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Identify Students' Critical Thinking Skills During Chemistry Learning Process of Molecular Shapes

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ABSTRACT

Critical thinking skills become essential skills for students demanded by the 2013 curriculum. Effective learning critical thinking is very important for students in the classroom. This study aimed to identify students' critical thinking skills during chemistry learning process of molecular shapes. The method applied in this study was descriptive qualitative with a case study approach. It was conducted at one of high schools in Bandung were the participants were the tenth grade students'. The instruments used for data collection were audio, video and observation sheets. The collected data were analyzed using Transcript Based Lesson Analysis (TBLA). The results indicated that four out of twelve indicators of critical thinking skill had been identified in learning molecular shapes. The four indicators are formulating questions, answering the "why" questions, focusing on a question, judging the credibility of the sources, and interacting with others. The low achievement of critical thinking indicators was due to the method used in teaching which is still informative or transferring knowledge from teacher to student (teacher-centered) without giving sufficient time for students to reflect the material presented, link it with prior knowledge, or apply it in real life situations.

1. Introduction

The 21st century skills has a great impact on various life aspects, including educational reform especially within the school level. It is important to prepare the generation to face the 21st century challenges by applying 21st century skills which include collaboration, communication, critical thinking, and creative skills, to develop competent human resources (Trilling et al., 2009).

The 21st century skills is needed to be integrated in various subjects especially in natural science, such as Chemistry, Physics, and Biology of the crucial

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components in technological era of 21st century. The role of natural science, especially chemistry, for future life is very strategic. It plays an important role in preparing students to be critical, creative, competitive, and able to solve problems and to help them make decisions quickly and precisely as they have to compete productively in the global digital era which are full of opportunities and challenges (Sударisman, 2015).

Among those skills, critical thinking skills are needed to achieve education goals. Critical thinking skills become essential skills for students demanded by the 2013 curriculum. In addition, one of the schools' main objectives is to increase students' ability to think critically and to make rational decision on what has been done or believed (Fuad, 2018). Effective learning critical thinking is very important for students in the classroom.

Critical thinking skill is the process of building reasons or arguments to decide what is believed and done based on reflective thought process (Ennis, 1985). In addition, critical thinking is an organization process that allows students to evaluate evidence, assumptions, logic, and language that underlies others' thinking (Johnson, 2007). This skill leads individuals to solve problems logically and appropriately. This is in line with Hassoubah (2002) who stated that critical thinking is a reasoned and reflective thinking activity with an emphasis on decision making based on what must be believed and done. According to Walker (2005) critical thinking skills teaches analytical skills, make messages using inductive or deductive reasoning, assess or make decisions, and make decisions or solve problems. Critical thinking means skills in assessing, wrong values, evidence, and judgments (Fuad, 2016).

Many education experts define critical thinking skills as follows. Trilling and Fadel (2009) defined critical thinking as the ability to analyze, interpret, evaluate, summarize, and synthesize information. Jones et al (2012) described critical thinking as the basis of future thinking skills which include the ability to analyze, detect and evaluate any possibilities happened in the future. According to Ennis (in Costa, 1985), there are twelve indicators of critical thinking skills namely: 1) focusing on a question, 2) analyzing arguments, 3) asking and answering questions of clarifications and or challenges, 4) judging the credibility of the sources, 5) observing and judging observation reports, 6) Deducing and judging deductions, 7) inducing and judging inductions, 8) making value judgments, 9) defining terms and judging definitions, 10) identifying assumptions, 11) deciding on an action, and 12) interacting with others.

Based on the aforementioned background of 12 indicators of critical thinking skills, the researcher conducted this study to assess students' critical thinking skills in learning molecular shape material. This study aimed to identify students' critical thinking skills emerged during the learning process in the classroom.

2. Methodology

The descriptive qualitative method with case study approach was applied in this study since the researcher intended to describe students' critical thinking skills during the learning process of molecular shapes topic. The subjects of this study were 32 students of grade X Natural Science program which was taught by a chemistry teacher at a senior high school in Bandung. The data were collected through observation of learning process by means of cameras and voice recorders to record the whole learning process. Then, the recorded video and voice were transcribed for further analysis. The description of students' critical thinking skills during the learning process was acquired based on the results of the analysis using the Transcript Based Lesson Analysis (TBLA) method (Arani, 2017). Transcript based lesson analysis is one of the lesson analysis methods used to analyze and reflect learning based on transcript. The analysis of critical thinking skills was based on five aspects with twelve indicators of critical thinking proposed by Ennis (1985).

3. Results and Discussion

The audio and video recording transcripts were analyzed using the Transcript Based Lesson Analysis (TBLA) technique and students' critical thinking skills identified according to the twelve indicators of critical thinking skills proposed by Ennis (1985). There were several critical thinking skills emerged during the learning process of molecular shapes in the classroom as follows.

Focusing on a question

Focusing on a question is one of the indicators of critical thinking skills included in providing a simple explanation where the sub-indicators consist of a) identifying or focusing a question b) identifying or formulating possible response criteria c) keeping mind at hand in any situation. The teacher gave a problem by asking students a question to measure the students' focus on the problem. The teacher provided motivation at the beginning of learning by giving an analogy of molecular geometry. The teacher gave analogy of molecular geometry by differentiating the properties of iron ruler and plastic ruler. The teacher asked the students: "what are the differences between iron ruler and plastic ruler if both are bent?" and "what about the iron one?" The students immediately answered "it will be bent". Then the teacher asked again, "what about the plastic one?" The students immediately answered "it will be broken". Then, the teacher asked again "how could it be like that?" Students immediately answered "because they were made of different materials". The teacher gave another question, "why do different materials affect the characters of things?" Students directly answered "because it is influenced by the molecular geometry". Then the teacher asked again "what is molecular geometry?" The students answered, "three-dimensional arrangement of atoms in a molecule". Then the teacher gave another question, "what is the difference between molecular geometry and Lewis structure?" The students

immediately answered “Lewis structure is only two dimensions, like two-dimensional figure”. The teacher asked again, “what is the difference with three-dimensional figure?” The students immediately answered, “we can see all the side of the figure”. The teacher asked again, “like a real thing, right?” Students immediately answered “yes”. The transcript can be seen in Table 1.

Table 1. Students’ Critical Thinking Identification in Focusing on a Question

Speaker T/S	Script
T	<i>What is that?</i>
SS	<i>Ruler</i>
T	<i>What is the ruler’s material?</i>
SS	<i>Ruler and plastic</i>
T	<i>What is the difference between iron and plastic ruler if they were bent?</i>
	<i>What about the ruler one?</i>
SS	<i>It will be bent</i>
T	<i>What about the plastic one?</i>
SS	<i>It will be broken</i>
T	<i>Why can it be like that?</i>
SS	<i>They were made of different materials</i>
T	<i>Why do different materials affect the characters of things?</i>
S1	<i>Because it is influenced by the molecular geometry</i>
T	<i>What is molecular geometry? Take a look at this (pointing at the power point slide. Molecular shape is the three-dimensional arrangement of atoms in a molecule</i>
SS	<i>Yes, it is three-dimensional arrangement of atoms in a molecule</i>
T	<i>What makes it different from Lewis structure?</i>
S2	<i>It is only two dimensions, like two-dimensional shapes</i>
T	<i>What about three-dimension?</i>
S2	<i>We can see the whole part of the things</i>
T	<i>Like a real one, right?</i>
SS	<i>Yes</i>

Based on the transcript above, the teacher encouraged students to think critically through the given questions. On the other hand, students did not ask any question because the teacher did not provide opportunities for students to think about the possible answers related to the analogy and the teacher gave insufficient stimulus to delve students' curiosity. Asking questions is an indication that students maintained their thinking conditions so that they focus on the problem. Moreover, by asking questions, students have high curiosity about a problem so that they can acquire knowledge (Sesen, et.al., 2010)

Analyzing arguments

Analyzing arguments is an indicator of critical thinking skills included in providing a simple explanation aspect where the sub-indicators consist of a) identifying conclusions b) identifying stated reasons c) finding similarities and differences d) identifying and dealing with irrelevance e) finding the structure of an opinion/argument, and f) summarizing. Nursiti (2013) stated that the basis of thinking in critical thinking skills is analyzing arguments. Furthermore, according to Farida (2015), arguing is a part of making decisions, defending them, and

influencing others. In addition, arguing shows the existence of critical thinking skills (Lailly, 2015). This indicator did not appear during the learning activities. Students were not able to express their opinions towards the problem. Students' lack of curiosity made them unmotivated to learn material in depth. Moreover, this indicator could not be identified during the learning as the students were lack of understanding and self-confidence.

Asking and answering questions

In this indicator, students were able to answer some questions given by the teacher such as answering the why questions, giving main reasons, and answering fact questions. The questions given by the teacher were critical questions about what, why, and how. The transcript during the lesson related to asking and answering questions is shown in Table 2.

Table 2. Students' Critical Thinking Identification in Asking and Answering Questions

Speaker (T/S)	Script
T	<i>What is the theory which explain about molecular geometry?</i>
S1	<i>VSEPER</i>
T	<i>That's not how the way you read it. It is VSEPR or in Indonesian it is Pasangan Elektron Valensi (valence electron pair)</i>
T	<i>So, the VSEPR theory is a geometrical arrangement which is formed as the result of electron pair repulsion. Can you explain, what does it mean?</i>
T	<i>Take a look at this CO₂, there are two O and a C. where are the O located?</i>
SS	<i>They are in the right and left side</i>
S1	<i>Why don't they locate in the right and below?</i>
S2	<i>Maybe they will be close ma'am</i>
S3	<i>Maybe there will be repulsion ma'am</i>
T	<i>Yes, go back to the previous explanation. There will be repulsion, so one on the left and one on the right.</i>
S1	<i>So they have opponent ma'am</i>

From the transcript above, it can be seen that students' critical thinking skills began to emerge even though the answers were still not perfect. In addition, the students have tried to answer what, why and how questions. This showed that students already had critical thinking skills based on asking and answering questions indicator.

Judging the credibility of the sources

Judging the credibility of the source indicator is included in building basic skills aspect. This kind of critical thinking skill can be identified if students can adapt the knowledge they acquire from solving the problems and from the sources, provide reasons, and be careful in any occasion. In this case, the teacher gave a compound to each group of students and asked they to determine the molecular

geometry of the compounds. Based on the given problems, students were required to find answers from various sources and adjust the sources they acquired. The transcript during the lesson is described in Table 3.

Table 3. Students' Critical Thinking of Judging the Credibility of the Sources

Speaker	Script
S1	Ma'am, the valence electron is 8, right?
T	Yes, is it from the addition of 5s and 5p?
S1	Yes
S2	But here it is 2, 2, 2, 2, 2
S1	It is 7, right?
S2	Here there is 1, this is 1, and we have another one, right?
S1	Wait a minute, let me open the book first
S3	I think, there should be 2 here, one here, another 1 here, and another 2 here.
S2	Hahh? It is still only 6
S3	Yes
S1	Is it 6? Should it be 8?
S2	Yes
S1	Wait (reading book)... As I remember, here should have 2 valence electron so we should write 2.. so it should be 8 but the position is here, here, here, and here... ehmm where do we need to put the last 2 electron?
S2	Aaaa... yes, I understand, so it should be here and here
S1	Yes, you're right
S1	Take a look at this table (looking at the molecular geometry table from the internet using cell phone)
S1	So, the lone pair is 2, right?
S2	Yes, so this is AB_2E_2
S1	Yes.... But I'm not sure about this. Is the electron here?
S1	Take a look at this! (pointing at Lewis structure about XeF_2 from the internet)
S1	But, it's quite different. The electron should be here, here, here, and here right?
S1	Wait! let's ask the teacher!
T	What is it?
S1	Is it like this ma'am?
T	This is 8, this is 9. Why does it 9? We move this here, here, and here so this is 8, here is 8 and 8 right?
S1	Ma'am, the electron is like this here. Is it ok?
T	It's ok, so what is the molecular geometry?
S1	Wait ma'am, (opening the book) the lone pairs are 3 right?
T	Yes
S1	So this means that AB_2E_3 is Trigonal..right?
T	Yes
S2	So it is similar with CH_4 right?
T	Are you sure? Find it first, OK?
S2	Oh no ma'am... wait a minute (opening book). Tetrahedral ma'am
T	Yes

From the identification result, it can be seen that students' critical thinking skills were emerged. The students considered to use various sources they acquired. This revealed that students already had critical thinking skills based on judging credibility of sources.

Observing and judging observation reports

Observing is part of experiment activity in learning. Experiment-based learning requires students to be active in learning and practice their critical thinking skills through experimental activities that involve students to observe, analyze, and draw conclusions. Experimental activities in learning was able to provide learning environment which can develop students' critical thinking skills. Through observation, students could create knowledge, and use the facts or evidence from the experiment data as the observation report. However, the learning process on molecular geometry material without experiment activity. The teacher mostly explained the theory and provided non-experimental worksheets for students. Therefore, this skill could not be identified during the learning.

Deducing and judging deductions

Deducing is an indicator of critical thinking skills that are included in deducing aspect. The purpose of this indicator is to draw conclusions based on the result of data analysis (Ennis, 1985). The conclusion drawing or deduction process can be done by interpreting the data. Students were given data and they must analyze the data. However, during the learning process, this skill could not be identified. In fact, students could deduce by delving literature from various sources as the reference materials. However, the teacher did not apply that and the students were still dependent on the teacher. Therefore, they could not understand the concept autonomously. This could be caused by the inquiry strategy that had not been trained.

Inducing and judging inductions

Inducing is an indicator of critical thinking skills in deducing aspect. The purpose of inducing indicator was general inference based on the knowledge obtained from specific facts (Ennis, 1985). During the learning process, this indicator could not be identified due to the fact that learning is predominantly lecture method. Although learning activities were conducted in groups, the students were still dependent on the teacher. Thus, they could not understand the concepts independently.

Making value judgment

Making value judgement is an indicator of critical thinking skills in deducing aspect (Ennis, 1985). This indicator could not be identified during the learning process because of insufficient teacher strategies in teaching. For example, the selection of learning methods was less appropriate for molecular geometry materials which was considered abstract. The teacher as a facilitator should meet students' various needs to achieve the learning objectives. In developing critical thinking skills, many factors must be considered. Strategies, approaches, methods,

and media used by teachers in learning process play a crucial role in developing critical thinking skills.

Defining terms and judging definitions

Defining terms and judging definitions is an indicator of critical thinking skills in providing further explanation aspect. This skill did not emerge during the learning activities. The learning activities illustrating this indicator did not appear during the learning since as the teacher did not provide opportunities for students to deduce what molecular geometry is. The teacher directly explained the definition of molecular geometry while the students were instructed to note the definition. The transcript during the lesson of this indicator is presented in Table 4.

Table 4. Students' Critical Thinking in Defining Terms and Judging Definitions

Speaker	Script
T/S	
T	<i>What is the meaning of molecular geometry/Take a look at this (pointing at the power point slides). Molecular shapes are the three-dimensional arrangement of atoms of a molecule.</i>
T	<i>Yes, please write it down</i>
SS	<i>Yes ma'am, please explain it slowly</i>

As a result of the assessment, that students' critical thinking skills on identifying terms and judging definitions could not be identified. The teacher as a facilitator, should be able to provide students' various needs to achieve the learning objectives. In developing students' critical thinking skills, many factors must be considered. The strategies, approaches, and learning methods used by teachers play an important role in developing critical thinking skills.

Identifying assumptions

Identifying assumptions is part of critical thinking skills indicators that is included in the providing further explanation aspect. Assumption is a perception that is considered to be a temporary truth for the assumption maker. In learning process, assumptions can be in the form of hypotheses. During the learning process this skill did not appear. Due to the approach used in learning activities which was not in line with the material being taught. During the lesson, the teacher was only oriented on the development of concepts without training the students to build their own concepts. One way that the teachers can do to assist students to hypothesize was by asking various questions to encourage students formulating temporary answers or various possible answers to the problem (Sanjaya, 2008: 202). Inquiry approach is an approach to construct knowledge based on the development of students' curiosity, direct students to ask questions to develop their concepts, and use 'why' and 'how' questions during the learning that is suitable for scientific research (Koksala, 2014). Therefore, the inquiry approach in learning can foster critical thinking skills through students' curiosity.

Deciding on an action

Deciding on an action is an indicator of critical thinking skills included in managing strategy and tactics aspect. One of the goals of critical thinking skills is to be able to make decisions of a problem. According to Ennis (1993) critical thinking skills as a thinking process aims to develop the ability to make decisions which can be accounted for the things being done and believed. In the learning process, this indicator could not be found. The lesson taught by the teacher did not give any challenge for students to understand the concept independently which made them to be passive. The absence of this skill can be caused by the teacher's insufficient understanding on the importance of critical thinking skills for students. These skills are important for students to make decisions or act appropriately towards something.

Interacting with others

Interacting with others is an indicator of critical thinking skills which is included in managing strategy and tactics aspect. During the lesson, this skill was observed. One of the sub indicators is doing spoken and written presentation. The students already had the ability to interact with their peers within the group and the other groups.

Students interacted in a group to discuss about how to make Lewis structures from ClF_3 compound. After finding the right Lewis structure, they presented to another group behind them. Student discussion activity could make them practice their ability in collaborating to develop their critical thinking skills and other abilities. This is in line with a study conducted by Curran et al (2013). They found out that collaborative learning could help students since there was cooperation or social interaction during the learning process which resulted on students' understanding of the materials, critical thinking ability, learning abilities, interpersonal relationships among students and between students and teachers, and more positive attitude during the lesson.

4. Conclusion

Based on the findings and discussion above, it shows that the critical thinking skills of high school students in learning applied by chemistry teachers to molecular shapes, It was found there were four out of twelve indicators of critical thinking skills by Ennis, (1985). The four indicators were focusing on a question, asking and answering questions, judging the credibility of the sources, and interacting with others. The low achievement of critical thinking indicators was due to the method used in teaching which is still informative or transferring knowledge from teacher to student (teacher-centered) without giving sufficient time for students to reflect the material presented, link it with prior knowledge, or apply it in real life situations.

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