Biology student’s Understanding of Nature of Science (NOS) and metacognitive awareness at higher education

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Abstract. The nature of science (NOS) is a crucial aspect of scientific literacy and also a major goal in science education. To achieve science education goal, students’ knowledge and metacognition are highly required. This study described Biology student’s understanding of NOS and their metacognition at higher education. This study was a survey of semester-four students. Data on NOS was from the Views of Nature of Science (VNOS) questionnaire form B, and students’ metacognition data was from the Metacognitive Awareness Inventory (MAI) questionnaire. Data were analyzed descriptively. The results showed that the average of biology students’ NOS understanding is 60.35%. Based on seven aspects of NOS understanding studied, the highest achievement is in the empirical-based science aspect (68.69%), the lowest performance is in the subjective science aspect which is full of theoretical content (49.49%). Students’ Metacognitive regulation has a lower average (77.4%) than metacognitive knowledge (81.33%). It is found that Biology student’s NOS understanding is still weak, and their metacognition still needs to be fixed. This research suggests that biology student’s NOS understanding and metacognitive awareness still needs to be upgraded through the learning process so that students would be scientifically-literate and successful in their higher education.

1. Introduction

Students majoring in science learn material and scientific knowledge that consists of theory, concept, principle, and law through lecturing process. Strengthening students’ understanding of scientific material is usually done by conducting experiment and scientific inquiry through practicing. Students are expected to have a good understanding of the nature of science. The construction of the understanding of the nature of science and scientific inquiry is the purpose of science education and it is recommended in science education. The Next Generation Science Standards posses literacy vision that emphasizes the understanding of science concept and also the connection between the concept (interdisciplinary), skill, and also the knowledge related to scientific inquiry (science process) [1].

Nature of Science (NOS) is defined as the nature of knowledge that poses complex concept involving philosophy, sociology, and history of knowledge. Learning Nature of Science refers to the epistemology and sociology of science, science as the way of knowing, or values and beliefs attached to the development of scientific knowledge [2]. NOS describes what science is, how it works, how a scientist works and how society is influencing and also influenced by science, and how scientific ideas are obtained [3, 4]. The characteristics of NOS are tentative, empirical-based, theoretically loaded, a product of human inference, creative and imaginary, and socially and culturally embedded [5, 6].
Nature of Science is a part often ignored in the teaching of science and biology whereas it supplies the students the ability to analyze how science and scientist work, how scientific knowledge is obtained, validated and used [7]. It is reported that students did not have adequate Nature of Science conception [4]. Pre-service science teachers were reported to lack understanding of Nature of Science (NOS) as they did not understand the difference between theory and scientific law and did not understand the aspects in NOS [8]. These would lead to misconception since the aspects in Nature of Science are needed to be taught and understood.

The understanding of Nature of science is critical to be mastered by the students. In the society that is highly affected by science and technology, it is crucial to develop students’ ability to think scientifically, to understand the surrounding world, to make decisions and to act for personal and social interest [9]. The key component of NOS has to be the focus on science learning because it plays a basic role in developing scientific literacy [3]. The students need to have a good understanding of scientific belief and practice and also decent conception on Nature of Science to develop scientific literacy.

One of the science education critical goals is to promote students’ science literacy [10]. The three components of science literacy are the contents of knowledge, scientific inquiry, and NOS. Science literacy emphasizes the understanding of science concepts and also on how science is obtained. Understanding the NOS is expected to improve the learning outcomes about science material, the interest in science, and decision making on science issues. Therefore, the students who study science would need some strategies to have a good understanding of NOS and to be able to apply science in their life.

One of the ways to obtain a good understanding of science is to implement metacognition strategy. The metacognition strategy is a sequential process used to control cognitive activities and to ensure that cognitive goals are attained. It consists of planning, monitoring cognitive activity, and evaluating the result of these process [11]. Metacognition is the capability to do self-control associated with learning, decision-making, problem-solving, and managing existing resources. It refers to knowledge, awareness, and self-control of the students who are studying [12].

According [13], metacognition could be taught. It is also stated that students who learn metacognition have better learning outcomes and also develop a higher level of thoughts. Metacognition empowerment would affect the improvement of cognitive learning outcomes and the mastery of concepts. The role of parents, teachers, and environment are supportive of the students’ development in learning process. Teachers need to understand their students’ capacity to direct their own learning process both inside and outside the classroom [13]. Therefore, pedagogical goal in learning should improve metacognition. Students are expected to apply metacognition as a tool to achieve science learning goals meaning to understand the Nature of Science and to employ metacognitive awareness as a device to solve problems in life. Based on the explained background, the purpose of this study is to describe students’ understanding of Nature of Science and metacognitive awareness to learn science at the university level.

2. Methods
This study applied survey research method. By definition, survey research is qualitative research where the researcher conducts a survey on sample or whole population to describe attitude, opinion, behavior, or characteristic of population using questionnaire [14]. The survey was conducted on the fourth-semester students of biology department to gather the profile of understanding of Nature of Science and their metacognitive awareness in learning in university. The data was gathered from March to April 2019 in even semester 2018/2019 academic year in the Biology Department, Faculty of Biology, Mathematics, and Science, Semarang State University. The research subjects were 66 fourth semester students. Instruments applied in this study were:

1. Data about the understanding of Nature of Science. It was collected using the Views of Nature of Science (VNOS) form B questionnaire adapted [15, 5]. Seven aspects of Nature of Science measured in the study were: science is tentative, empirical-based, subjective, a result of inference, creative and imaginary, socially and culturally embedded, the difference between observation and inference, connection between theory and scientific law.
2. Metacognitive Awareness Inventory (MAI) questionnaire adapted from metacognition questionnaire, consisted of 50 questions with two answer choices, True or False [16]. Data were analyzed in descriptive percentage to define the understanding of Nature of Science and metacognitive awareness of the biology students.

3. Results and Discussions
The focus of this study encompasses seven indicators of NOS. All the indicators have been described specifically. The results are presented in Table 1.

| No  | Indicator of NOS                                                      | Students’ Understanding (%) |
|-----|-----------------------------------------------------------------------|-----------------------------|
| 1   | Science is tentative                                                  | 66.16                       |
| 2   | Result of inference                                                   | 65.15                       |
| 3   | Difference between theory and law                                     | 56.57                       |
| 4   | Socially and culturally embedded                                     | 65.91                       |
| 5   | Role of human creativity and imagination in science                  | 50.51                       |
| 6   | Empirical based                                                       | 68.69                       |
| 7   | Science is subjective or theoretically loaded                         | 49.49                       |
|     | Mean                                                                  | 60.35                       |

Table 1 shows the understanding of Nature of Science of Biology Department students at seven indicators of NOS gaining the mean score of 60.35%. It means that students’ understanding of NOS still needs to be optimized. The mean score of students’ understanding of NOS was low because students did not know the aspects that construct the Nature of Science yet. The aspects of science were not specifically studied in particular subjects. It had not been one of the learning goals that integrated into the curriculum. The concept of NOS was briefly introduced in General Biology class. It was discussed in the chapter of the scientific method, including how the scientists apply the steps of scientific methods and the result obtained in scientific inquiry. The empirical result of inquiry obtained by scientists comes from observation, experiment, and also inference. It is tentative and contains imaginary and creativity from the scientists, and it is also subjective.

The development of adequate view about Nature of Science should become a fundamental point for students to understand the potential and limitations of science and it would also contribute to the development of science literacy. Modeling is considered crucial as it helps the students to construct and to develop a consistent mental model [3]. Nature of Science as the epistemology of science could be learned and taught to the students. There are two ways to teach the Nature of Science to students, implicitly and explicitly. Implicitly, it is a learning process involving students in an inquiry which requires process skills that promote the students’ understanding of Nature of Science automatically. Explicitly, it is a learning process where students’ understanding of Nature of Science is designed with consideration to the understanding of Nature of Science as a cognitive result.

This study found out that the lowest understanding of NOS was in the indicator that science is subjective or theoretically loaded (49.49%) and in the indicator of human creativity and imagination role in science (50.51%). It happened because students have not had a good view yet that science is subjective. It was considered contradictory with the subjective characteristic of scientific observation. Students had not had the ability to place the subjective characteristic of science. Some students had not been aware that scientists doing scientific works have beliefs, prior knowledge, experiences, and hopes that could affect their works. All these background factors formed a mindset that affected the problems being investigated and how they did the investigation, things being observed and things not being observed, and the way they understood or interpreted their observation. Science has never been started with a neutral observation, yet it is always based on certain perspective in finding for meaning and answer from every question [5, 15].
Table 2. Summary of students’ views about NOS

| No | NOS Indicator                                                                 | Students Answer Patterns                                                                                                                                                                                                 |
|----|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Science is tentative                                                          | The theory could change along with the time and the development of science and technology. Even though it could change, the old theory still is studied to understand more by comparing the old and new one; A theory is not changeable, it is being perfected by new theories. |
| 2  | A result of inference                                                          | Plant and animal cell structure are different when observed under the microscope. Scientists make verification by observing the cell structure under the microscope; Scientists are highly confident about the shape and structure of plant cell proven by direct observation under the microscope. |
| 3  | The differences between theory and law                                         | A scientific theory is a theory obtained from research that will be used by many people. A scientific law is the fundamental rules of scientific research, A scientific theory is an explanation system that is internally consistent, established, and highly proven. A scientific law is a descriptive statement about the connection between observed phenomena. |
| 4  | Socially and culturally embedded                                               | Science and art are deemed similar as both need imagination and creativity. Both also need developing thoughts; Science and art are deemed different as art has more freedom and applies high imagination, while science has a tendency to research objectivity; Science and art are not alike because art is limitless, while science has certain limits and rules. |
| 5  | The role of human creativity and imagination in science                        | Scientists are applying creativity and imagination in collecting data, for example when drawing table to record observation. Imagination is needed to visualize/describe things being observed; The role of creativity and imagination when formulating hypotheses; Creativity and imagination are unnecessary when collecting data since science uses the scientific process. |
| 6  | Empirically based                                                              | Scientific knowledge is based on supporting and rational scientific evidence. Scientific knowledge is based on accountable scientific attitudes and thoughts. Information gathered is based on natural observation and the validity of a scientific claim. |
| 7  | Science is subjective and theoretically loaded                                 | The scientists’ research results could be different from one another. Every scientist has views and references that might be different; every scientist has a different point of view; Research result could be different due to time difference and also the theory and consideration difference. |

Students’ understanding of the aspect of human creativity and imaginary role in science gained 50.51%, means that it still needs some improvement. This is because students have not had a strong understanding of the role of creativity and imagination in science yet. The result of V-NOS form B questionnaire showed that students were not sure about the role. Some students stated that creativity and imagination are unnecessary because science is done by scientific process, that the data obtained are the way it is without any manipulation. Students’ understanding was limited in that they interpreted creativity and imagination as immeasurable and invalid. NOS has clarified that science is all rational and measured, not a stagnant activity. Science involves findings, explanations, and theoretical entities which need scientists’ creativity [5]. Students’ answers on every question were analyzed so that it indicated a tendency or a pattern. Summary of students’ answers are presented in Table 2.

The data recapitulation about students’ views on NOS indicated that there were various views about students’ understanding. Some of the students’ views were already correct in certain indicators. However, some other views were still incorrect. In the first indicator (science is tentative), students generally had a correct view that the scientific claim could change due to new evidence is found and the development of science and technology. However, there was a doubtful answer that said the cell theory...
remains the same and unchanged. The indicator of inference result showed that students were able to explain the structure difference between plant animal cell, but they did not mention the difference of detailed structures. The microscopic cell was not explained in detail.

It is showed in the difference between scientific theory and scientific law indicator that students were able to explain a scientific theory, which generally was correct. However, the explanation of scientific law was incorrect since they said that law is absolute while the law could change. In the socially and culturally embedded indicator, the students generally were able to differentiate between science and art. There was a statement that the difference between science and art laid in the limitation. It is stated that science is limited by scientific law, while art is unlimited. In the 5th indicator, the role of human creativity and imagination in science indicator, it is showed that some students already had the right view that creativity and imagination used by scientists. However some students were doubtful to place the creativity and imagination in science practice. The empirically-based indicator showed that students were able to differentiate scientific knowledge and opinion but did not mention the example. On the science is subjective indicator studying the students’ views on various results of scientists’ research (that science is subjective), the reason stated were correct. However, most of them were still doubtful and could not apply the subjective nature of science. Research results about metacognitive awareness of students in the Biology Department are presented in Table 3 and 4.

Table 3. Knowledge of Metacognition

| No. | Knowledge about Cognition       | Score |
|-----|--------------------------------|-------|
| 1.  | Declarative Knowledge           | 82    |
| 2.  | Procedural Knowledge            | 81    |
| 3.  | Conditional Knowledge           | 81    |
|     | Mean                            | 81.33 |

Table 4. Regulation of Metacognition

| No. | Regulation of Cognition        | Score |
|-----|--------------------------------|-------|
| 1.  | Planning                       | 77    |
| 2.  | Comprehension Monitoring       | 69    |
| 3.  | Information Management Strategies | 73   |
| 4.  | Debugging Strategies           | 89    |
| 5.  | Evaluation                     | 79    |
|     | Mean                            | 77.4  |

This research found that the mean score of metacognition knowledge of the biology students was 81.33. It means that the students were aware of self-thinking and could differentiate the input-elaborate-output steps in their mind. They occasionally applied some models to manage how they think and how they study. This showed that biology students were aware of their conceptual, procedural, and conditional knowledge. However, metacognition knowledge is still needed to be improved to reach the “super” category. Achieving this category means the students would be able to manage their metacognitive awareness systematically to regulate their thinking and studying processes.

Students were aware of the knowledge of metacognition, but their activity to regulate metacognition still needed some improvement. The study covered five aspects of knowledge of metacognition: planning, comprehension monitoring, information management strategies, problem-solving strategies, and evaluation. The monitoring aspect gained the lowest score (69) and the debugging or problem-solving strategies gained the highest score (89). This indicated that students were quite capable to arrange plans to achieve a goal, to create problem-solving strategies, and to evaluate. On the other hand, their ability to monitor or to control thinking process was poor. The capability to monitor and to manage information would be mastered if the students could develop good self-regulation skills.

Regulating metacognition is closely related to Self Regulated Learning (SRL) ability of the students [17]. Metacognition is control and awareness of someone’s thoughts, while Self Regulated Learning
(SRL) is the individual ability to plan, to monitor, and to evaluate his/her learning independently [18]. Self-regulation can be seen from the ability to set goals, to determine and to make use of the right strategy to achieve goals and to monitor learning progress. Therefore, students’ metacognition is needed to be developed and used in the process of learning through a learning strategy that accommodates the use of metacognition optimally or through the assessment process. The Assessment as Learning technique could be used to develop effective metacognitive thinking [19].

The students of Biology Department understanding of the Nature of Science still needs to be optimized, and so does the metacognitive awareness. It is crucial to support the learning process and learning outcomes. The use of metacognition in the process of learning science is highly needed to achieve meaningful learning outcomes. The relationship between metacognitive and thinking strategy is that metacognitive serves the way to control students’ thinking which eventually will be resulting skills in critical thinking. Metacognition as an individual ability in thinking involves how learning should be done, what is already known and what is not. It consists of three steps: the planning about what is need to be done, the monitoring self-progress in learning, and evaluating things learned. Students’ metacognition needs to be continuously trained and developed so it could support the achievement of more optimal outcomes in science learning.

4. Conclusions
It is concluded that students’ understanding of Nature of Science and metacognitive awareness of the biology students were low and they needed to be developed through the learning process to make them scientifically literate and finally successful in studying in the university level. It is suggested that biology learning process should implement such learning strategies that promote Nature of Science and metacognition. Metacognition is needed to be developed through learning to promote students’ success rate in learning science and a better understanding of Nature of Science.

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