Research Article

Analysis of Student Critical and Creative Thinking (CCT) Skills on Chemistry: A Study of Gender Differences

Ryzal Perdana[1]

Budiyono[2]

Sajidan[2]

Sukarmin[2]

[1]*Doctoral Program of Educational Science, Universitas Sebelas Maret, Surakarta, Indonesia*
[2]*Faculty of Teacher Training and Education, Universitas Sebelas Maret, Surakarta, Indonesia*

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Abstract

Critical and creative thinking skills are an essential attribute for success in the 21st century. This study aimed to determine the students' critical and creative thinking skills in the Islamic senior high schools of Surakarta City so that teachers can pay attention to the strength and weakness of each student based on gender differences. This study used descriptive qualitative analysis. The subject of this study amounted to 180 students consisting of 80 male and 100 female students. The measurement of critical-thinking skills used a 6-essay-question instrument of the chemical material of electrolyte and non-electrolyte solutions that measures the aspects based on Facione theory, namely: analysis, inference, explanation, interpretation, evaluation, and self-regulation. Then, to measure creative-thinking skills, a 4-essay-question test instrument of the chemical material that includes 4 aspects according to Torrance, fluency, flexibility, original and elaboration, was used. The results showed that the creative-thinking skills of male students are better than those of female students and the critical-thinking skills of female students are better than those of male students.

Keywords: *Gender, Critical and Creative Thinking (CCT), Chemistry*

1. Introduction

In the 21st-century learning system, schools are required to change teacher-centered learning patterns to be student-centered, so that students can think deductively, inductively, critically and creatively (Kuhltlau, 2007; Trilling & Fadel, 2009; Soong, 2005; Vong&Kaewurai, 2017). They are required to find the learning concept through direct experience because with direct experience students will have more complex knowledge to understand (L. Vygotsky, 1986; L. S. Vygotsky, 1978). The basic skills students must possess to support the achievement of this learning are critical and creative thinking skills. By having high critical and creative thinking skills, students will also be able to find concepts independently with little guidance from the teacher. High critical and creative thinking skills will also affect the students' learning achievements compared to those who have low critical and creative thinking skills (Ennis, 2011; Yee, Lai, Tee, & Mohamad, 2016).

Critical and creative thinking skills are one of the domains in the high-order thinking skill (HOTS) concept (Heong et al., 2011; Sulaiman et al., 2017; Yee et al., 2011.; Yee, Lai, Tee, &

Mohamad, 2016). High-order thinking has been confirmed as an important predictor of success for the future. Critical and creative thinking skills are important in the world of education because they allow students to really get a more complex understanding of information (Dwyer, Hogan, & Stewart, 2014; Forawi, 2016; Vaske, 2001).

An innovative, effective and efficient learning model in accordance with the training of critical and creative thinking skills is needed by students. Critical and creative thinking skills are very necessary and must be empowered by each student (Ataizi&Donmez, 2014; Ledward& Hirata, 2011; Nilsson & Gro, 2015) to achieve success, especially in the 21st century. Besides, critical and creative thinking skills will make students see the world differently and will happily experiment to get something new (Anna, Jeffrey &Leibling, 2001; Chalkiadaki, 2018). In addition to learning the learning model or strategy, in the previous research, gender is also often associated with empowering high-order thinking skills, especially critical and creative thinking skills. Critical and creative thinking skills related to gender differences are based on memory, language skills, and problem-solving skills.

Gender is a term of both sexes or sexual categories namely men and women. Gender is an inherited gender influenced by social and cultural factors that refer to the psychological and socio-cultural dimensions. Gender is related to the way men and women think, act and reason (Santrock, 2011; Erkoc&Kert, 2013; Peretomode & Bello, 2018). Gender differences are divided into two types, namely attitude, and knowledge. Gender is one dimension that influences the conceptualization process in education. The development of a gender perspective has influenced several scientific disciplines (Browne et al, 1989; Ujiro& Norris, 2017). Male and female students have different perspectives in describing ideas (Piaw, 2014; Harish, 2013). Gender differences also affect different ways of solving chemical problems between male and female students. According to Rachmatullah & Ha, (2019), there are differences in the cognitive processes of male and female students in solving chemical problems. According to Zheng Zhu (2007) and Fetalvero (2019), there are differences in solving chemical problems influenced by gender differences, differences in experience and education. Biological, psychological and environmental variables appear to contribute to gender differences.

The exploration of potential is expected to empower students' critical and creative thinking skills so that later on they will become an ability possessed by students to be used in daily life (Omari et al., 2016; Elisanti et al, 2018; Thomas, 2017). However, there are several other factors that influence students' critical and creative thinking skills. These factors are gender factors. Differences in biological growth, especially in terms of gender, cause significance between students' critical and creative thinking skills (Ramdiah&Corebima, 2014; Polat, 2018). In another study, it has been proven that gender significant differences affect scores in students' critical and creative thinking skills (Ricketts & Rudd, 2004; Mahanal, 2012; Zubaidah et al., 2017). However, different studies show that there is no significant influence on critical and creative thinking skills in terms of gender differences (Cimer et al, 2013; Chukwuyenum, 2013; Thompson & Miller, 2017). Male students have spatial skills while female students have communication skills (verbal). Therefore, it is quite interesting to do research to see gender roles in the process of students' critical and creative thinking skills, especially in solving chemical material problems. Based on the background above, it is necessary to conduct a study entitled Analysis of Student Critical and Creative Thinking (CCT) Skills on Chemistry; A Study of Gender Differences.

2. Purpose of the Study

This study aimed to determine the students' critical and creative thinking skills in the Islamic Senior High School of Surakarta City so that teachers can pay attention to the strength and weakness of each student based on gender differences.

3. Methodology

The design of the study was carried out with the effect of gender differences on students' critical and creative thinking skills. It used a purposive sampling technique. The population of the study

was tenth-grade science students of all Islamic senior high schools of Surakarta City in 2018/2019 academic year. The subject of this study amounted to 180 students consisting of 80 male and 100 female students.

The critical-thinking skills were measured using a 6-essay-question instrument of the chemical material of electrolyte and non-electrolyte solutions with 6 aspects of critical-thinking skills based on Facione theory (201), including analysis, inference, explanation, interpretation, evaluation, and self-regulation. Then, to measure creative thinking skills, a 4-essay-question test instrument about the chemical material of electrolyte and non-electrolyte solutions adjusted to 4 aspects of creative-thinking skills based on the theory of Torrance (1980), including fluency, flexibility, original and elaboration, was used.

The instrument for measuring critical and creative thinking skills was the assessment rubric with a range of scores 1-4. The instrument has been validated by using the moment product person correlation test provided that if r > r table then, the item is valid. If r < r table, then the question is invalid. The lowest score of the instrument validity test is 0.116 and the highest 0.795 > f table with 33 student respondents with the value of r = 0.344 (value of r product-moment). This means that the instrument about critical and creative thinking skills is valid. The reliability score obtained by Cronbach's Alpha is 0.728 > 0.344, which means that each item is reliable to implement.

4. The Results of the Study

4.1 The results of the descriptive analysis of the score percentage of each aspect of critical-thinking skills based on gender differences

The results of the descriptive analysis of the score percentage of each aspect of critical thinking skills based on gender differences are presented in the table below.

Table 4.1: The results of the descriptive analysis of the score percentage of each aspect of critical thinking skills based on gender differences.

Aspects of Critical-Thinking Skills	Gender		Aspects of Critical-Thinking Skills	Gender	
	Male	Female		Male	Female
Analysis	58%	61%	Fluency	50%	44%
Inference	44%	42%	Flexibility	47%	46%
Explanation	51%	53%	Originally	47%	47%
Interpretation	47%	46%	Elaboration	44%	40%
Evaluation	47%	46%			
Self-Regulation	38%	40%			

Based on Table 4.1, the results of the score percentage of each aspect of critical-thinking skills based on gender differences for female students include the 61% for analysis, 42% for inference, 53% for an explanation, 46% for interpretation, 46% for evaluation and 40% for self-regulation. For male students, the results include 44% for fluency, 46% for flexibility, 47% for originally, and 40% for elaboration.The scoring percentage of female students' critical-thinking skills is higher than that of male students. The score per aspect for male students' creative-thinking skills is higher than that for female students. It can be concluded that female students are better at critical-thinking skills while male students are better at creative-thinking skills.

4.2 The results of the descriptive analysis of critical-thinking skill scores based on gender differences

The results of the descriptive analysis of critical-thinking skill scores based on gender differences are presented in the table below.

Table 4.2. The results of the descriptive analysis of scores of critical and creative thinking skills based on gender differences

Gender	Number	Skills	Min Score	Max Score	Mean	S.td
Male	80	Critical	29.17	62.50	47.50	7.15
	80	Creative	31.25	68.75	46.95	9.53
Female	100	Critical	37.50	62.50	47.50	7.15
	100	Creative	25.00	68.75	44.31	9.32

Based on Table 4.2, the lowest score of female students' critical-thinking skills is 37.50 and the highest score 62.50 with a mean of 47.50 and a standard deviation of 7.15. The score of female students' critical-thinking skills is higher than that of male students. Meanwhile, the lowest score of the male students' creative-thinking skills is 31.25 and the highest score 68.75 with a mean of 46.95 and a standard deviation of 9.53. The score of male students' creative-thinking skills is higher than that of female students.

4.3 The results of the ANCOVA test on critical and creative thinking skills based on gender differences

Analysis of covariance (ANCOVA) was conducted to determine whether there were significant differences in critical and creative thinking skills based on gender. Prerequisite tests were in the form of normality using the Kolmogorov-Smirnov test and homogeneity test using the Levene test. Before the ANCOVA test, the scores obtained from critical and creative thinking skills based on the existing gender are usually distributed and homogeneous. The results of the normality and homogeneity tests can be seen in Tables 4.3.1 and 4.3.2 below.

Table 4.3.1: Normality Test Result

Skill	Gender	Kolmogorov-Smirnov[a]			Skill	Gender	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.			Statistic	df	Sig.
Critical Thinking	Male	.142	80	.010	Creative Thinking	Male	.206	80	.014
	Female	.139	100	.016		Female	.149	100	.020

Table 4.3.2: Homogeneity Test Result

	Levene Statistic	df1	df2	Sig.
Critical Thinking	.217	1	178	.642
Creative Thinking	3,334	1	178	.070

Table 4.3.1 and Table 4.3.2 shows that based the normality test, the data were normally distributed and based on the homogeneity test, the data were homogeneous. The next step was conducting the ANCOVA test. The results of the ANCOVA test can be seen in Table 4.3.3 below.

Table 4.3.3: Result of ANCOVA Test on critical and creative thinking skills based on gender differences.

Dependent Variable: Gender					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	[1,017] A.	2	.509	2,074	.000
Intercept	1,248	1	1,248	5,088	.000
Critical-Thinking Skill	.162	1	.162	.660	.000
Creative-Thinking Skill	.953	1	.953	3,886	.001
Errors	43,427	177	.245		
Total	100,000	180			
Corrected Total	44,444	179			

a. R Squared = .023 (Adjusted R Squared = .012)

Based on the results of the covariance analysis, the significance level obtained is 0.000 and 0.001. This signification value is less than 0.05 ($p < 0.005$), so Ho is rejected and the research hypothesis is accepted which indicates that there are significant gender differences in the effects of critical and creative thinking skills.

5. Discussion

Students' Critical and Creative Thinking (CCT) skills in chemical material are based on gender differences. Critical-thinking skills based on this study reveal that female students tend to get better results in critical-thinking skills than male students do. The results of the relevant study, according to Mahanal (2012) show that female students are better able to explore critical thinking and are better able to regulate their way of thinking than male students. The results of this study are indirectly in accordance with the study of Fuad et al, (2017) stating that female students have better learning achievement than male students. Female students are better at processing textual information than male students (Yang, 2016).

The strength of female students is in line with the study of Biehler (2013) and Reendy (2011) stating that women are superior to their male counterparts, especially in linguistic and verbal studies. Male students, in general, have more problems in learning, especially in chemistry, than female students (Dori et al, 2018; Situmorang et al., 2018). The fact is that learning achievement is the main modality for students to be able to think higher, especially critical thinking (Blaževi, 2013; Ahrari et al, 2016; Peretomode& Bello, 2018). According to Graybill, gender differences are evidenced in problem-solving tasks, where men are left behind by women in developing critical and logical thinking skills. It was found that positive attitudes towards science and higher achievements in the science of female students were better than male students (Eliasson et al, 2016).

Gender differences between men and women diagnosed can be examined from the anatomical organs of the brain affecting the learning system and activities of the human brain (Gurian et al., 2010). The male brain is more likely to develop and has a more complex spatial, for example, in the ability of the planning mechanism, making decisions, abstraction, measurement, and manipulating physical objects. The male brain cortex works more in performing spatial functions and tends to provide more productive portions in processing words. The nerve that connects the left and right brain or corpus callosum of the male brain is quarterly smaller than the female brain. When this male brain uses only the right brain, the female brain uses both left and right brain parts to the fullest (Hines, 2004; Fuad et al., 2017).

Although the learning model and gender show significant differences between critical-thinking skills, the interactions between the two variables do not show a significant difference between critical-thinking skills. The significant difference is supported by a very low and high score from the results of the test measured by gender effects. As a result, differences in critical-thinking skills are influenced by many learning models implemented. Gender gives a small but significant contribution. The results of the study of Fuad et al. (2017) state that gender influences critical-thinking skills, although not too significant. Gender, in addition to influencing physical differences, also influences students' thinking skills, especially critical-thinking skills. One of the factors causing these differences is intelligence differences (Harish, 2013). This is in line with the study that states that there are intelligence differences and individual activities between men and women (Halpen&LaMay, 2000; Zeng, Xu, & Chen, 2019)

The average difference is due to the answers of female students in the aspects of analysis, inference, explanation, interpretation, evaluation, and self-regulation the critical-thinking skill test better than those of men. This result is in line with the study of Mahanal (2012), which also found that gender influences the improvement of critical-thinking skills as indicated by the corrected mean value of women's critical-thinking skills higher than that of men's critical-thinking skills. According to Riketts& Rudd (2004) and Suardana et al., (2018), the female students' scores of critical-thinking skills, covering the aspects of the analysis, inference, explanation, interpretation, evaluation, and self-regulation,are higher than men's scores. Women are also considered better at identifying problems, giving statements and questions, explaining concepts, giving reasons and opinions, and the ability to make conclusions than men.

The low mean scores of male students' critical-thinking skills in the aspects of the analysis, inference, explanation, interpretation, evaluation, and self-regulation are caused by their answers that are not following the given instructions or questions. Male students' critical-thinking skills to provide further explanations such as giving examples, expressing ideas, and providing logical reasons are also still the factor causing the low results of the tests. Students need more motivation and practice to be able to improve their critical thinking skills, especially to improve exploration of skills in the aspects of analysis, inference, explanation, interpretation, evaluation, and self-regulation.

Whether the scores of critical-thinking skills are good or not can be influenced by the syntaxes of learning models, environment, age, experience differences, gender differences based on memory, language skills, and problem-solving skills. This is in line with the study that states that some influence the development of a child's critical-thinking skills, namely: age, knowledge, and experience that can be influenced by the environment. Besides, the use of learning methods or models that can stimulate students 'critical-thinking skills can also influence students' critical-thinking skills (Heong et al., 2011; Kamarulzaman&ahmad, 2014; Wan et al, 2017; Husamah et al, 2018). This study states that gender differences (male and female) differ significantly in their critical-thinking skills. This means that female students show better performance, cognitive knowledge, argumentation than male students do in critical thinking-skills in the chemical material of electrolyte and non-electrolyte solutions.Critical-thinking skills need to be trained because it is an effective way to improve students' understanding of material concepts especially the chemical material of electrolyte and non-electrolyte solutions (Biasi, Vincenzo, & Patrizi, 2018; Demiral&Çepni, 2018).

Students' creative-thinking skills in chemical material are based on gender differences. Based on the results of the study, gender is a significant factor of creative-thinking skills. A study suggests that men are more creative than women. This means that male students are better at describing creative ideas than female students. However, there was no significant difference between students in the four components of the aspects of creative-thinking skills. The results of the study are in line with the study that states that male students' creative-thinking skills are significantly higher than female students' skills. Male students have creativity and innovation as a creative style in the thinking process significantly higher than female students at the level of education (Ulger&Morsünbül, 2016; Zubaidah et al., 2017). There is a significant difference between the creative-thinking skills of male and female students. The mean score of male students 'creative-thinking skills is better than that of female students' creative-thinking skills. The results of gender analysis in measuring four aspects of creative-thinking skills based on the theory of Torrance (1980) and Torrance et al., (1986) include fluency, flexibility, original and elaboration. Male students in the chemical material of electrolyte and non-electrolyte solutions obtain higher results in aspects of creative-thinking skills including fluency, flexibility, original and elaboration. Male students have a better ability to solve problems than female students.

The results of the Zeyer et al., (2018) study state that there are differences between male and female students in learning styles that influence their creative-thinking skills. The impact is the tendency of learning styles in thinking using the left and right brains. Male students use the left-brain learning style more in thinking and focus more on logical thinking to be more innovative, creative and competent students in empowering creative thinking skills than female students (Fuad 2017; Zubaidah et al., 2017). Some gender development factors include (1) biological factors in male and female behaviours; (2) social factors that highlight the importance of various social contexts in which children develop, especially families, peer friends, schools and the media; and (3) cognitive factors that contribute to the gender development of children (Abraham, 2016; Shalka, 2019).

The strength of male students is that they have good skills in the Visio-spatial process while female students have communication skills (verbal). Gender has a role especially in solving chemical problems in the process of creative-thinking skills (Scherer & Gustafsson, 2015). Male and female students show creative-thinking skills and cognitive profiles rather differently (Anyafulude, 2013; Sasai, 2017). According to Proudfoot et al., (2015) the talent and experience have a role in gender differences in scientific reasoning. The results of the study show that the task

of scientific reasoning is known to be solved by men more often than women. Male students were found to be better than women in building concepts and using theory (Olagoke, 2016). Similarly, the study conducted by Tsai (2013) and Eliasson et al., (2016) showing that men's performance in creative-thinking skills is significantly better than women's performance in probabilistic reasoning.

Students need to be trained in critical and creative thinking skills. High-order thinking skills, namely critical and creative thinking skills, must be trained because they are the key points needed in the globalization era of 21st-century (Kan'an, 2018; Neziri, 2019). High-order thinking skills, namely critical and creative thinking skills must be trained to students through instruction as early as possible.

6. Conclusion

The results of this study indicate that there are significant differences between gender differences (male and female) in critical and creative thinking skills. Further studies related to the study on critical and creative thinking skills viewed from gender still need to be done by using a wider sample, but still need to be done to reveal whether or not gender differences (male and female) have potential effects on students' critical and creative thinking skills. The study provides important information for educators. It is hoped that educators or teachers plan their teaching and learning activities in a more innovative, effective and efficient way to empower students' critical and creative thinking skills. Educators or teachers should foster and train the exploration of all students' potentials to empower their critical and creative thinking skills in achieving effective educational goals.

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