224	6.742	.000
Intercept	462639.884	1	462639.884	4070.978	.000
Academic	751.057	1	751.057	6.609	.011
Gender	1483.909	1	1483.909	13.058	.000
Academic * Gender	242.919	1	242.919	2.138	.145

Error	27388.062	241	113.643
Total	598495.000	245	
Total Average	29686.735	244	

R Squared = .077 (Adjusted R Squared = .066)

a. The Description of High and Low-Ability Students' Critical Thinking Skills

The results of the ANOVA test indicate that the value of F_{count} for high and low-ability students' critical thinking skills was 6,609 with $p\text{-value} = 0.011 < \alpha$ ($\alpha = 0.05$). This value suggests that there is a difference between high-ability and low-ability students' critical thinking skills. Table 4 presents the mean scores of the ANCOVA test on high and low-ability students' critical thinking skills. This table shows that the mean score achieved by the high-ability students is significantly higher than the mean score achieved by the low-ability students.

Table 4

The Description of High and Low-Ability Students' Critical Thinking Skills

Academic	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Low	45.130	1.147	42.870	47.389
High	48.919	.926	47.095	50.743

b. The Description of Male and Female Students' Critical Thinking Skills

The results of the ANOVA test indicate that the value of F_{count} for male and female students' critical thinking skills was 13,058 with $p\text{-value} = 0.000 < \alpha$ ($\alpha = 0.05$). This value suggests that there is a difference between male and female students' critical thinking skills. Table 5 presents the mean scores of the ANCOVA test on male and female students' critical thinking skills. This table shows that the mean score achieved by female students is significantly higher than the mean score achieved by male students

Table 5

Description of Male and Female Students' Critical Thinking Skills

Academic	Gender	Mean	Std. Deviation	N
Low	Female	48.8704	12.33961	54
	Male	41.3889	14.22528	36
	Total	45.8778	13.55872	90
High	Female	50.5047	8.72145	107
	Male	47.3333	9.42232	48
	Total	49.5226	9.03409	155
Total	Female	49.9565	10.07121	161

	Male	44.7857	12.01512	84
	Total	48.1837	11.03027	245

c. The Interaction Between Students' Academic Ability, Gender, and Critical Thinking Skills

The results of the BNT test on the interaction between the students' academic ability, gender, and critical thinking skills are summarized in Table 6.

Table 6

Results of the BNT Test on the Interaction Treatment

Interaction	Mean	BNT Notation
Male students with low academic ability	41,389	a
Male students with high academic ability	47,333	b
Female students with low academic ability	48,870	b
Female students with high academic ability	50,505	b

The results of the ANOVA test indicate that the value of F_{count} for various treatments was 2,138 with $p\text{-value} = 0.145 > \alpha$ ($\alpha = 0.05$). This value suggests that there is no difference in students' critical thinking skills despite different interactions occurring between the students' academic abilities and gender. Table 4 shows that male students with high academic ability achieved better than male students with low academic ability while the mean score of female students with high academic ability is relatively similar to the mean score of female students with low academic ability.

d. The Results of the Analysis on Students' Critical Thinking Skills Based on the Critical Thinking Skills Criteria

Table 7 presents the level of students' critical thinking skills. It shows that 173 out of 245 (71%) students have less apparent or less developed critical thinking skills. Meanwhile, 72 (29%) students fall into the category of having start-to-develop or well-developed critical thinking skills.

Table 7

Results of the Analysis on Students' Critical Thinking Skills Based on the Critical Thinking Skills Criteria

Criteria	Score	Academic ability	Gender	Number of students	Percentage	Sum of percentage
Not apparent or less developed	0-2	High	Male	35	14%	71%
			Female	73	30%	
		Low	Male	30	13%	
			Female	35	14%	
Start to develop	3-5	High	Male	13	5%	29%

or well-developed		Female	34	14%
	Low	Male	6	2%
		Female	19	8%

Discussion

a. Students' Critical Thinking Skills Based on Finken & Ennis' Category

Research findings suggest that 71% of the students have less developed critical thinking skills. This result was identified from the students' responses which do not show good language use and focus. In addition to that, these responses also indicate that the students have not yet developed good way of thinking and strong arguments. Wang & Liaou, (2012) state that students with good critical thinking skills will be able to express an opinion while answering a question. Furthermore, Bailin, (2002) suggests that providing a logical reason and clear argumentation can lead students to an effective conclusion drawing.

Students' lack of critical thinking skills is indicated by their inability to show a good way of thinking and good focus. Following is the instance of students' responses to question number 1:

Student RM: *"It depends on the sitting position. We should work hard first and get the happy ending later. Those words match with that situation"*

Student VAP wrote an opinion which was closely similar to the answer provided by student RM:

"Someone's sitting position really affects his/her bone shape especially if such sitting position is maintained every day".

Some other students said that someone's sitting position should be adjusted to the individuals' comfort. One of the examples is:

Student AA: *"Yes, I agree, it is true that wrong sitting position will influence the backbone, but everyone has a different habit and if it is imposed, they will get angry and not accept that. Besides, if the sitting position is imposed, it will influence their concentration and intelligence."*

Student DSN also gave similar answer with student AA:

"Someone should sit comfortably. Comfortable is the key to an individual's health."

The students' responses indicate that their critical thinking skills have not been well developed. Most of the answers are full with doubts and inappropriate supports. Furthermore, the concepts they wrote do not seem to correlate with each other and the sentences they used are apparently not well structured.

Around 29% of the students have started to develop their critical thinking skills. Their responses are well organized. They could provide good and appropriate supports to their answer. In order to solve problems, students have to be able to argue based on the theory (Alfonso, 2015) and provide evidence to support their arguments (Flores, 2008). By doing so, the students can analyze the problems and draw a particular conclusion (Fahim & Eslamdoost, 2014).

Followings are some examples of students' answers showing a good way of thinking and clear reasons.

Student ABS: *"I disagree because burning the garbage will bring a negative impact to the nature such as air pollution. Air pollution can damage the respiration system of living things. Besides, the inorganic garbage burning will allow the chemical substances to penetrate the land and change the land environment naturally. The inorganic garbage should be recycled into a handicraft while the organic garbage should be recycled into a fertilizer"*.

Student TOW gave an explanation that was closely similar to the answer of student ABS:

"I disagree with garbage incineration because the fog can pollute the air. If humans inhale the polluted air, their respiration system will be damaged. The fog can cause death, too."

Student LIS, however, had a different answer, such as following:

"I agree with garbage incineration. Garbage will be decomposed into ash, and the ash can be used as a fertilizer."

The three examples above indicate that some of the students have developed their critical thinking skills. Despite their different points of view towards garbage incineration, the students' responses can still be categorized as correct, clear, and specific.

Language skills help students achieve better in learning because they can be used as a tool to acquire knowledge (Rashid & Hashim, 2008). These skills are correlated with critical thinking skills. Students with good critical thinking skills are also competent in communicating effectively (Paul & Elder, 2008). It means that linguistic components used in someone's writing or speaking could reflect his/her way of thinking (Indah, 2017). In other words, one of the ways to evaluate an individual's critical thinking is by assessing his/her speaking and/or writing competencies.

Thompson, (2011) points out that students can improve their critical thinking skills by frequently asking questions, making connections or acquiring new information. Students need to be able to gather as much information as possible to help them solve more complex problems. In solving the problems, they should be confident in giving arguments, and evaluate the proofs (Firdaus et al., 2015). Giancarlo & Facione, (2001) state that critical thinking skills will be useful for students in decision making.

b. Critical Thinking Skills of the Students with Different Academic Abilities

The results of variance analysis presented in Table 2 show that the mean score achieved by the high-ability students is higher than the mean score achieved by the low-ability students. Research findings suggest that students with high academic level have better critical thinking skills than students with low academic level. The high-ability students are more capable of receiving, processing and managing information properly, reasoning and making deduction. Besides, they are more curious and open minded. They are much braver in accomplishing a new task and facing any challenges in the educational world (Kamaei & Weisani, 2013). In addition, the high-ability students also have firmer establishment, independence and better cognitive ability compared to the low-ability students (Afshar et al., 2012). On the other hand, students with low academic ability have less control over their emotions. As a result, their performance, thinking skills, and cognitive achievement are poorer than the high academic ability students (Dzulkifli & Alias, 2012).

Nordin (2015) suggests that academic achievement is closely related to students' learning process. A learning process should be emphasized on promoting students' critical thinking process. Students must be exposed to problem analysis, analytic discussion, ideas generation in order to solve the issues. Students' critical thinking skills can also be enhanced through students' presentation and group task activities.

c. Male and Female Students' Critical Thinking Skills

Table 3 shows that female students have better critical thinking skills than male students do. This research finding is in line with the results of the research conducted by Moafian & Ganizadeh (2011). The study reported that female students' critical thinking skills (mean score was 47.17) were higher than male students' critical thinking skills (mean score was 44.61).

The effect of gender on students' academic abilities has been confirmed by some researchers. Fuad et al., (2017) discovered differences in male and female students' critical thinking skills. Mahanal, (2012) states that the score of female students' critical thinking skills is higher than that of male students. Furthermore, Crawford et al, (2005) also found that female students ask more precise and credible questions compared to male students which means that female students have better critical thinking skills compared to male students. In short, gender has an effect on students' critical thinking skills. Ricketts, (2004) also point out that female students are more able in drawing a conclusion, expressing an opinion, delivering information, or considering relevant information.

Female and male students use similar skills in solving a problem but females are more careful and rigorous to recheck what they have done and have better arguing ability than males (Rasiman, 2015). Another research finding by Salahshoor & Rafiee, (2016) also

suggests that there is no significant difference in Iranian male and female students' critical thinking skills.

The LSD test results indicate that male students with low academic ability have significantly lower mean score compared to male students with high academic ability. Meanwhile, female students with high ability achieved the same score as female students with low ability did. Burris & Garton, (2006) suggest that academic achievement rank contributes 18% of variance to students' score in analytic thinking.

Moss & Koziol, (1991) state that male students are more excellent in logical reasoning while female students are more superior in precision, and thinking accuracy.

Harish, (2015) in his study shows that male and female students have different critical thinking skills. According to Aliakbari & Sadeghdaghighi, (2011) female critical thinking skills are better than male critical thinking skills. However, some other research concludes that there is no significant difference between male and female students' critical thinking skills (see, for example Nordin, 2015; Salahsoor & Rafiee, 2016).

Male and female students are different in terms of their critical thinking skills. Women are more careful than men. They always ask for second opinion before making a decision (Wood, 1994). Shaywitz et al., (1995) have reported that female students are more competent in verbal communication. Females could successfully activate the inferior frontal gyrus on both right and left brain lobes. Meanwhile, males could only activate one frontal gyrus on the left brain hemisphere.

d. Promoting Students' Critical Thinking Skills through Learning Strategy

Students have different levels of critical thinking skills (Bahr, 2010). The interview results suggest that some students faced difficulties in managing time in learning. The limited access to the internet made it harder for them to search new information. Some research results report other factors that may contribute to students' lack of critical thinking skills. They include time management, willingness to explore learning resources (Indah & Kusuma, 2016), motivation, reading habit (Mahapoonyanont, 2012), self-confidence, and competencies (Duncan, 2016).

Students with good critical thinking skills have been proven to be able to develop ideas, make a good decision, solve problems and evaluate effective solutions (Thomas, 2011). The students are capable of analyzing and evaluating a problem from different points of view.

Students' critical thinking skills may be affected by students' motivation and ability in reading (Conceicao, 2005). Another factor that may influence students' critical thinking skills is language competence. Therefore, students who can use good language when speaking or writing are considered able to think critically (Indah & Kusuma, 2016).

Teacher also plays an important role in developing students' critical thinking skills (Mahapoonyanont, 2012). It is important for the teacher to design a learning process

which can help promote students' critical thinking skills in the classroom (Kamarulzaman, 2015; Kalelioglu & Gulbahar, 2013). The teacher can also implement various strategies, techniques, and methods to facilitate students' critical thinking skills and active participation (Walker, 2003; Demirdag, 2015; Myers & Dyers, 2015).

Debate can help enhance students' critical thinking skills since it allows students to argue, collect information, analyze data, justify arguments, question assumptions, and show their interpersonal skills (Scott, 2008). Besides, critical thinking skills can be improved by making students think not only as an information receiver but also a user (Peter, 2012). In order to think critically, students need to learn to question a problem (Kim & Choi, 2014), read comprehensively (Tous et al, 2015), construct their own learning (Leach & God, 2011; Kwang & Wong, 2014), apply online learning (Conceicao, 2005), learn cooperatively, and establish problem-based learning (Nezami et al, 2013).

Critical thinking should be taught explicitly (Zubaidah, 2016). In science subject, especially biology, critical thinking skills can be enhanced by implementing problem-based biology learning, and experiment learning (Meisel, 2010), investigation in the laboratory (Koray & Koksal, 2009). The implementation of various learning strategies enables students to connect one concept with another. As a result, the students can sharpen their critical thinking skills (Zohar e al., 1994).

Critical thinking skills also cover communication skills such as the ability of checking, analyzing, interpreting and evaluating evidence. In the digital literacy era in which information is abundant, students should be able to select appropriate sources and information. They need to justify the sources from the objectivity, and reliability aspects. Teachers, in this context, play a significant role in helping the students develop their communication skills. .

The results of the research indicate that students' critical thinking skills need to be promoted in the classroom. Implementing various learning strategies can be an alternative to develop high and low-ability students' critical thinking skills (Zubaidah, 2010).

Conclusion and Suggestions

Research findings suggest that the critical thinking skills of students who go to some Senior High Schools in Batu, Indonesia have not been well developed. Male students with low academic ability achieved the lowest mean score on critical thinking skills compared to other group of students. The results of the research in general, however, indicate that despite the students' difference in gender and academic abilities, their critical thinking skills still need to be improved by applying various learning strategies in the classroom.

This research was only limited on investigating students' critical thinking skills in Biology subject at the senior high school level. The results of the research, however, can

still apply to different contexts discussing other higher order thinking skills such as creative thinking and problem solving skills. It is recommended for future research to develop an instrument to measure students' critical thinking skills in other subjects.

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