

The Effect of the Empirical Base Nature of Science Learning Model on the Understanding of Nature of Science in Empirical Aspect

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ABSTRAK

Pemahaman tentang hakikat sains, khususnya aspek empirik, saat ini kurang mendapat perhatian dan keseriusan dari kalangan pendidikan. Tujuan penelitian ini adalah melihat pengaruh model pembelajaran Empirical Base Nature of Science (EBNOS) terhadap pemahaman NOS terutama pada aspek empiris siswa sekolah dasar. Penelitian ini menggunakan metode pre-experimental melalui one group pretest post-test design. Subjek penelitian yang dipilih secara convenience sampling adalah 51 siswa kelas V sekolah dasar swasta di kota Bandung. Instrumen yang digunakan untuk mengumpulkan data terkait pemahaman siswa terhadap NOS pada pretest dan posttest menggunakan skala Likert. Aspek tambahan yang digali dari subjek penelitian untuk mendukung hasil penelitian adalah aspek jenis kelamin dan minat terhadap sains. Metode deskriptif kuantitatif dengan bantuan SPSS dan Microsoft Excel digunakan untuk menganalisis data yang dikumpulkan dari kuesioner. Hasil penelitian menunjukkan bahwa penerapan desain model pembelajaran Empirical Base Nature of Science (EBNOS) berpengaruh signifikan terhadap peningkatan pemahaman NoS siswa khususnya pada aspek empiris. Namun pemahaman NOS aspek empiris tidak dipengaruhi oleh jenis kelamin siswa maupun minat siswa terhadap sains itu sendiri. Penelitian ini diharapkan dapat memberikan kontribusi dalam perbaikan proses pembelajaran yang bertujuan untuk mencapai tujuan pembelajaran sains pada dimensi NOS, khususnya pada aspek empiris. Saran untuk penelitian selanjutnya yaitu mengembangkan model pembelajaran yang spesifik dapat meningkatkan pemahaman NOS pada aspek lain.

ABSTRACT

Understanding of the nature of science, especially the empirical aspect, is now receiving less attention and seriousness from the educational community. The aim of this study was determine the effect of the Empirical Base Nature of Science (EBNOS) learning model on understanding NOS, especially on the empirical aspects of elementary school students. This study used a pre-experimental method through a one group pretest posttest design. The research subjects selected by convenience sampling were 51 students of class V of a private elementary school in the city of Bandung. The instrument used to collect data related to students' understanding of NOS at the pretest and posttest uses a Likert scale. Additional aspects explored from research subjects to support research results are aspects of gender and interest in science. Quantitative descriptive method with the help of SPSS and Microsoft Excel was used to analyze the data collected from the questionnaire. The results showed that the application of the Empirical Base Nature of Science (EBNOS) learning model design had a significant effect on increasing students' understanding of NoS, especially on the empirical aspect. However, understanding of the empirical aspect of NOS was not influenced by the gender of the students or their interest in science itself. This research is expected to contribute to the improvement of the learning process which aims to achieve science learning goals on the NOS dimension, especially on the empirical aspect. Suggestions for further research are developing specific learning models that can improve understanding of NOS in other aspects.

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1. INTRODUCTION

The term Nature of Science (NOS) is defined as the nature of knowledge which is a complex concept involving philosophy, sociology, and history of knowledge. NOS is the epistemology of science, science as a way to acquire knowledge or values and beliefs attached to scientific knowledge or to the development of science (Abd-El-khalick & Lederman, 2000; Norman G Lederman et al., 2013). In other words, NOS is a part that relates to an understanding of the nature of science as a whole. As an epistemology of knowledge from science, NOS has characteristics or aspects (Norm G. Lederman et al., 2002; Sutinah & Widodo, 2020). Previous study states that the existence of NOS in education is not to indoctrinate, but to show reasons for accepting a certain condition (W. McComas, 2017). An understanding of NOS is certainly important in the world of education. Understanding NOS in this case is seen as very necessary as a graduation standard from science education before entering lectures so that students have scientific literacy skills (Dogan & Abd-El-Khalick, 2008; Jumanto & Widodo, 2018). NoS contributes to a complete understanding of the nature of science, because a deep understanding of NoS is correlated with increased scientific literacy (Khishfe et al., 2017; Norm G. Lederman et al., 2002). Previous study argues that by understanding NoS, students will be able to: 1) understand science, manage objects, and process technology in everyday life (utilitarian), 2) contribute information to decision-making processes on social science issues (democratic), 3) appreciate scientific values as part of contemporary culture (culture), 4) develop an understanding of norms among scientific communities that aim to realize moral commitments, universal values, that apply in society (moral), and 5) facilitate eye learning science lessons (Michel & Neumann, 2014; Sutinah & Widodo, 2020).

Previous study put forward seven important aspects of NoS, namely: (1) Tentative (2) Theories and Law (3) Socio Cultural Embeddednes (4) Creativity (5) Scientific Method, (6) Subjective, and (7) Empirical Base. The empirical aspect is one of the essential aspects of NOS (Jumanto & Widodo, 2018). Previous study explaining the empirical aspect means that science is based on observations from the natural world, so that it becomes a tool to explain natural phenomena (Hardianty, 2015). Science can be trusted if its findings are supported by observational and empirical evidence. In simple terms, Empirical Base means scientific knowledge based on data/evidence obtained from observation with the five senses and/or experiments. The empirical base has two indicators, namely: (1) Scientific knowledge is based on data/evidence obtained from observation with the five senses (2) Scientific knowledge is based on data/evidence obtained from experiments (Jumanto & Widodo, 2018; Solomon et al., 1992). Adequate student conception of the empirical aspects of NOS is necessary to be able to create effective NOS learning. By understanding the empirical aspect, students will realize that: first, although knowledge depends on evidence, scientific activity is still driven by theory, and scientists carry out their investigations from a certain frame of reference. Second, although inquiry in science relies on logic and is empirically based, it still involves creativity and invention of explanation. Third, some knowledge may not yet be found because it is not yet possible to study it. Fourth, although not accompanied by real evidence, scientific knowledge can still be recognized for its truth as long as it is produced in an accountable way.

However, understanding of the nature of science, especially the empirical aspect, is now receiving less attention and seriousness from the educational community. Previous study states that Nature of Science (NOS) is a part of science that must be taught by teachers but is often neglected or receives little attention (W. F. McComas, 2015). Even though the empirical aspects of NOS can provide important background for students about how science and scientists work and how scientific knowledge is created, validated, and influenced either through experience, observation, or experiments. The learning process in schools that has been carried out so far generally still uses the old paradigm, namely teacher-centered learning. Other study revealed that the dominant learning methods applied in class were lecture methods (70%), discussion methods (10%), demonstration methods (10%), and experimental methods (10%) (Sadia, 2008). The same thing was expressed based on the results of research conducted by involving 48 science teachers in Bali, the results show that lecture and question and answer methods are still dominantly used in learning (Subagia, I. W., & Wiratma, 2009). Thus, learning evaluations conducted by teachers also tend to be in the concept domain so that evaluations to measure student competence in other domains include the application domain and the NOS domain.

Therefore, various efforts are needed by all parties to start pioneering changes in learning in responding to problems and challenges. One of them is the efforts that can be made by the teacher considering that the teacher plays an important role in effective and efficient learning. Teachers must be competent in choosing innovative learning models that are able to facilitate student learning involving mind-on and hands-on activities. One of them is the NOS-based learning model. The NoS-based learning model is a constructivism learning model with an inquiry approach that places students as subjects in learning (*student centered*) (Sudirgayasa et al., 2014; Tala & Vesterinen, 2015). Several previous studies focused on NOS learning, including: study that examined the correlation between teaching NoS and

learning achievement in science subjects (Michel & Neumann, 2014). The results of the study show that teaching NoS can increase the effectiveness of the science learning process because it helps students achieve science learning objectives. Besides, other study propose a learning design model to teach NoS (Köksal, 2009). This model is considered as a potential prototype used as a reference for developing NOS teaching in tertiary institutions. Moreover, there is study aimed to assess the understanding of NOS of prospective science teachers using V NOS form B (Listiani & Kusuma, 2017). The findings show that V NoS form B can be used to assess prospective teachers' understanding of the nature of science. This study also found that most prospective teachers have a limited understanding of the nature of science. Similar research was conducted which showed the significant effect of the explicit NOS learning model on students' understanding of NOS (Aflalo, 2018; Sutinah & Widodo, 2020).

However, of all the research on NOS learning conducted by previous researchers, there is still no research that focuses on one aspect of NOS using a specific learning model. The aspects of NOS that are studied are still in general terms so that the learning model used does not refer to and is oriented towards one aspect of NOS. Thus, this study focuses on the effect of the Empirical Base Nature of Science (EBNOS) learning model on the empirical aspects of NOS understanding of elementary school students. The purpose of this study was to analyze the effect of the Empirical Base Nature of Science (EBNOS) learning model on understanding NOS, especially on the empirical aspects of elementary school students. This study also looks at how students' understanding of the empirical aspects of NOS is viewed from a gender perspective where the term gender refers to differences in functions, responsibilities and individual roles of both men and women which can change according to the times (Gunawan et al., 2020; Marchetti & Cullen, 2015). Besides, students' understanding of the empirical aspects of NOS in this study was also reviewed from students' interest in science.

2. METHOD

This study uses a pre-experimental method through *one group pretest post-test design* (Borg & Gall, 2003). The pre-experimental method was chosen because the intervention was only carried out in one group without a control group as a comparison (Creswell, 2013). The initial stage of the research was giving the pretest and treatment, while the posttest was given at a later stage. **Table 1** below describes the one-group pretest-posttest design in this study.

Table 1. Research Design

Group	O ₁	X	O ₂
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Research subjects selected by convenience sampling (Gall, et al., 2010) were 51 fifth grade students of private elementary schools in the city of Bandung. The instrument used to collect data related to students' understanding of NOS at the pretest and posttest used a Likert scale of 1-4 for positive statement items with the aspects of "strongly disagree, disagree, agree, and strongly agree" and vice versa for negative statement items. Additional aspects explored from research subjects to support research results are aspects of gender and interest in science. The empirical aspects of the NOS understanding questionnaire lattice are described in **Table 2**.

Table 2. Empirical Aspect NOS Understanding Instrument Grid

Indicators	Number of Item
1. Science is based on empirical facts	4 statements
2. Scientific knowledge is based on the results of investigations	4 statements
3. Some knowledge has not yet been proven, but is produced in an accountable way	2 statements

Quantitative descriptive method with the help of SPSS and Microsoft Excel was used to analyze the data collected from the questionnaire. In uncovering the effectiveness of implementing the EBNOS learning design, the results of understanding the NOS empirical aspects before and after EBNOS learning were processed with SPSS with a paired sample t-test. The significance of the design implementation is obtained from the test results. In addition, increasing understanding of NOS empirical aspects is also reviewed from gender and students' interest in science. The design of the EBNOS learning model which consists of 5 stages is presented in **Table 3**.

Tabel 3. EBNOS Learning Model Design

Stages	Teacher Activities	Student Activities
Orientate	The teacher begins to arouse doubts in students about information or claims	Growing doubts and curiosity of students about the truth of the information or claims
Design	The teacher provides opportunities for students to explore and design what can be done to prove the claims or information	Students explore and design what can be done to prove a claim
Verificate	The teacher guides students to prove by conducting investigations, both experiments, observations, etc	Students carry out investigations with the guidance of the teacher
Analyze	The teacher guides students to carry out an analysis of the results of investigations into the truth of claims	Students carry out an analysis of the results of investigations into the truth of claims
Reflect	The teacher guides students to reflect on the investigations that have been carried out by students. The teacher guides students to the initial goal to realize that the nature of science or knowledge is empirical (requires proof). But not all knowledge is supported by concrete evidence. Even though some knowledge is not accompanied by real evidence, knowledge can still be acknowledged for its truth as long as it is produced in an accountable way	Students reflect together with the teacher and grow awareness that the nature of knowledge is empirical (needs proof). But not all knowledge is supported by concrete evidence. Even though some knowledge is not accompanied by real evidence, knowledge can still be acknowledged for its truth as long as it is produced in an accountable way

3. RESULT AND DISCUSSION

Result

The data were analyzed descriptively statistically, and the average data on students' understanding of NoS was obtained, before and after learning with the EBNOS model seen in [Figure 2](#).

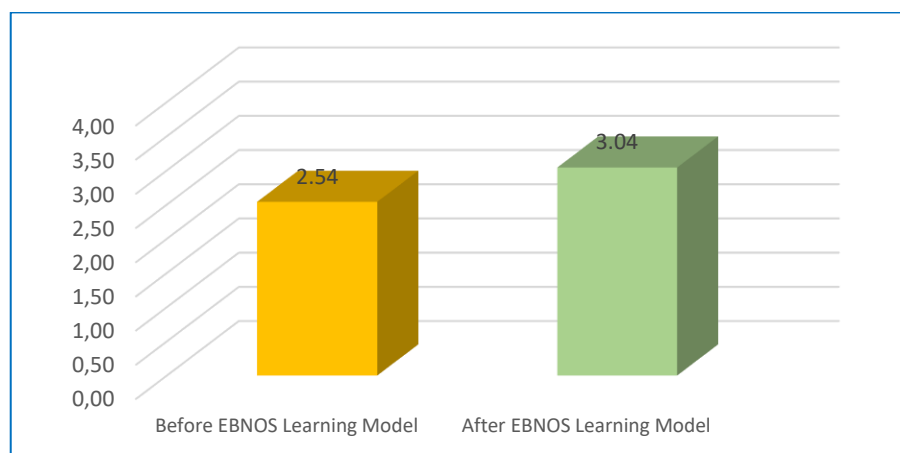


Figure 2. Graph of the Average Value of Questionnaire Results of Students' Understanding of NOS Empirical Aspects Before and After Learning with the EBNOS Model

[Figure 2](#) shows that there is an increase in students' understanding of NOS on the empirical aspect between before and after the administration of the EBNOS learning model. Before giving the EBNOS learning model, the average value of students' empirical NOS understanding was 2.54, while after giving the EBNOS model it was 3.04 so that there was an increase of 0.50. So it can be concluded that there are differences in the understanding of the empirical aspects of NoS by elementary students before and after being given the EBNOS learning model, meaning that there is an influence of the EBNOS learning model on increasing understanding of the empirical aspects of NOS by elementary students. To determine whether there is a significant difference in students' empirical NOS understanding before and after being given the EBNOS learning model, the data was tested by paired sample t-test using SPSS 23 software at α (0.05), and the output was obtained as show in [Table 4](#).

Table 4. Paired Sample T-Test Results

	N	Mean	Deviation Standard	Sig (2-Tailed)
The results of understanding NOS empirical aspects before learning	51	2.53	0.21	0.000
The results of understanding NOS empirical aspects after learning	51	3.04	0.19	

Table 4 shows a sig (2-tailed) value of 0.000 less than α (0.05), then H_0 is rejected and H_1 is accepted, meaning that the results of the study show that there are significant differences in students' understanding of NOS empirical aspects before and after learning with the EBNOS model. The average value of the questionnaire results shows that the value of understanding NOS empirical aspects after learning EBNOS is higher than before learning EBNOS. Therefore, these findings indicate that students' understanding of NoS on the empirical aspect, after the intervention in the form of learning with the EBNOS model has increased. The results of the average score per item statement are presented in Figure 3.

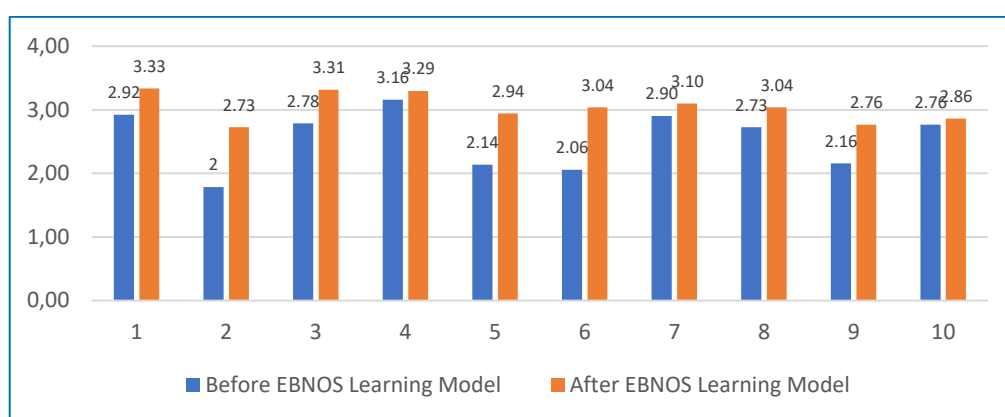


Figure 3. Graph of Average Per Item of NOS Understanding Empirical Aspect Questionnaire

Figure 3 shows that there is an increase in understanding of the empirical aspects of NOS in each statement before and after learning with the EBNOS model. Of the 10 items on the empirical aspect, there was not one statement that did not experience improvement. Then to see whether gender differences have an effect on increasing students' empirical understanding of NOS or not, the data is then analyzed based on the gender of male and female students presented in Figure 4.

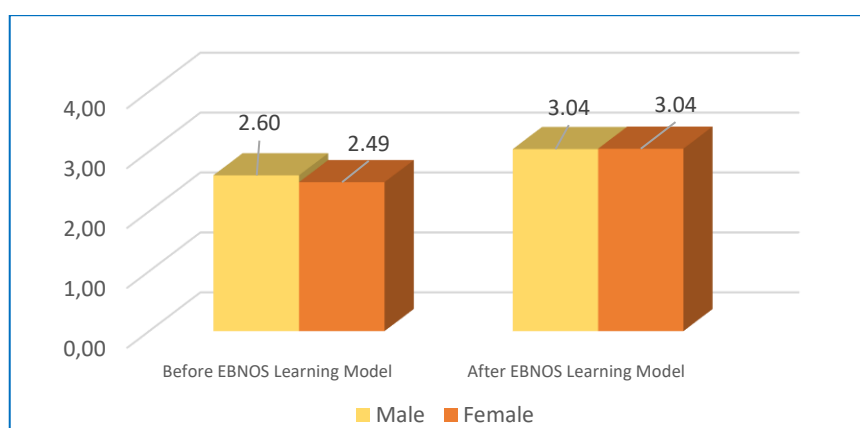


Figure 4. Graph of Differences in Empirical Aspects of NOS Understanding Results Before and After NOS Learning Based on Gender

Figure 4 shows that the average acquisition of empirical aspects of NOS understanding for both male and female students is at the same score, namely 3.04, while the average pretest results for male and female students obtain different scores where male students obtained a score of 2.60 while female

students were 2.49. This shows that the students' initial NOS understanding of the empirical aspects of male students is higher than female students, but the increase in NOS understanding of female students is greater than that of male students between before and after learning the EBNOS model. In general, the acquisition of empirical aspects of NOS understanding scores between male and female students did not differ significantly after the EBNOS learning model was applied. Then the results of the average understanding of the empirical aspects of NOS are also seen from the students' interest in science presented in Figure 5.

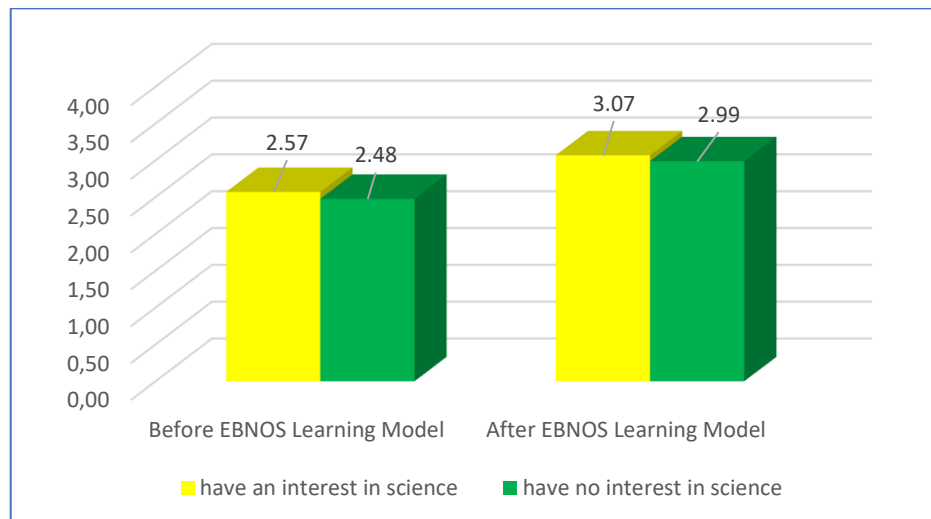


Figure 5. Graph of Differences in Average NOS Understanding Values in View of Students' Interest in Science

Figure 5 shows that there is a difference in the average pretest and posttest scores between students who have an interest in science and students who do not have an interest in science. The average acquisition of the posttest understanding of empirical aspects of NOS for students who have an interest in science is 3.07 while those who do not have an interest in science are 2.99. This gain has a difference, although not significant because it is still in the same range. The increase in scores between students who have an interest in science and students who do not have an interest in science is the same, which is around 0.50 seen from the score of understanding the NOS empirical aspects before and after learning EBNOS.

Discussion

Data collection was carried out using a questionnaire which was filled in directly without being taken home. So it is hoped that the statements included in the questionnaire truly represent the understanding of the nature of science by research subjects without the help of other people and without looking at book or internet sources. The data shows that the average value of the empirical aspects of understanding NOS after learning EBNOS is higher than before learning EBNOS. Therefore, these findings indicate that students' understanding of NoS on the empirical aspect, after the intervention in the form of learning with the EBNoS model has increased. This finding is in line with the results of the study from which states that the NOS learning model can significantly improve students' understanding of NOS, especially on the empirical aspect (Imran & Wibowo, 2018; Kampourakis, 2016; Lestari & Widodo, 2021; Nurmaulida, 2016). Then in general, the acquisition of empirical aspects of NOS understanding scores between male and female students did not differ significantly after the EBNOS learning model was applied. These results are in line with the results of research conducted where the acquisition of NOS understanding of male and female students did not differ significantly after the NOS learning model was applied (Adi, Y & Widodo, 2018). The same results were shown from other research where even though there are differences in the acquisition of the percentage of understanding NOS, especially in the empirical aspect, between male and female students but not significantly different in the range (Metin et al., 2012).

Judging from the students' interest in science, the increase in scores between students who have an interest in science and students who do not have an interest in science is the same, namely around 0.50 seen from the score of understanding the NOS empirical aspects before and after learning EBNOS. The results of this study are in line with the study conducted that show a person's understanding of NOS is not influenced by gender bias, conflicts of interest, economic status, and their interest in science (Allchin,

2011). Someone who is accustomed to scientific literacy will have a broad understanding of scientific practice even if they have no interest in science (Rato et al., 2022; Rudolph, 2003). However, the results of this study are contrary to a study conducted which stated that someone who has an interest in understanding science is proven capable of assessing and proving how valid and reliable an information or claim is (Pellegrino, 2002). From the overall results of students' understanding of the empirical aspects of NOS, it can be concluded that EBNoS learning applied in learning activities facilitates students understanding the empirical aspects of NOS by providing experience to students working and acting like a scientist in understanding natural phenomena and training students to study and develop science through investigation. The results of this study are in line with the results of research conducted which showed that NoS learning is applied in learning activities, providing experiences about NoS in meaningful contexts in developing understanding of scientific concepts, principles, theories and processes, by training students to learn to use the way scientists work and act in studying natural events and phenomena through empirical activities, both experimental and observational (Adi, Y & Widodo, 2018; Kampourakis, 2016; Kelly & Erduran, 2019; Norman G. Lederman et al., 2014).

The Empirical Base NOS learning model makes students understand science as a whole empirically including: (1) reviewing and exploring theories and laws that have been understood by students, (2) looking for new evidence empirically to formulate new knowledge with scientific methods such as carried out by scientists, (3) developing new knowledge proven by empirical evidence, and (4) synthesizing new knowledge obtained to solve problems related to everyday life through empirical exploration (Lestari, 2020; Rahayu & Widodo, 2019), and (5) understanding that although some knowledge is not accompanied by real evidence, knowledge can still be acknowledged for its truth as long as it is produced in an accountable manner. These five stages make students understand that scientific knowledge is built and developed based on empirical data/evidence obtained from experiments with scientific methods that can be accounted for (Lestari, 2020; Mudavanhu & Zezekwa, 2017). The implications of this study indicate that the use of the EBNoS learning model can increase students' understanding of scientific nature in an empirical aspect. The implication is that this learning model can be used by teachers in teaching scientific concepts to students, thereby helping them to better understand the scientific method and how science works. However, the limitations of this research were conducted at schools or groups of students which were limited in number and characteristics. Therefore, the results of this study may not be directly generalizable to the wider student population. It is therefore recommended that additional studies involving larger and more diverse samples are needed to ensure more general and applicable results.

4. CONCLUSION

This study shows that the application of the Empirical Base Nature of Science (EBNoS) learning model design has a significant effect on increasing students' understanding of NoS, especially on the empirical aspect. After the intervention in the form of teaching, students' understanding of the empirical aspects of NoS increased. The NOS understanding score on the empirical aspect was not influenced by the student's gender or the student's interest in science itself. This study shows that the application of the EBNoS learning model design helps students understand the nature of empirical science holistically. This research is expected to contribute to the improvement of the learning process which aims to achieve the objectives of learning science, especially in the empirical aspect of the NOS domain. Suggestions for further research are developing specific learning models that can improve understanding of NOS in other aspects.

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