Exploring Chemistry Education Students' Critical Thinking Skills and Ethnochemistry-Based Learning Experiences based on Gender

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Abstract-This study explores critical thinking skills and ethnochemistry-based learning experiences in chemistry education students. A total of 200 students' (70 men and 130 women) were selected as the sample with the cluster random sampling technique. The research design was a cross-sectional survey. The data collection instrument on critical thinking skills utilized was the Oliver Hoyo rubric (OHCRT). Meanwhile, ethnochemistry-based learning experience data were collected through a CAEQ (chemistry attitudes and experiences questionnaire based on ethnochemistry) questionnaire. The quantitative data were analyzed by the MANOVA test at a significance level of .05. At the same time, interview data were examined using the Patton technique. This study resulted: 1) the CTS and ELE levels of chemistry education students were higher in female and freshman grades, and 2) there were differences in CTS and ELE based on Gender. In which, the interview data strengthen the survey findings since female students have higher CTS abilities and have more positive attitudes towards implementing ethnochemistry-based learning.

Index Terms- critical thinking skills, ethnochemistry-based learning experience, gender differences, chemistry education students.

I. INTRODUCTION

The new direction of chemistry learning goals in universities is oriented toward achieving 21st-century learning demands to face in the phase of the industrial revolution 5.0. The role of universities is required to generate graduates who have adequate hard skills and soft skills to live in the era globalization (Cheung, 2011; Wahyudiati et al., 2020). Since critical-thinking skills are 21st-century skills needed by chemistry education students to strive in the industrial revolution 4.0 (Villafane & Lewis, 2016; Syafrial et al., 2022). Unfortunately, looking at the previous research, it has proven that lecturers focus more on cognitive learning outcomes than soft skills to achieve chemistry learning objectives. It leads to chemistry education students' being categorized as low of their critical thinking skills (Tiruneh et al., 2018; Wahyudiati, 2022). In addition, the neglect of students' soft skills development in learning activities also affects their low critical thinking skills at the primary, secondary, and tertiary levels (Taber, 2011; Fadli, 2020).

Education experts believe that students' critical thinking skills as one of the 21st-century skills which need to be developed in creating competent graduates in their fields and have the competitive capability in the job market (Sumardi, Rohman, & Wahyudiati, 2020; Wahyudiati, 2022; Patonah et al., 2021). Critical thinking is the ability to analyze problems logically and rationally to find solutions to the issues faced. Aspects of critical thinking skills are reflected in the ability to analyze, evaluate, identify, assess, and develop thinking to think logically and systematically in solving a problem. The student's critical thinking skills development can be explored through classroom learning activities and experimental activities in the laboratory to foster their curiosity, self-confidence, responsibility, problem-solving skills, and social awareness. These can be the main provisions for each individual to survive in a global society (Wahyudiati, Sutrisno, & Louise, 2019; Tiruneh et al., 2018; Bandyopadhyay & Szostek, 2019). In addition, CTS skills cannot be taught using textbooks or based on theory only. Contextual activities such as the ability to investigate, express opinions, respond to other people's views, and dare to make decisions are needed as supporting elements (Aljaafi, 2019). Thus, providing contextual and relevant learning experiences to students' daily lives can be the way to develop critical thinking skills.

The learning experience is one of the indicators of attitudes toward science. Attitude towards science are defined as an individual's ability to solve a problem through a systematic scientific method (Wahyudiati, 2021). Learning experiences relevant to students' daily lives and culture are believed to improve students' critical thinking skills and problem-solving abilities (Ferrel & Barbera, 2015; Wahyudiati et al., 2020). This situatiation hints that there is a close relationship between the learning experience and critical thinking skills. Moreover, a contextual learning experience that combines science and culture (ethnochemistry) could train students to develop analytical skills, formulate and prove hypotheses, and think logically in constructing knowledge, attitudes, and skills independently (Fadli & Irwanto, 2020; Sumardi & Wahyudiati, 2021). However, research studies that examine critical thinking skills and ethnochemistry-based learning experiences are still very limited and are focused more on scientific attitude (Sutrisno, Wahyudiati, and Louise, 2019). On top of that, the measurement of both aspects (critical thinking skills and ethnochemistry-based learning experiences) has never been done simultaneously. Therefore, more studies are needed to measure critical thinking skills and ethnochemistry-based learning experiences in universities.

Critical thinking skills and ethnochemistry-based learning experiences must be acquired to achieve chemistry learning objectives, including soft skills and hard skills domains. However, based on empirical studies, the factual conditions of chemistry learning at universities in Indonesia show that chemistry learning prioritizes mastery of concepts rather than the development of soft skills (Irwanto, Rohaeti, & Prodjosantoso, 2018; Wahyudiati, 2021; Wiwit, Ginting, & Firdaus, 2013). Referring to these results, it further explains that the problem of learning chemistry in universities is the use of learning models that are less varied and methods and the lack of learning activities that allow students to construct knowledge based on real everyday life experiences. Likewise, the student's learning experience is less related to their cultural background, so the concepts taught tend to be memorization and ignore factual and contextual ideas that make learning less exciting and meaningful for them (Sutrisno, Wahyudiati, & Louise, 2019; Fadli & Masnun, 2020; Sumardi & Wahyudiati, 2021). All in all, improving the quality of chemistry learning requires various innovative strategies in applying learning models, methods, or media and must be balanced with improving the quality of lecturers (Zeidan & Jayosi, 2014; Taber, 2011).

In addition to strategy and learning environment factors, relevant previous research studies reveal an interesting fact that there is a link between the chemistry learning experience and critical thinking skills based on gender. This condition is in line with Cheung (2007), Calik, U"Itay, Kolomuc, and Aytard (2014) studies, which show that there are differences related to students' gender and grades level learning experience. This factual condition is supported by other research in various countries, such as Villafane, Garcia, and Lewis (2014) in the United States, in Hongkong by Cheung (2011), Xu, Villafane, and Lewis (2013) in America, Salta and Tzougraki (2004) in Greece. In conclusion, gender affects the learning experience and scientific attitude. The findings of these studies from several different countries have illustrated the current state of gender-influenced learning experiences. However, studies regarding critical thinking skills and ethnochemistry-based experiences from a gender perspective in Indonesian universities are still rare. Therefore, it is urgent to research and map the factual conditions of ATC, LE, and SE for prospective chemistry teachers in Indonesia in terms of gender and grades level. The research findings could help tracing the factual conditions of critical thinking skills and ethnochemistry-based experiences of chemistry education students simultaneously, which has never been done so far. Furthermore, the benefits of research are; 1) as a basis for planning and implementing chemistry learning to develop critical thinking skills, 2) as a reference in developing ethnochemistry-based learning experiences, 3) improving the quality of chemistry education graduates through developing critical thinking skills and ethnochemistry-based learning experiences. Hence, based on the elaborated information above, This study aims to determine whether there are differences in critical thinking skills and ethnochemistry-based learning experiences based on gender.

II. METHOD

The research approach uses a quantitative approach with the type of survey research using a cross-sectional survey design (Creswell, 2000). The interview technique for collecting research data uses a focus group interview with a structured technique. The focus group interview aims to collect qualitative data that has relevance to the research data from the questionnaire (Ismail & Jarrah, 2019). The use of a cross-sectional survey design has the advantage that it can measure the relationship between two or more variables through the interpretation of the actual research object (Cohen, Manion & Morrison, 2007).

The research samples were taken from two different universities, Mataram State Islamic University and Mataram University, in the chemistry education study program. The number of participants is 200 students. At the survey stage, 130 women and 70 men were determined as samples, which were determined using the cluster random sampling technique. The next research stage is to conduct in-depth interviews with the research sample (Creswell, 2000).

Research data collection was carried out in stages and sequentially through the provision of questionnaires and interviews (Teddlie & Tashakkori, 2009). The instrument for measuring critical thinking skills refers to Oliver Hoyo's (2003) rubric with 5 selected indicators, namely (1) analysis, (2) attitudes towards scientific investigations, (3) the application of scientific attitudes, (4) curiosity attitudes, and (5) behavioral tendencies to learn chemistry. The ethnochemistry-based experiential learning instrument used in this study adopted the CAEQ (questionnaire of chemistry attitudes and experiences) developed by Coll, Dalgety, & Salter (2002). The researchers developed it into an ethnochemistry-based CAEQ instrument. Before the instrument used, an expert validation test was performed and an empirical test was completed to measure instrument reliability. Based on statistical tests, Cronbach's alpha coefficient value was = .89 > .70, which means that the instrument already met the reliability requirements (Hair, Black, Babin, & Anderson, 2006).

Research data analysis activities were carried out in two stages. The first stage of data was obtained from the administration of OHCRT and CAEQ questionnaires and analyzed using the Manova test. Prior to the Manova test, the homogeneity prerequisite test was conducted through the Levene test with p-value > 0.05, which means the data is homogeneous (Bernard, 2000). Likewise, the results of the normality test obtained p-value > 0.05 so that the research data were normally distributed. For the multicollinearity test, the VIF value was = 0.40 (there is no multicollinearity). In the second stage, the data from the interviews were compiled and categorized into recurring themes or patterns regarding the qualitative analysis suggested by Patton (2002). The main reason for using the Patton technique was to ensure that the repeated patterns or themes obtained were relevant to the research objectives to support quantitative data from the questionnaire. In addition, the use of the Patton method assisted in identifying the emergence of elements that could not be anticipated during interview activities ((Ismail & Jarrah, 2019).

III. FINDINGS

The level of critical thinking ability (CTC) and Ethnochemistry-based learning experience (ELE) in chemistry education students by gender refers to the mean and standard deviation values, as shown in Table 1. The highest average scores were obtained by female students and freshmen with 86.55 (Table 1). Concerning chemistry education students' CTS level, the female freshman grade was higher (69.67) than the male CTS; freshman, sophomore, and junior grades. Furthermore, to explore these findings, the questionnaire data were complemented by the results of interviews (described in the discussion).

Table 1
CTS and ELE Mean Scores based on Gender

	Gender	Grades	Mean	SD
Critical Thinking Skills	Male	Freshman	69.04	7.63
		Sophomore	67.45	8.71
		Junior	66.29	8.63
	Female	Freshman	69.67	5.65
		Sophomore	63.27	4.88
		Junior	65.55	6.44
Ethnochemistry-based Learning Experiences	Male	Freshman	85.27	4.85
		Sophomore	84.54	6.88
		Junior	85.73	3.98
	Female	Freshman	86.55	7.39
		Sophomore	84.49	5.90
		Junior	84.25	3.86
Overall	Male	Freshman	75.16	6.82
		Sophomore	72.23	8.59
		Junior	73.44	6.73
	Female	Freshman	75.95	7.95
		Sophomore	68.98	8.82
		Junior	73.13	6.86

The results of the Manova test showed there were differences in CTS and ELE based on Gender with a p-value of <0.05 (Table 2), meaning that the null hypothesis was rejected and Ha was accepted.

Table 2
Student's Manova CTS and ELE Test Results based on Gender

Effect		Value	F	Sig.
Gender	Pillai's Trace	.002	.590	.000
	Wilks' Lambda	.001	.590	.000
	Hotelling's Trace	.003	.590	.000
	Roy's Largest Root	.004	.590	.000

Test of Between-Subjects Effects test was employed to find the differences between each factor on the dependent variable. The results showed differences in CTS and ELE based on Gender because the p-value was < 0.05 (Table 3), meaning that the null hypothesis was rejected and Ha was accepted.

Table 3
Test results of Between-Subjects Effects ATC, LE, and SE

Effect	Dependent Variables	F	Sig.
Gender	CTS	.001	.000
	ELE	.003	.000
	Overall	.002	.000

IV. DISCUSSION

The research findings revealed an interesting fact; women have higher levels of CTS and ELE than men. The results of this study are in line with Shubina and Kulakli (2019) and Bart et al. (2015), which show differences in critical thinking skills based on gender. This condition is also relevant to Mawaddah, Ahmad, and Duskri's (2018) research that women have critical thinking skills compared to men. In addition to critical thinking skills, students learning experience (LE) dramatically influences the development of positive attitudes toward chemistry learning, especially the application of inquiry-based learning (Ayyildiz & Tarhan, 2012; Hugerat & Kortam, 2014). There is a tendency for women to have higher CTS and ELE because women have more positive motivation, perseverance, self-confidence, and chemistry attitudes than men (Villafane, Garcia, & Lewis, 2014; Zeldin, Britner, & Pajares, 2008). Further, the research findings were also strengthened by the interviews results as follows:

> According to Ru (lecturer), "female students have stronger motivation, persistence, and confidence in studying or doing college assignments, which makes their curiosity higher than male students. It has an impact on their critical thinking skills".
>
> Sa (female) said, "I am very motivated and interested in studying chemistry because it is related to everyday life relevant to the experiences I got in the community, especially with the integration of chemistry with culture."
>
> Furthermore, Za (male) stated, "I feel more interested in doing experimental activities in the laboratory compared to learning chemistry which links chemistry with culture."

The higher women's CTS and ELE abilities than men shows that women can solve problems well. Robbins (1998) confirms that the female brain works more effectively and efficiently because the neurons that regulate the female brain communicate better than the neurons in the male brain, so women can complete tasks and work more effectively than men. In addition, the current research findings verified that women are more conscientious in solving problems than men. As Mawaddah, Ahmad, and Duskri (2018) stated, the differences in character between men and women. Generally, men are better at reasoning while women are better in accuracy, thoroughness, and attention to reasoning. Women scored higher than men on several critical thinking scales and higher-order critical thinking skills (Subina & Kulakli, 2019).

Moreover, other research findings also discovered that ethnochemistry-based learning experiences are higher in women than men. The application of ethnochemistry in learning integrates chemistry material with the students' daily experience, both in cultural products and the values of local Sasak wisdom. Similarly, Rahmawati and Taylor (2017) believe that integrating science culture will help teachers involve students in linking and analyzing chemical concepts with everyday life to make learning more meaningful. Besides, ethnochemistry has stimulated students' learning motivation by describing chemical concepts applied in cultural traditions that make students more interested in learning chemistry (Rickey & Stacy, 2000; Sumardi & Wahyudiati, 2021). In applying ethnochemistry, student involvement in new learning approaches, environments, and relevance to students' daily lives will maintain cultural identity and increase a sense of nationalism. Identity can be improved and be strengthened through dynamic social interactions through collaborative activities between students (Lee & Anderson, 2009). When students collaborate with other students, they develop their socially constructed identities in social or cultural contexts. Various previous studies have also proven that the learning environment, innovative technology, and learning strategies significantly improve students' chemistry learning experience (Osborne, Simon, & Collins, 2003; Calik et al., 2014).

Related to research findings based on the survey, women have higher ELE abilities than men. The following interview results supported this statement.

Fa (female) said, "I become more interested in studying chemistry because I got a learning experience integrated with everyday life experiences so that learning became more meaningful."

Hi (male) stated, "The system of lectures and practical activities in the laboratory is more interesting to me because it helps to prove chemical concepts through experimental activities compared to integrating chemistry materials with local culture."

The research findings are relevant to previous research which proved that critical thinking skills and ethnochemistry-based learning experiences affect student chemistry learning outcomes (Patonah et al., 2021; Wahyudiati, 2022). Therefore, it is very important to develop critical thinking skills and ethnochemistry-based student learning experiences so as to improve students' soft skills. In addition, given the differences between CTS and ELE based on gender, the development of CTS and LE during learning activities must refer to learning that is not gender biased so that male and female students have relatively balanced CTS and ELE abilities.

V. CONCLUSION

Based on the study results, it can be concluded that: 1) CTS and ELE levels of chemistry education students' are higher in female and freshman grades, and 2) there are differences in CTS and ELE based on gender. Also, the interview results strengthen the survey findings that female students have higher CTS abilities and have a more positive attitude towards implementing ethnochemistry-based learning. Referring to the research results, it is hoped that the implementation of chemistry learning activities will prioritize learning practices that are not gender biased through the application of a gender responsive learning approach. As for further research, it can be studied not only from the gender aspect, but also from the level of education so that the data obtained is more comprehensive.

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