

# Metacognitive Analysis of Pre-Service Teachers of Chemistry in Posting Questions

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**Abstract.** Questions addressed to something can induce metacognitive function to monitor a person's thinking process. This study aims to describe the structure of the level of student questions based on thinking level and chemistry understanding level and describe how students use their metacognitive knowledge in asking. This research is a case study in chemistry learning, followed by 87 students. Results of the analysis revealed that the structure of thinking level of student question consists of knowledge question, understanding and application question, and high thinking question; the structure of chemistry understanding levels of student questions are a symbol, macro, macro-micro, macro-process, micro-process, and the macro-micro-process. The level Questioning skill of students to scientific articles more qualified than the level questioning skills of students to the teaching materials. The analysis result of six student interviews, a student question demonstrate the metacognitive processes with categories: (1) low-level metacognitive process, which is compiled based on questions focusing on a particular phrase or change the words; (2) intermediate level metacognitive process, submission of questions requires knowledge and understanding, and (3) high-level metacognitive process, the student questions posed based on identifying the central topic or abstraction essence of scientific articles.

## 1. Introduction

Students who are learning then ask questions, they are thinking involving metacognitive knowledge. Activities students ask questions would trigger the use of deep thinking strategies, and if students do not ask questions, strategic thinking will not show up [1,2]. Also, questions students have substantial potential, which is to direct the investigation and guide the formation of students' knowledge. The question of students are thinking the tool to encourage meaningful learning, and as a useful feedback to teachers about student understanding [3]. Questions help us to understand the world and construct meaning from the data and information, as a psychological tool to think because questions help to explore and scaffolding ideas, directing specific thinking in a particular direction, and can enhance students' understanding of phenomena and scientific concepts [4]. Thus, asking is the key to active, meaningful learning, and as the heart to do scientific work in all disciplines of science and technology. Therefore, in teaching and learning, the skills of students to ask questions need to be developed and facilitated.

The findings of several studies illustrate that the questions are produced by teachers and posed to students or question that has been available in textbooks. The teacher assigns students to answer the questions so that students hardly have any questions during the learning takes place [5,6]. This finding is supported by Kaberman & Dori [7] in his research report, the phenomenon with increasing level of students education rarely ask the question had even stopped asking. The consequences of this



condition will have an impact on the majority of learner's impaired ability to formulate questions and to conduct an investigation. The next consequence is certainly reducing the level of students' activity in constructing their knowledge based on what became an issue for him or her.

Several studies related to asking questions have been done. For an example, inquiry activities in the chemical laboratory [8], questions teachers to stimulate productive thinking [4], computer-based environmental laboratory activities [9], arguments in discussion groups in science classes [10], and the attitude and practice of teacher's questions in science classes [11]. The influence of external metacognitive activities to produce the questions in learning are less effective [7]. Meanwhile, effective questioning influenced by internal metacognitive activities such as the metacognitive process of student, this research is still not many to do. Based on these finding, the exploratory of the level and the metacognitive process of pre-service teachers of chemistry in posing questions will be done. The fundamental questions of research are: (1) what do questions profile of pre -service teachers' chemistry? (2) how do the characteristics of the metacognitive process of pre-service chemistry teachers in developing skills of posing questions?

## **2. Literature Review**

### *2.1. Metacognition in learning*

The search for meaning is the core of any educational activity. In the process of the search for meaning requires critical thinking and inquiry. Critical thinking and inquiry based on the awareness and ability of learners to take responsibility and control in constructing meaning and confirm knowledge. Awareness and ability is an attribute of metacognition [12].

Metacognition is defined as "thinking about thinking" involves the awareness and control of one's cognitive processes [13]. National Research Council (NRC) defines metacognition as the process of pondering and directing his thinking. Application of metacognitive skills in learning requires knowledge of learning strategies and awareness of when to apply the right strategy [14]. Also, the control or regulation is also necessary to examine what is currently known and determine what still needs to be studied [13]. Thus, it can be said that metacognition is someone's reflection and awareness on the cognitive processes to induce self-regulation and coordinating learning tasks.

Conceptualization of metacognition consists of two dimensions, i.e. knowledge of cognition and the regulation of cognition [12]. In general, knowledge of cognition refers to what people know about their cognition. Knowledge of cognition includes declarative knowledge, procedural and conditional. Declarative knowledge is knowledge of ourselves as learners and what factors affecting our performance. Conditional knowledge includes knowledge about why and when to use a particular strategy. Individuals who have a high level of knowledge of the conditional will be better able to assess the situation demands a certain learning, and in turn, choose the most appropriate strategy for the situation [14,15].

Regulation of cognition consists of three components, planning, monitoring, and evaluation [14,15]. Planning involves selecting the strategy and the right resources, goal setting, activate the relevant background knowledge and set the time and budgeting. Monitoring involves looking back and skills of self-examination, which is required to control the learning. Evaluation relates to assessing the regulatory process of learning and learning outcomes of a person. Example: re-evaluate one's goals, revise predictions, and consolidate intellectual acquisition.

### *2.2. Asking questions as Metacognitive Skills*

In metacognitive perspective, an asking question serves to know what they know and what they do not know [16]. In asking the question requires the application of knowledge of cognitive and metacognitive strategies, but the extent to which this strategy can be applied vary widely depending on the area of content and knowledge students. When students practice asking questions will lead to self-awareness on the success of his understanding.

Asking questions directed to higher-level thinking plays a central role in understanding, monitoring comprehension, self-testing and self-control. To become active learners and independent thinkers, learners should generate questions that form, focus, and guide their thinking [17]. Several studies have found that metacognitive activities externally imposed, for example by teachers, generate questions that are less effective than those produced by students [7].

Students who have good metacognitive skills will become active learners that make learn more fun and effective [14]. Evidence suggests that metacognitive activities have a positive impact on students' thinking and awareness of student learning at both the secondary and college education [18]. Activities metacognition is intended to provide the knowledge, awareness and critical strategies in the learning process [12]. According to Schunk [19], the development of metacognitive skills correlated with achievement and success of student learning. These statement supported by Stewart et al. [20] who state that students with better metacognitive skills gained great academic success.

### *2.3. Asking Questions in Learning*

Asking questions in learning activities has long been recognised as a useful strategy to improve the formation of knowledge and increased interaction of learners to share thoughts [11]. Almeida [21] suggest that the students involved in the process of asking questions can help the cognitive growth of students. Blonder [22] explains further that the most important lesson is to challenge students to take an active role to ask questions that can encourage independent learning. The results of questioning activity is to give students the opportunity to: (1) developing communication, teamwork and skills to self-evaluation among them myself and my fellow colleagues, (2) increase the higher order cognitive processes such as evaluation, reflection and critical thinking, (3) encourage active learning, (4) to encourage deeper learning, and (5) improving student feedback process [23].

Questioning skills have been recognised as an essential component to promote inquiry learning potential in developing scientific thinking and support the formation of critical thinking of students, therefore, need to be emphasised in learning, especially in science education [5]. If the teacher focuses on a student only to find the answers, it means teachers stop students to think, otherwise, if the teachers can teach students to ask questions and provide an opportunity for students to ask, it means the teachers create the stage of the student to think [6]. In another word, thinking is driven by the question, therefore, the creation of a learning strategy that supports an environment in which students questions can generate other students to ask question need to be done. The types of questions that generate more questions or productive are critical questions [2]. The critical question is induces to high-level cognitive processes, such as the analysis of ideas, comparison and contrast, inference, prediction, and evaluation [16]. When such as learning strategies are provided, so students and teachers will be actively involved in the process of critical thinking. This learning strategy in line with the standards of the learning process in Curriculum 2013 [24].

### *2.4. Categorization of Student Questions*

The classifying types of questions students are difficult to establish. However, a certain criterion can be made to classify the types of student questions. Watts et al. [25] offer a way to analyse the kinds of questions that occur in science classes, into three categories: consolidation, exploration, and elaboration. Categorization of these questions is an effort to distinguish between questions that are seeking to understand, resolve conflicts, examine the situation, give a discourse (the issue), and keep track of ideas and their consequences.

## **3. Research Methodology**

This research is a case study in learning basic chemistry. Study participants have involved as many as 87 students of Chemical Education FKIP UNTAD. The research instrument was questionnaire-based student worksheets. Questionnaire-based student worksheets (WS) was used to explore the skills students to pose questions. In WS, students were asked to read an article teaching materials and a scientific article, and then students asked to submit questions in writing. Questions students analysed their contents by using the classification of questions developed by Kaberman & Dori [7]. The classification of these questions consists of, (1) thinking level, a question that requires a response at the level of higher thought than knowledge; and (2) chemistry understanding levels, are questions that seek answers by understanding the chemistry symbolic, macroscopic, microscopic, and process. Each student questions were analysed separately for the level of thought and the level of understanding of chemistry using the rubric as presented in Table 1. The question was given a score. A score of the students is a combined score of the level of thinking and understanding the chemistry which is classified into three groups, i.e. high, medium, and low. Two students from the group were interviewed using the think-aloud method, to explain why they ask certain questions.

Table 1 Rubric to assess the skills of the students ask questions (adapted from [7]).

Score	Thinking levels	Chemistry understanding levels
0	The question requires an answer fully described in the article	The question does not require an answer with an understanding of one aspect of chemical thought (symbols, macro, micro, or process)
1	The question requires an answer with the level of knowledge and understanding.	The question requires an answer with only one aspect of understanding the chemical thought.
2	The question requires an answer to the understanding and application-level thinking.	The question requires an answer to the understanding of the two aspects of chemical thinking
3	The question requires an answer to the thinking level of analysis and synthesis, for example, analysis of information and applications, the ability to identify problems and make conclusions, prediction, assessment, took the position.	The question requires an answer to the understanding of the three aspects of chemical thought.

#### 4. Results and Discussion

Exploration inquiry carried out by the students were given the task of reading the teaching material and scientific articles, and students asked to submit questions in writing. Each student questions were scored separately according to the level of thinking and understanding the chemistry. The total score of the question is the sum of these two values the question level. The example such as a question analysis presented in Table 2. Distribution of skill student questions on the teaching material is presented in Figure 1 and 2.

Tables of research data show changes in levels of student skills in asking questions. Level questioning skills of students to scientific articles is more qualified than the level questioning skills of students in the teaching materials. Changes in the level of thinking skills that occur, namely: (1) knowledge question decreased by 20%, (2) a question of understanding and applications increased by 15%, and (3) higher-level thinking questions increased by 5%. Changes in the level of the chemical comprehension skills, namely the question of symbols and macro decreased by 6.89% and 10.35%, while the question of micro, macro-micro, macro-processes, micro-process, and the macro-micro-process increased by 6.89%; 1.15%; 5.75%; 2.29%; and 1.15% respectively. In this study, we analysed the quote "think-aloud" when students ask questions. Quote "think-aloud" is assumed as representations of student metacognitive process. There are three profiles of students when asked a question. First, the students asked after finding or are interested in a particular sentence. Examples of student "A" ask a question "whether there are other substances contained in the nine turns into acetic acid?" The question relates to the fact that in the article. Answers to these questions include the level of knowledge of thinking; the answer is a list of names of substances in the nira that has been written in the article. If the questions from the students "A" were analysed using the chemical comprehension level, the answer requires only one chemistry understanding level, namely the macro (the name of the substance).

**Tabel 2.** Analysis of the question: (a) example 1, (b) example 2, and (c) example 3

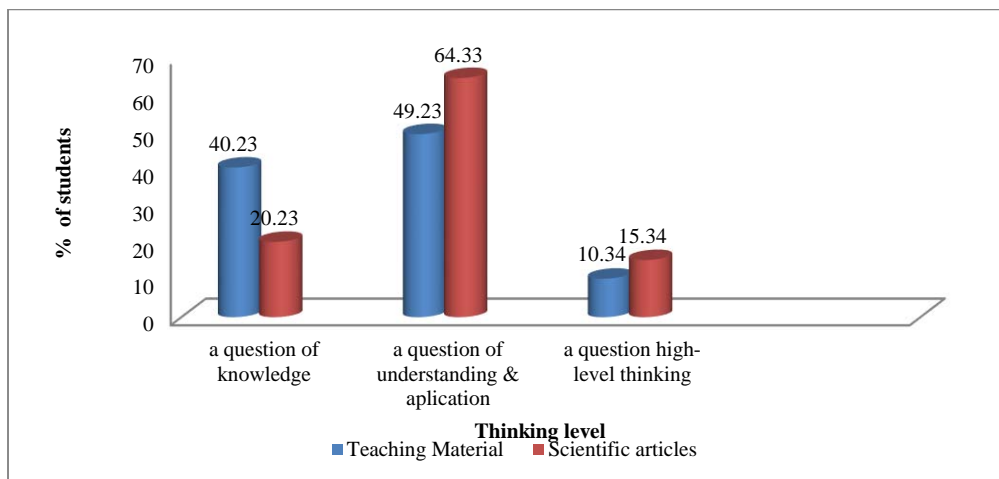
Aspect	Thinking Levels	Chemistry understanding levels
(a). Example 1: What is the chemical reaction rate?		
Answer only requires knowledge of thinking level, which is just a definition		Answer only requires an understanding of the level of symbols: $\text{mol/Ls}^{-1}$
Score	0/3	1/3
(b) Example 2: What is the relationship between the rate of decomposition of $\text{N}_2\text{O}_5$ and $\text{NO}_2$ formation on the decomposition reaction $2\text{N}_2\text{O}_5(\text{g}) \rightarrow 4\text{NO}_2(\text{g}) + \text{O}_2(\text{g})$ ?		
The answer requires understanding and application-level thinking.		Answer require two levels of understanding chemistry: <ul style="list-style-type: none"> <li>• Symbol: chemical equation</li> <li>• Process: The decomposition of a chemical reaction rate of <math>\text{N}_2\text{O}_5</math></li> </ul>
Score	2/3	2/3
(c) Example 3: Example 3: What are the molecular collision theory and activated complex can explain the changes fast, slow, and there is no change in a chemical reaction?		

Answer requires thinking level analysis of information, the ability to create relationships between concepts, and make inferences

The answer requires three levels of understanding chemistry:  
 Micro: the reaction rate  
 Micro: collisions between molecules  
 Process: reaction changes, fast, slow, and there was no change

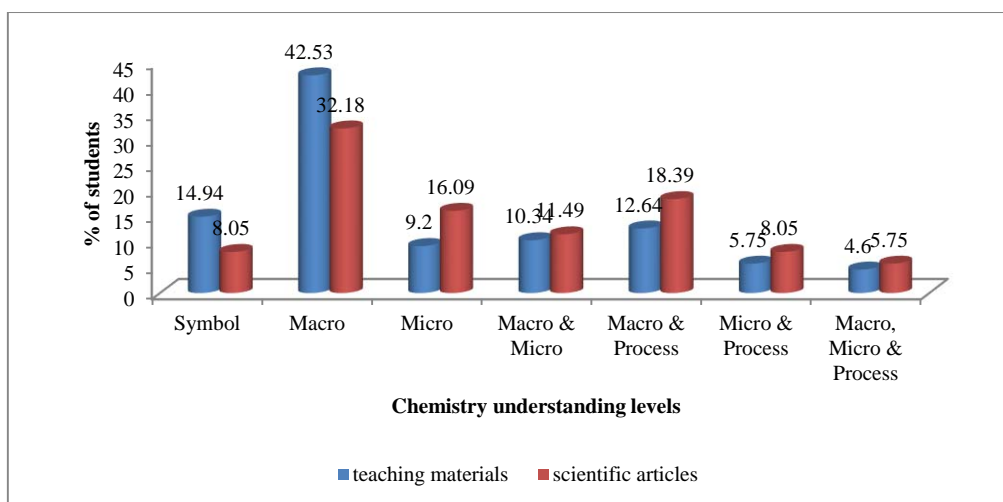
Score 3/3

3/3



**Figure 1.** Distribution of skills students questions according to the thinking levels for teaching materials and scientific articles.

Second, students ask questions after they tried to know and understand the contents of some or all articles, as an example of a student "C" to ask "How did the fermentation of sucrose in the nira occur? Moreover, how mechanisms of reaction? "Through the interviews revealed that questions arose after students read thoroughly and make records that need to be studied further. It means that students recognise the need to ask questions that require detailed explanation. The answer to this question requires a level of knowledge and understanding of thought t. While the answer at the level of understanding the chemistry requires two levels, namely the symbol (equation) and processes (chemical reaction mechanisms for the formation of acetic acid by catalytic enzyme invertase). Third, the questions asked by the students based on the identification of issues referring to the central topic of the article or the result of abstraction. For example, a student "D", ask "How different the effect of temperature on the rate of reduction of sucrose and the rate of formation of acetic acid?" The student is aware of the need to ask questions of the investigation.



**Figure 2.** Distribution of skills students questions according to the chemistry understanding levels for teaching materials and scientific articles.

The answer to this question requires thinking the level of understanding, analysis and prediction; while the answer at the chemistry understanding level needed four levels. They are symbol chemical equations; macrophysical shape and taste of sucrose and acetic acid compounds; micro: the rate of sucrose reduction and acetic acid formation; process: chemical reactions mechanisms of sucrose reduction and acetic acid formation. Based on the description of the process analysis students questions mentioned above and according to Kabermen & Dori [8], the questioning student can be classified into three groups metacognitive process; (1) low-level metacognitive process, students formulate questions based on a specific sentence; (2) intermediate level metacognitive process, students formulate questions after knowing and understanding, and (3) high-level metacognitive process, students make questions based on the results to identify the central topics or abstraction the essence of scientific articles or teaching materials.

#### 4. Conclusion

The profile of the questions formulated by chemical education students has a level of thinking, chemistry understanding, and metacognitive process. In term of thinking level, the questioning student consists of three types, i.e. knowledge, understanding and application, and higher level thinking. In the chemistry understanding levels, the questioning student has seven categories; symbol, macro, micro, macro-micro, macro-processes, micro-process, and the macro-micro-processes. While on the line with the metacognitive process level, the questioning student has three kinds; low-level metacognitive process, medium level of metacognitive process, and high-level metacognitive process. Level questioning skills of students to scientific articles is more qualified than the level questioning skills of students in the teaching materials.

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