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Understanding The Nature of Science (NOS) of In-Service Science Teachers: Instructional Practices and Their Implications on Renewable Energy

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Abstract

The purpose of this study was to determine the understanding of science teachers about the nature of science (NOS) and its instructional practices and implications for renewable energy. Surveys and interviews were conducted on science teachers and elementary, middle, and high school/vocational school students in this study. The instrument used was adapted from the NOS questionnaire instrument and interview questions Abd-El-Khalick, Bell, and Lederman, then developed and refined according to the respondents to measure NOS understanding and instructional practice. Questions added regarding teaching about renewable energy. This research is a qualitative research conducted online on science teachers in Java, Indonesia. Then the contents of the questionnaire are projected on the NoS understanding rubric which is divided into don't understand the NOS aspect yet, little understanding of the NOS aspect, and know and understand aspects of NOS. While the results of the interviews are presented in a qualitative descriptive manner. The results showed a lack of understanding of science teachers about NOS and its instructional practices. Understanding is still very lacking in the tentative aspects, observation and inference, as well as theory and law. The teaching of renewable energy that can train students' NOS which is felt urgent to be taught is also not applied by the teachers in their teaching. Various obstacles were expressed such as immature preparation, limited learning time, and lack of understanding. This resulted in poor implementation of aspects of NoS in classroom learning which had an impact on students' understanding.

Keywords: NOS, science teacher, renewable energy

INTRODUCTION

Currently, many studies in the field of science education emphasize the importance of teaching science education to be more authentic (Archer et al. 2010; Osborne et al. 2003). This is in line with the aim of promoting scientific literacy which contributes to good critical and reflective skills (Sasseron et al. 2011). These research studies have highlighted the importance of teaching styles that can contribute to the development of a broader view of science, to the extent that it supports understanding and thinking about the process of scientific knowledge construction, including product creation, communication, evaluation, review, to validation. Many researchers specializing in this field have investigated the importance of introducing aspects of Nature of Science (NOS) into science teaching (Abd-El-Khalick 2012; Allchin 2017; Irzik 2013). In this field-specific literature, we can find many

definitions for the term NOS. This includes the definition put forward by McComas (McComas 2008) which reflects the general perspective taken in this article. According to McComas, NOS can be defined as:

A hybrid domain that blends aspects of various social science studies including history, sociology and philosophical sciences combined with research from cognitive sciences such as psychology into a rich science description; how it works, how scientists operate as social groups and how society itself directs and reacts to scientific impacts (McComas 2008).

The research has also emphasized the need for NOS to be discussed in a contextual and explicit and integrated way. The contextual approach refers to context as a foundation, such as historical context when teaching different atomic models; the explicit approach refers to an open discussion of the aspects of NOS that exist and influence the construction of scientific knowledge (for example, Marie Curie's motivation to explain the unexpected data that resulted in the discovery of the chemical element Radium), and finally the integrated approach refers to incorporating aspects of NOS for the development of a scientific context in the curriculum. . The NOS aspect must be included in the general objectives of the teaching and learning process. In this way, a contextual, explicit, and integrated approach to the NOS aspects of teaching about science can support not only the learning of scientific content, but also the development of more. This is needed to equip students in dealing with problems in their daily lives, whether related to science or not. Through understanding the nature of science, people can know that science is changeable, comes from the universe, subjective, based on human inference, creative, socio-cultural, distinguishes between observation and interpretation and whether there is a relationship between law and theory (Abd-El-Khalick et al. 1998; Perla & Carifio 2008).

Currently students have not maximally applied their understanding of science in their daily lives. This can be seen from the not many creative products produced by science-based students in Indonesia. A person can only apply his scientific understanding when he has taken a higher level of education in college. Students are also still unfamiliar with the relationship between current technology and science material that they get in class.

The integration of every aspect of NOS in learning is expected to have an influence on students' understanding of both the science material being studied and in the social context of society when students return to the world of reality outside the classroom. Thus, teaching science based on the NOS aspect aims to help students understand science and be able to distinguish it from other disciplines. The instrument developed by Lederman to determine the level of understanding of NOS is in the form of open-ended questions that are descriptive in nature so that they can see the understanding of NOS. many studies have validated this instrument, so it can be said to be valid in determining respondents' NOS understanding.

One aspect of NOS that is not used to being trained in learning is the relationship between science and socio-culture. This aspect can be approached with socio-scientific issues and then solved by making renewable energy products. As we already know, the scarcity of energy sources is a global problem today, so the need to make renewable energy that is effective, efficient and environmentally friendly is very urgent at this time. If individuals are not trained as early as possible from school, then where else can they be trained to care about this problem. All aspects of NOS can be well trained if learning is integrated by asking students to create renewable energy products from materials that are not utilized in their area.

METHODS

This research is a qualitative research by taking data and then analyzing it qualitatively. The NOS questionnaire instruments and interview questions were adapted from (Abd-El-Khalick, Bell & Lederman 1998). Respondents are teachers from elementary, junior high, and high school/vocational school levels. This is because this research wants to see students' understanding of NoS at every level of education which is still common in the learning material. The questionnaire was filled out by 10 teachers and interviews were conducted with three permanent teachers, there are 3 different levels. Questionnaires and interviews were distributed online in November 2021. Then the answers to the questionnaire were grouped into not understanding, little understanding and knowing and understanding aspects of NOS. While the results of the interviews are presented in a qualitative

descriptive manner. Qualitative data is presented in accordance with the contents of the interview then analyzed and strengthened with appropriate references.

RESULTS AND DISCUSSION

The results of this study are described in two separate sections. The first part focuses on understanding the NOS of elementary, middle, and high school/vocational school teachers. The second section deals with the interactions between teachers' understanding of NOS and their beliefs about instructional and pedagogical outcomes.

NOS understanding

The results showed that the understanding of NOS science teachers in elementary, junior high, and high school/vocational schools varied from knowing little about NOS aspects to not understanding at all about NOS aspects. A summary of data on respondents' NOS understanding is in TABLE 1.

TABLE 1. Comparison of Understanding Nature of Science Teachers

Question Number	Aspects in the NOS	Description and categories of respondents' answers		
		Don't understand the NOS aspect yet	Little understanding of the NOS aspect	Know and understand aspects of NOS
1	Tentativeness	Some think theory is impossible to change (60%)	Some think theory can change without giving a reason (30%)	Some think the theory can change along with the explanation (10%)
2	Observation and Inferences	Do not understand aspects of observation and subjectivity (60%)	Little understanding of the observation aspect but not involving subjectivity (40%)	-
3	Theories and Laws	Unable to distinguish between theory and law (90%)	Already able to distinguish only the answers still look copied from the internet and without examples (10%)	-
4&5	Creativity	Can't connect creativity with science (20%)	Can connect creativity with the creation of science but not the whole process (80%)	-
6	Empirical Base	-	-	Already understand empirically based scientific knowledge, but have not provided examples (100%)
7	Socio/cultural Embeddedness	Unable to relate science to influencing factors (40%)	Can relate science to other factors, just haven't mentioned it yet (60%)	-

TABLE 1 illustrates that not all respondents understand all aspects of NOS. Based on the NOS questionnaire adapted from (Abd-El-Khalick, Bell & Lederman 1998), which consisted of six tested aspects of NOS, the teachers indicated their lack of knowledge and understanding of the aspects of NOS.

Tentativeness

Many teachers argue that theory is impossible to change. Only a few say it can change, but without an explanation that can describe the extent of this understanding. Only a few can give good examples of the reasons for continuing to teach scientific theories even though they can change. Scientific knowledge is tentative and dynamic. However, claims are intuitively interesting ideas that may be true

to some degree and with important qualifications (Perla & Carifio 2008). So it is necessary to teach this scientific knowledge even though it is tentative. The example of the change in atomic theory in the problem does not provoke respondents to understand the tentative nature of NOS. The following is representative of the teacher's comments:

Atomic theory is immutable. With scientific theory, we can study more deeply about atomic theory.

Following the development of science, the theory could change. Only existing theories can become knowledge and foundations for thinking.

A theory can change if better research is found.

Observations and Inferences

No one has yet understood the difference between observation and inference so that it does not involve subjectivity when explaining scientists get their atomic theory. More respondents did not understand, so they did not answer when asked about the specific evidence that scientists used to get their theory. A few others stated that the reason was the result of experiments but did not involve the subjectivity of scientists. Whereas a person can infer the subjective beliefs of others through their actions and this conclusion depends on each subject's performance when taking action (Patel 2012). The following is representative of the teacher's comments:

Atoms are like balls that have particles.

One of the scientists mentions it like raisins.

Atoms are very small particles. Very sure. Through research in the laboratory.

Theories and Laws

Most of the respondents cannot distinguish between laws and scientific theories. Very few have correctly answered the difference, but it is very visible copying from internet sources, nor does it provide examples to defend or clarify understanding. None of the respondents could explain the difference between law and theory well with examples. According to the National Science Teaching Association (NSTA), the ability to distinguish theory and law should have been selected from grade 9-12 school. The following is representative of the teacher's comments:

Theory is a legal concept is a theory that has been tested.

There is. If the theory can still be countered again, but if the scientific law is certain.

Scientific laws are descriptions of observed phenomena. The law does not explain why the phenomenon exists or what causes it. An explanation of a phenomenon is called a scientific theory.

Creativity

Most of the respondents have been able to relate the existence of creativity in carrying out the scientific method. However, they do not explain all the processes of the scientific method using creativity, they assume that only some activities in the scientific method require creativity. Others say that there is no relationship between creativity and science because they study very different sciences. Creativity has a role in directing the predictive power of the scientific method process on scientific creativity (Ozdemir & Dikici 2017). The following is representative of the teacher's comments:

Scientists must experiment in solving problems not based on imagination.

Scientists use their creativity when providing analysis of research results and processing data also using their creativity, if the data is too far apart, the scientist takes the data again or the data range is enlarged.

Yes scientists use creativity and imagination before they conduct further research.

Empirical Base

The empirical-based aspects of NOS are well known and understood by teachers. So that all respondents answered correctly about the difference between scientific knowledge and opinions along with explanations that illustrate their understanding. The role of the empirical method in science is well known by teachers. The following is representative of the teacher's comments:

Scientific knowledge based on facts and evidence or experiments. Opinions are based solely on creativity and imagination.

Scientific knowledge based on data. Opinions are assumptions that have not been verified.

There is. Scientific knowledge basically has a clear and empirical legal basis and can be proven. Opinions tend to be incidental and their legal basis is not as strong as scientific knowledge.

Socio/cultural Embeddedness

There are no respondents who can relate the factors of the formation of different theories from the same data. They have not been able to relate the existence of social and cultural factors that influence a person's mindset. More than half could state that there were other factors that influenced a scientist's conclusion, but had not yet gone into mentioning these factors. A small proportion have not been able to understand the existence of other factors that influence the conclusions of the study. They still think that science is the exact science of data obtained during experiments. Conceptions of sociocultural attachment are not resistant to change, but are almost non-existent due to lack of discussion (Müller & Reiners 2021). The following is representative of the teacher's comments:

Each experiment will lead to different conclusions.

Because each scientist has their own perspective and has their own evidence.

As long as the research is carried out by several scientists & carried out at different times, the differences in the findings encountered by scientists occur with various past and present experiments.

Overall, the results of the questionnaire indicate a lack of understanding of the respondent's teachers at the elementary, junior high, and high school/vocational education unit levels. This lack of understanding can have an impact on the students they teach because it implies that students are not trained in every aspect of NOS in science learning. According to Lederman's research (Schwartz 2007), teachers' understanding of NOS is significantly related to their students' understanding. This aspect of NOS should be trained as early as possible because it is not only a provision for students in understanding lessons at school but also very important in its application in solving problems in everyday life that students will later face.

The interaction between knowledge, pedagogy and outcomes

The results of the interviews obtained various understandings and applications of NOS from teachers and students at elementary, junior high, and high school/vocational schools. Teachers who have little understanding of the aspects of NOS apply it better than those who do not understand it in their instructional practice. The first question in the interview before the NOS theme was raised, asked teachers what they thought was most important to emphasize in their teaching. In answering this question, the three teachers have various answers according to their respective perspectives regarding learning in their schools. The first teacher said that the media played an important role in every lesson. This is because students are less interested and understand the material if learning does not use interesting media. Learning can be more fun if it involves students actively. Even with interesting media, students may not understand the material if the media presented does not invite students to participate in learning. The second teacher argues that not far from the first teacher's answer, facilities and media play an important role in learning. The second teacher expressed the same opinion regarding the reason. The third teacher has a quite different answer, namely the entry behavior of students which is an important component in achieving the success of learning objectives. So that this teacher explores students' initial conceptions to be able to support learning at each meeting. With the ability to analyze and solve problems that are still low according to the third teacher, students must first focus on the concepts related to problem solving in a particular material, so that they are able to analyze more deeply when they already have a good initial understanding of the material that is the core of the subject. solving the problems they face. No science teacher stated that NOS or one of its aspects was the most important emphasis in their learning. Only the third teacher's answer is close to an aspect of NOS, where this student's initial conception can support the tentative aspects of science by understanding the development of science over time. In line with what students said when interviewed for the third teacher, the basic concepts were explained more and then examples in everyday life so that the introduction of concepts could be more in-depth. Nature of Science (NOS) is the basis for

understanding how science concerns human life and social development (Prachagool & Nuangchalerm 2019).

The understanding of NOS can also be seen from the second question regarding the differences between science and other disciplines. Although the three teachers had not heard of Nature of Science, after being approached in various ways, the word substitute for science was sufficient to describe it. Two teachers did not understand by saying that science is an exact science while art is not. This alludes to two non-existent aspects of NOS, namely tentative and creative. However, the third teacher simply understands science by mentioning the three components that are trained in science, namely process, attitude and product. The teacher said there was a lot that could be trained in learning science such as critical thinking, creative thinking, the scientific method and other competencies needed today. With this good understanding, the teacher has conducted lessons that practice the scientific method, although it is not done often due to time constraints. The element of creativity has not been widely included in science learning, so students are only accustomed to being fed and cannot develop their potential. In fact, science can really train this ability. Starting from designing hypotheses from the given problem, during the solving process creativity is needed to use various experimental procedures that can be carried out to drawing conclusions that can vary from each student depending on the experimental process they are doing. All students only said that science is an exact science and a science that studies nature related to daily life, so that it does not relate that social and human creativity are also used in producing science. Students need to be repeatedly reminded and shown how to be creative, to integrate material across subjects, to question their own assumptions, and to imagine other points of view and possibilities (DeHaan 2009).

All answers to the third interview question agreed on the importance of properly taught NOS because:

Can be used to solve problems in everyday life.

There are many good practices such as discipline, curiosity, character building, honesty, conscientiousness, responsibility, gratitude, and respect.

Can underlie students' understanding in the way of thinking, critical thinking and scientific methods used in everyday life.

Based on these answers, the three teachers realized the importance of implementing NOS in learning because it could have a good impact on the daily lives of their students. Not only affects the better students understand the concept of science which has an impact on the good learning outcomes obtained. This is in line with students' opinions about the importance of studying science because it can be used in the application of technology and other daily lives.

The application of the NOS aspects in learning can be seen from the explanation of the answers on how teachers teach science. The first teacher said that he had brought students to the open world directly to introduce various explanations to scientific concepts. Here there is an aspect of NOS that is trained, namely socio-cultural which relates the science being studied is actually influenced by the social and cultural environment around which they observe. The second teacher teaches science with various experiments that can train the various good characters needed by students. The aspects of NOS that are tried to be trained here can be almost entirely. It's just that the experiments carried out are still in the form of experimental instructions that students must do every step of the way, so that the NOS aspect cannot be instilled in students. The third teacher applies science with various learning models such as PBL (Problem based Learning) and PjBL (Project based Learning). Learning begins by presenting problems to be discussed and solved with students, it's just that the application of this kind of model is not often done due to time constraints and immature preparation. The students said it was fun learning science they got. Students also expressed their science learning in the form of practice questions and simple practice. In line with what the teacher said that they rarely practice or apply learning models because they require careful preparation. Though careful preparation on how to construct students' scientific knowledge is very important. Guidance in the construction of knowledge depends on how the teacher designs the type of learning, the teaching methods he applies in learning and the extent to which the teacher pays attention to the epistemic actions of students in the classroom because efforts to construct knowledge are complex endeavors. (Schwarz et al. 2004).

The obstacles faced by science teachers in applying aspects of NOS were stated in interview questions regarding their satisfaction in teaching science. The first teacher complained that the lack of

media and laboratories hindered the science learning process. As he stated in the original question, this is indeed the main emphasis that must be in learning. The second teacher revealed that the obstacles were obtained from the different character of students and the lack of school infrastructure. That way he seeks a variety of different learning strategies to be able to facilitate the various characters of students. The third teacher complained about the learning time, immature preparation and limited face-to-face learning which made the teacher not used to carrying out learning.

The students' ability in learning science is explained in this sixth answer. The first and second teachers said that the students' ability in science was good from the test results. Meanwhile, the third teacher felt that his students' abilities were not enough because he assessed the students' scientific attitude from the rubric he made. All assessments carried out have not been able to see every aspect of NOS that students have. All students feel they have not understood all the science material taught by their teacher.

Discussion and implications for teaching renewable energy

The teacher's understanding of the NOS aspect certainly affects the instructional practices carried out. Even though a good understanding of NOS is not necessarily well applied to the instructional practice, especially if you don't have an understanding of NOS. The questionnaire data obtained that there are still many aspects of NOS that teachers have not understood yet, so there is a need for training for teachers and good supplies when studying for prospective teacher students. Due to formal education that a person can learn with a focus and more motivated. This lack of understanding of NOS from teachers can be due to their lack of training in every aspect of NOS in their lectures and it can also be because they have been out of college for a long time to become a teacher. Of course this understanding of NOS is a benchmark for the way the teacher acts and teaches science material. According to Lederman's research (Schwartz 2007) teachers' understanding of NOS is significantly related to their students' understanding.

The emphasis on the NOS aspect has also not become the goal and the emphasis on science teacher learning. There are still many who complain that the lack of school facilities affects learning. This indicates that teachers still rely on existing facilities and infrastructure in schools so that there is a lack of creativity in using simple media that can be made by teachers and students. Careful preparation in implementing the NOS aspect is also still burdensome for teachers who do not want to change their learning patterns. The lack of desire to improve learning is quite large for the instructional practice itself.

Teachers should also be equipped in teaching and assessing NOS. Such experiences should be based on a practical understanding of how students learn and what is needed to modify instructional activities in order to strengthen the development of an adequate understanding of NOS. Every effort should be made to ensure that student teaching aims to strengthen aspects of NOS rather than weaken them. So it is necessary to apply this while in college for prospective teachers to have planned opportunities to teach NOS when they practice at school.

One way to apply the NOS aspects in science learning is experimentation on renewable energy. Because from these experiments students are challenged to create renewable energy which is an important need today. If the process of making renewable energy products is carried out in accordance with NOS, many thinking skills will be trained. Raising socioscientific issues like this can make students more aware and concerned with what is happening on Earth where they live. When asking about this renewable energy in the questionnaire, the same answers were obtained from all respondents. They all understand the urgency of this material regarding renewable energy, but they have just introduced some renewable energy and have not yet arrived at guiding students to make products with the theme of renewable energy. Lack of awareness about the long-term impact of the problem of not creating renewable energy is not trained in formal education. Science learning should have arrived here because only science can be applied in the manufacture of renewable energy. New sustainable energy solutions are expected to create new job opportunities and challenge current expertise in sustainability and renewable energy (Irena 2014; Sooriyaarachchi 2015; Unesco 2012).

CONCLUSION

Based on the results of the study, it can be concluded that the understanding of aspects of the NOS of science teachers is still inadequate and there is also no application in the teaching practice of teachers in the classroom. This is because the obstacles that have not been resolved and are still the reason for teachers to be able to apply the NOS aspects. The relationship between renewable energy and NOS is that the NOS aspect can be fully described with instructional practices in the form of assignments to manufacture renewable energy products, of course with the right guidance from the teacher. So it is necessary to integrate aspects of NOS with renewable energy in the learning of prospective teachers during lectures. It is necessary to carry out further research regarding students' understanding of NoS aspects and their application in supporting renewable energy.

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