The Students’ Understanding Profile on Nature of Science (NOS) of Physics

M N R Jauhariyah*, S N Rohmah, and N Y Permatasari
Physics Department, Universitas Negeri Surabaya, Indonesia

*E-mail: mukhayyarotinjauhariyah@unesa.ac.id

Abstract. Nature of Science (NOS) is an important concept in learning science. This is a much larger issue in science education research. This study aims to find out how students understand NOS in physics learning. This research describes the students’ understanding profile of the NOS based on the questionnaire in the form of a set of open questions or written statements to respondents to be answered. Respondents were 33 students of science class at one of school in east java in the academic year 2019/2020. The results showed that the level of understanding of the NOS by students in the range of categories is sufficient. Considering the importance of understanding the nature of science, this research implies that knowledge about aspects of the NOS should be paid more attention and study by all members of the education community so that students can better understand the NOS.

1. Introduction
The 21st century is an era that has fierce competition in science. Therefore competent humans were needed to face the competition in this era. Developments in education in this century have emphasized science learning which has the aim of developing scientific literacy skills in students [1]. In this 21st century era, science literacy is increasingly linked to economic growth and is necessary for finding solutions to complex social and environmental problems, all citizens, not just future scientists and engineers, need to be willing and able to confront science-related dilemmas [2]. But, the students’ scientific literacy in Indonesia was very low. PISA 2015 showed that Indonesian students’ scientific literacy skills are at a low level [2], in PISA 2018 showed that Indonesian economic’s performance in science is still at level 1 [3]. This shows that it is necessary to find out the cause of the low scientific literacy skills of students in Indonesia.

In another study related to science literacy, the understanding of the Nature of Science (NOS) is a significant and primary component of scientific literacy [4-7]. Abd-El-Khalick et.al states that someone who has science literacy skills will have the ability to understand concepts, theories, principles, the nature of science, the development of scientific knowledge, and realize the interrelationships between science, technology, and society [8]. Having people with the desired understanding of how science works has been presented as a crucial component in achieving scientifically literate society [9]. Lederman states that NOS is an epistemology of science where science is a way to obtain knowledge, or the values and beliefs inherent in scientific knowledge or the development of science [10]. Therefore, the nature of science is very necessary to get attention in learning science, physics learning is no exception.

The NOS is part of science that must be taught by teachers in learning but often ignored. In some schools in Indonesia in learning physics in the early grades of high school, the nature of physics is rarely
taught properly. Students tend to study independently at the beginning of lectures to understand the nature of physics. Whereas, on the other hand, the nature of physics is the basic material that needs to be taught well by the teacher so that students have a correct understanding of science. McComas states that the NOS is an often neglected part of science teaching, yet it provides a vital background for students, detailing how science and scientists work and how scientific knowledge is created, validated, and influenced [11].

Some research in this decade shows that the students’ understanding of the NOS is quite low. The results of the study by Bell showed that students and teachers did not yet have an appropriate understanding of NOS [12]. Other research by Abd-El-Khalick et.al generally shows that kindergarten students until grade 12 students and also teachers have not yet reached the desired understanding of NOS [8]. Some studies show that pre-service teachers generally possessed the partial understanding of NOS [13], so there are need efforts to improve pre-service science teachers’ pedagogical content knowledge for teaching NOS should put more emphasis on strategies for assessing NOS and how to integrate NOS explicitly into science content [9]. The other finding, most teachers have admitted that their NOS knowledge is insufficient but also stated that NOS is important in science teaching and themselves [14]. Jiang & McComas stated that one of the problem factors is possible because almost all science textbooks focus on scientific knowledge, while scientific investigations, scientific thinking and social aspects of science receive less attention [15]. Though the nature of physics can provide important background for students about how science and scientists work and how scientific knowledge is created, validated, and influenced.

According to McComas, the NOS has several aspects, including (a) empirical evidence is required, (b) science shares methods (induction, deduction, etc.), (c) law/theory distinction, (d) science is distinct from technology and engineering, (e) science is tentative but durable, (f) science cannot address all questions, (g) creativity is vital in science, (h) subjectivity is frequent element in science, (i) social and cultural elements impact science [11]. Based on the expert's explanation, it can be concluded that the nature of science has several aspects, among others: (a) empirical-based, meaning that scientific knowledge is based on data/evidence obtained from observations through the five senses and/or experiments; (b) tentative, meaning that scientific knowledge is not absolutely truthful and without error, but can be changed (refined) with new observational evidence and by reinterpreting existing observations; (c) theories and law, meaning that the law describes relationships, observations, perceptions of natural phenomena which are usually accompanied by mathematical formulas, while theory is an explanation for natural phenomena and the mechanism of the relationship between natural phenomena; (d) sosio-cultural embeddedness, means that science is the result of human effort, so that the process of obtaining it can be influenced by the society and culture where it is practiced, then the value system and culture will influence what and how science is carried out, interpreted, and accepted; (e) creativity, meaning that scientific knowledge is created from human imagination, creativity, and logical reasoning so that it will continue to develop, the creation of scientific knowledge is based on creative planning, observation, and conclusions; (f) scientific method, which means that there is no definite and universally valid scientific method, scientists are free to use any method as long as it can be accounted for; and (g) subjective; which means that personal subjectivity is unavoidable in science, factors such as personal values, beliefs, self-agendas, and previous experience will influence what and how a scientist does his work.

Given the previous information that states that the NOS material is often ignored so that students’ understanding of NOS is still incomplete, on this occasion a small survey of early high school students was conducted to capture the students’ understanding profile of the NOS of physics. Every aspect of the NOS is then developed into a research instrument to find out the students’ understanding of the NOS of physics. As for the implications of this study, it is hoped that the dialogue can be continued with efforts to increase understanding of the NOS better.

2. Method
This study used descriptive research of survey to describe the students’ understanding profile on NOS of physics. The survey used a questionnaire about the understanding of NOS and given to 33 grade 10 students of science class at one of senior high school in east java. It used a purposive sampling technique
because this survey was taken when one of the authors has to teach in that class on an internship program. This study used an open questionnaire to soliciting information about students’ understanding of the nature of physics.

The questionnaire and interviews were chosen to be the appropriate data collecting techniques. Questionnaires were used to examine the students’ understanding of NOS aspects. The first instrument was the Views of the Nature of Science Questionnaire (VNOS-C) [8]. It was administered to assess the participants’ understanding of NOS. The VNOS-C consists of ten open-ended questions that help identify the understanding of the tentative, empirical, creative, subjective, theoretical, cultural and social nature of science [8]. But, in this study, we modified the ten aspects into five aspects of NOS and make the questions appropriate with physics as part of science.

In developing this instrument, there are three stages were done. The first stage is determining aspects of the NOS based on the experts’ review. These aspects are (a) empirical-based, (b) tentative, (c) theories and law, (d) socio-cultural embeddedness, (e) creativity, (f) scientific method, and (g) subjective. Based on the literature review, this instrument with 5 aspects was developed, i.e. tentative, theories and law, socio-cultural embeddedness, scientific method, and creativity. These aspects are determined based on the consideration of adjusting the survey questionnaire questions with indicators of learning to be achieved in school. The instrument was in the form of an open questionnaire with eight (8) question items in the form of essay questions with five Likert scales. In the second stage, testing the instruments of understanding the NOS to students and teachers. Through this trial, there is input based on interviews with the teacher and then used to assess the content and format of the instrument questionnaire. Regarding the contents, there are input improvements in the selection of languages in the student questionnaire. Regarding the instrument format, the input is found in selecting the type of open questionnaire that is considered appropriate and easy to fill in by students. In the third stage, items are developed and tested. The expert reviews the items for content validity and checks the meaning of each item. The question development was retested so that the results obtained were then measured and described by researchers.

The validity of the statement content is determined based on expert judgment. Also, discussions with the teacher were conducted related to minimizing bias in interpreting statements on the questionnaire. The first data analysis technique in this study is distributing questionnaires to students and ensuring that respondents have filled out all statements in the questionnaire. Then give a score of respondents' answers on each item based on the rubric of assessment. Furthermore, the data is classified according to the group and tabulated in the form of a table. Furthermore, the survey results are calculated according to the criteria.

3. Results and Discussion
The instrument in this study was the development of a literature review on the NOS. Research with this type of survey uses open questionnaires to collect data. Data is collected using a questionnaire filled directly without being taken home so that it is expected that the statements contained in the questionnaire represent the pure understanding of the NOS by research subjects without the help of others and without looking at the source of books and the internet. Based on the data obtained, in general, the average percentage of understanding of the NOS is 49.8% with a sufficient category, although in some aspects of NOS understanding is very minimal.

In the other research used VNOS-C Questionnaire showed that grade 9 students’ understanding of NOS was inadequate and fragmented [6], even some elementary and early childhood pre-service teachers held several misconceptions regarding NOS [16], the junior high school science teachers’ understanding of NOS inadequate to teach NOS to their students [17], so an improvement of the understanding of the NOS is needed [6,16,17]. Professional development programs may important to improve the understanding of NOS, such as the Chaiyabang and Thathong done, they found that the Thai teachers’ understanding and instruction of NOS had improved after the workshop of professional development program [18]. Hopefully, through the teacher’s understanding of NOS and how to teach it can have a significant impact on students’ understanding of NOS. Giving attention to NOS material in lectures and special emphasis on NOS material to teacher candidates also needs to be considered, given the findings of Yalcığın and Yalcığın that the facts the teacher candidates cannot develop their views on the
NOS in their educational life before they come to education faculty [19]. So, it is necessary to improve the pedagogical content knowledge of teacher candidates for teaching NOS [9].

Understanding grade 10 students get a different percentage of each aspect of NOS. Data on the percentage of students' understanding of the nature of science in terms of NOS aspects are presented in table 1.

### Table 1. Understanding the NOS of physics

| NOS Aspect               | Percentage |
|--------------------------|------------|
| Tentative                | 70.4 %     |
| Theories and Law         | 25.0 %     |
| Sociocultural Embeddedness | 68.2 %  |
| Scientific Method        | 61.4 %     |
| Creativity               | 24.2 %     |

Based on table 1, it appears that students' understanding of the tentative, socio-cultural embeddedness and scientific method aspects reach the sufficient category. In this aspect, students are quite good at identifying the nature of physics, the role of physics in everyday life, and can identify scientific methods. While the aspects of theories and law are aspects that are not understood by students with a percentage of 25% and the very poor category. In this aspect, students cannot distinguish physical products in the form of facts, concepts, principles, theories, and laws. Based on the answers to the survey results, it was stated that students had never gained knowledge about the differences in the physics products. This is in line with Sangsa-ard and Thathong’s findings which show that the majority of research subjects did not clearly saw theories as inferential in nature and scientific law as a generalization, a high inadequate in understanding the NOS is the distinction between a scientific law and theories [17].

Learning the NOS is inseparable from work safety materials in the laboratory. Therefore, in the survey questionnaire, there were also questions belonging to the aspects of creativity related to the preparation of work safety procedures in the laboratory. The survey results show, in this aspect students' understanding gained a percentage of 24.2% with a very poor category. Based on the answers to the survey results, it is stated that students have never conducted experiments in a laboratory, so students cannot answer these questions. The creativity aspect can develop if students have a good understanding of NOS. Students will have the NOS understanding well if the teachers have a true conception of the NOS. Teachers will have a true and good conception of NOS if the pre-service teachers have the true and well understanding of NOS. But in fact, Jain et.al found that it is important to diagnose and address pre-service teachers’ conceptions in understanding NOS, it must be corrected from the grass-root level [13].

This research shows that learning provided by teachers will influence the understanding of the NOS by students and have an impact on students' ability to integrate into science learning. This is in line with Hacieminoğlu which states that there are factors that influence the understanding of the NOS in students, such as factors of misconception, classroom discipline, lack of teacher experience, and lack of stock of student knowledge from the school of origin [20]. So, before the teacher learns the NOS it is better to prepare himself to fully understand the concept of the NOS and its aspects. Physics learning that only provides a collection of facts and knowledge to students’ results in little understanding and cannot develop intellectual freedom. Learning in the form of only providing information is not appropriate, and is in line with other experts and education practitioners to change the learning process which only prioritizes the provision of information into the learning process as well as prioritizing the development of students' thinking skills, attitudes and process skills. Learning should not only be done with lectures, but development can be done by adopting the story of the history of scientists in gaining scientific knowledge that is through laboratory experiments that can also help students see how science works. Bell stated that discussions and reflections, experiments, investigations, socio-scientific issues, and the history of science are effective for use in introducing and reinforcing the NOS concepts [12].
4. Conclusion

Based on the results of research and discussion that has been studied, it can be concluded that the understanding of grade 10 students of the NOS of physics is categorized as sufficient. The curriculum implemented does not explicitly include the NOS as content in learning physics. Considering the importance of understanding the NOS, it is best to get the attention of all members of the education community. Efforts are needed to improve the understanding of the NOS by all parties. Teachers as learners should be able to integrate the NOS in learning by using appropriate learning strategies, models and media.

References

[1] OECD 2013 PISA 2015 Draft Science Framework
https://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Science%20Framework.pdf

[2] OECD 2015 PISA 2015 Results in Focus
http://iave.pt/images/FicheirosPDF/Estudos_Internacionais/PISA_2015_Focus_v6.pdf

[3] Schleicher A 2019 PISA 2018 Insights and Interpretations
https://www.oecd.org/pisa/PISA%202018%20Insights%20and%20Interpretations%20FINAL%20PDF.pdf

[4] Lederman NG 1992 J. Res. Sci. Teach. 29 331

[5] Abd-El-Khalick F and BouJaoude S 1997 J. Res. Sci. Teach. 34 673

[6] Sangsa-ard R, Thathong K, and Chapoo S 2014 Procedia Soc. Behav. Sci. 116 381

[7] Abd-El-Khalick F and Lederman NG 2000 Int. J. Sci. Educ. 22 665

[8] Abd-El-Khalick F, Lederman NG, Bell RL, Hall R, and Street E 2002 J. Res. Sci. Teach. 12 267

[9] Bilican K, Tekkaya C, and Cakiroglu J 2012 Procedia Soc. Behav. Sci. 31 468

[10] Lederman NG and Lederman JS 2004 Sci. Teach. 71 36

[11] McComas WF 2015 Am. Biol. Teach. 77 485

[12] Bell RL 2008 Best Practices in Science Education Teaching the Nature of Science: Three Critical Questions (Hampton-Brown: National Geographic Learning/Cengage)

[13] Jain J, Lim BK, and Abdullah N 2013 Procedia Soc. Behav. Sci. 90 203

[14] Mhladiz G, Dogan A 2014 Procedia Soc. Behav. Sci. 116 3476

[15] Jiang and McComas WF 2014 Sci. Educ. 23 1785

[16] Kaya S 2012 Procedia Soc. Behav. Sci. 46 581

[17] Sangsa-ard R and Thathong K 2014 Procedia Soc. Behav. Sci. 116 4785

[18] Chaiyabang MK and Thathong K 2014 Procedia Soc. Behav. Sci. 116 563

[19] Yalcın SA and Yalcın S 2011 Procedia Soc. Behav. Sci. 15 942

[20] Hacieminoglu E 2014 Procedia Soc. Behav. Sci. 116 1268.