



The Effect of Nature of Science (NoS) Explicit Learning Design on Students' NoS Comprehension at Elementary School

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Abstract

This research aims to investigate the effect of Nature of Science (NoS) learning design implementation on students' NoS comprehension. The research employed the pre-experimental method with one group of pretest and post-test design. The samples, selected by purposive sampling technique, were 34 fifth grade students at one public school in Bandung city. A Likert-scale questionnaire was used as the instrument for collecting the data. The data analysis employed a descriptive quantitative technique by independent sample t-tests with the assistance of SPSS and Microsoft Excel tools. The findings show that there was a significant increase from the scores in pretest and post-test as the significance score is $0.000 < \alpha = 0.05$. The average score in the post-test was higher than the score in the pretest, indicating that student's NoS understanding improved. In terms of percentage, NoS comprehension aspects increased from 13% to 78%, then 91%. The aspect with the highest increase was creativity (100%), whereas the aspect with the lowest increase was the socio and cultural embeddedness, with 87% increase. This research suggests that the implementation of the Nature of Science (NoS) explicit learning design has a significant effect on the students' NoS comprehension.

Keywords: *learning design, nature of science, students' NoS comprehension.*

Abstrak

Penelitian ini bertujuan untuk mengetahui pengaruh implementasi desain pembelajaran Nature of Science (NoS) terhadap pemahaman NoS siswa. Metode yang digunakan dalam penelitian ini adalah metode pra-eksperimen dengan *one group pretest and posttest only design*. Sampel diambil dengan teknik purposive sampling, yaitu sebanyak 34 siswa kelas V di salah satu sekolah negeri di kota Bandung. Kuesioner skala likert digunakan sebagai instrumen untuk mengumpulkan data. Analisis data menggunakan teknik deskriptif kuantitatif dengan *uji independent sample t-tests* berbantuan SPSS dan Microsoft Excel. Hasil penelitian menunjukkan bahwa terdapat peningkatan yang signifikan dari nilai pretest dan post-test, di mana nilai signifikansinya sebesar $0,000 < \alpha = 0,05$. Nilai rata-rata post-test lebih tinggi dari pada nilai pretest, yang menunjukkan bahwa pemahaman NoS siswa meningkat. Dari segi persentase, aspek pemahaman NoS meningkat dari 13% menjadi 78%, kemudian 91%. Aspek yang mengalami peningkatan tertinggi adalah kreativitas (100%), sedangkan aspek yang mengalami peningkatan terendah adalah keterikatan sosial dan budaya, yaitu sebesar 87%. Penelitian ini menunjukkan bahwa penerapan desain pembelajaran eksplisit Nature of Science (NoS) memiliki pengaruh yang signifikan terhadap pemahaman NoS siswa.

Kata kunci: *desain pembelajaran, nature of science, pemahaman NoS siswa.*

INTRODUCTION

Nature of Science (NoS) can be defined as knowledge of epistemology and the initial process of science, or value and belief inherent in science development (Khalick, Lederman, & Bell, 1998; Lederman. et al., 2002; Lederman, 2006; Lederman, Lederman, & Antink, 2013). NoS is not science process, but knowledge of science obtained from the process. Khalick et al. (1998) state that even though NoS and scientific process are essentially different, the two terms are often overlapping and misunderstood. Science process can be defined as activities pertained to collect and interpret the data, as well as the derivation of conclusion, while NoS pertains to epistemological values and assumptions which are the foundation of scientific process activities (Lederman et al., 2002).

As an epistemological knowledge of science, NoS has characteristics or aspects. According to McComas & Nouri (2016), those aspects are 1) Scientific knowledge is not entirely objective; 2) Scientists use creativity; 3) Scientific knowledge is tentative but durable; 4) Scientific knowledge is socially and culturally embedded; 5) Laws and theories are distinct kinds of knowledge; 6) Scientific knowledge is empirically based; 7) There is no universal stepwise scientific method; 8) There is a distinction between observations and inferences; 9) Science cannot answer all questions (and is therefore limited in its scope); 10) Cooperation and collaboration are parts of the development of scientific knowledge; 11) There is a distinction between science and technology; 12) Experiments have a role in science.

From the aspects above, Jumanto & Widodo (2018) suggested that the seven essential aspects of NoS are empiric-based, tentativeness, theories and law, socio-cultural

embeddedness, creativity, scientific method, and subjectivity. Furthermore, the analysis conducted by Tursinawati & Widodo (2019) suggested that aspects of NoS most relevant to the digital era today are the aspects of creativity, tentativeness, socio-cultural embeddedness, theories and law, scientific method, no answer all question nature, and scientific ethos.

NoS contributes to the complete understanding of nature of science (Lederman, et al., 2002) since deep comprehension of NoS correlates with the improvement in scientific literacy (Khishfe, et al., 2017). Driver et al. suggest that by comprehending NoS, students will be able to: 1) comprehend science, manage objects, and process technology in daily life (utilitarian), 2) contribute information to decision making process on socio-science issues (democratic), 3) respect scientific values as a part of contemporary culture (cultural), 4) develop the understanding of norms among scientific community aimed at realizing moral commitment, a universal value, that applies in society (moral), and 5) facilitate the learning of science subjects (science learning) (Lederman, 2006; Rahayu & Widodo, 2019).

NoS comprehension becomes one of the aims of science education as its comprehension is essential (Cil, 2014). Teachers should incorporate the teaching of NoS (McComas & Nouri, 2016), mainly through three approaches of science teaching, namely implicit, historical, and explicit approaches (Lederman, Lederman, & Antink, 2013). The first approach is the implicit approach. According to Cil (2014), in this approach, students are encouraged to conduct direct scientific observation on objects to get more comprehension of NoS. In a similar vein, McDonald (2010) suggested that comprehension of NoS will improve when students are involved in inquiry-based activities without explicit and focused instructions. Teachers are not encouraged to develop NoS to the specific lesson and discuss aspects of NoS explicitly. Students are expected to learn about NoS by exploring various scientific concepts, theories, and laws like professional scientists. This approach does not treat NoS as a product of cognitive learning, but more as an appendage.

The second approach is the historical approach. Unlike the implicit approach, this approach incorporates the history of science in science teaching to improve student comprehension of NoS (Lederman, Lederman, & Antink, 2013). In science class, teachers teach the history of science to show students how science is generated with the expectation that the historical process will lead to the improvement of NoS comprehension.

The last approach is the explicit approach. The application of this approach utilizes instructions directed to various aspects of NoS and historical as well as philosophical elements of science to improve student comprehension (Lederman, Lederman, & Antink, 2013). According to Abd-El-Khalick and Akerson (2004), this approach allows teachers to

select various pedagogical approaches such as active learning, student-centered, collaborative, and inquiry-based. In terms of the option, some experts (see for example Akerson, Hanson, & Cullen, 2007; Khishfe, 2008; Khishfe & Abd-El-Khalick, 2002) suggested that the inquiry-based approach is the most preferred by teachers. McDonald (2010) explains that in the explicit NoS teaching approach, teachers explicitly encourage students to focus on various aspects of NoS during a discussion in class. The underlying principle of this approach is the assumption that NoS instructions should be planned and implemented as the main component, not an appendage, of science class. In a similar vein, Cil (2014) suggests that explicit teaching of NoS involves students in a discursive situation that allows them to inquire, design experimentation, collecting data, decide the coding and analysis of data, and answer contextual questions based on empirical data. In applying this approach, teachers should lead a class discussion on a particular science content focused on the aspects of NoS selected.

Several experts have reported research on NoS. Michel & Neumann (2014) researched the correlation between NoS teaching and learning achievement in science subjects. The research result suggests that NoS teaching can improve the effectiveness of science learning process as it helps students to meet the objective of science classes. In contrary, Wicaksono, Minarti, & Roshayanti (2018) found that there is no correlation between motivation to learn science with NoS comprehension. Possessing high motivation to learn science does not automatically lead to NoS comprehension. Hence, the research suggests that various comprehensive methods be used in the teaching of NoS and improving students' motivation.

In addition, Köksal (2009) proposes a learning design model to teach NoS. This model is considered a potential prototype to be used as a reference for developing NoS teaching in tertiary education. Furthermore, Listiani & Kusuma (2017) aim to assess NoS comprehension of pre-service science teachers by using V NoS form B. The findings show that V NoS form B can be utilized to assess the pre-service teachers' understanding of the nature of science. The research also found that most of the pre-service teachers have limited understanding of aspects of the nature of science. Research conducted by Aflalo (2018) aims to investigate how NoS teaching affects the perception of religious and secular students toward NoS. The findings demonstrate that the intervention affects several aspects of perception toward NoS of all participants, but not changing the perception of religious students on the relation between science and religion.

Other experts investigate the effectiveness of implicit approach of NoS teaching. Lederman (2006) suggested that the implicit teaching of NoS is not adequate. Cite & Hanuscin (2014) add that teachers' substantial comprehension of NoS, the knowledge, cannot

convert automatically into NoS instructions understood by students. Hence, to improve student comprehension effectively, NoS should be taught explicitly to students (Khalick et al., 1998; Lederman, Lederman, & Antink, 2013). Khishfe & Abd-El-Khalick (2002) further suggest that the explicit teaching of NoS will emphasize the idea that NoS comprehension is the result of well-planned and targeted cognitive learning, similar to the teaching of abstract concepts involving complex scientific theories.

This research aims at investigating the effect of NoS learning explicit design implementation on elementary school students' NoS comprehension. The research follows the explicit approach and designs the lessons based on the aspects of NoS. In the initial stage, the design analyzes of aspects of NoS suggested by some experts (Jumanto & Widodo, 2018; McComas & Nouri, 2016; Rahayu & Widodo, 2019; Tursinawati & Widodo, 2019) to reveal the core aspects of NoS. The results of the analysis are illustrated by intersected Venn diagram, as follows:

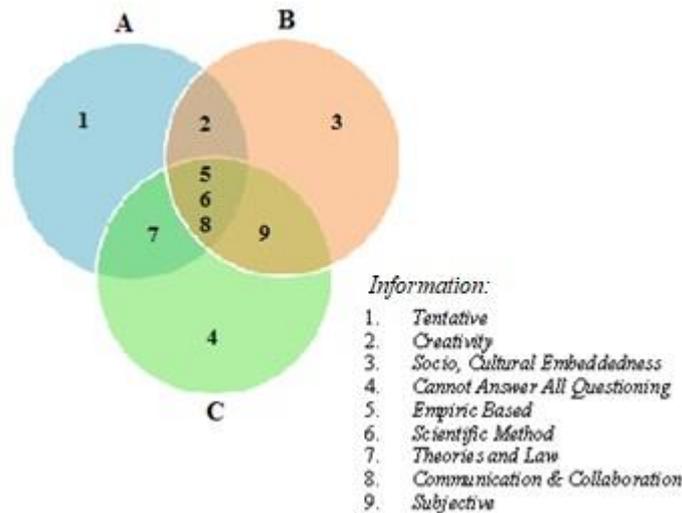


Figure 1. The analysis of aspects of NoS

Figure 1 depicts that the aspects of NoS are divided into three big circles representing the core aspects, namely empiric-based, scientific method, also communication and collaboration. As lessons cannot facilitate the learning of all aspects of NoS simultaneously, this research limits the scope into the analysis of circle B, containing creativity, socio and cultural embeddedness, empiric-based scientific method, communication and collaboration, as well as subjectivity aspects. Furthermore, circle B is used as the basis for developing NoS explicit learning design.

After selecting the aspects of NoS for explicit teaching, the cognitive structure of the lesson is analyzed (Duschl & Grandy, 2013; Khalick et al., 1998). The cognitive structure, the

inner structure, is used as the basis to develop learning activities or the outer structure. In general, the process of NoS explicit learning is as follows:

Table 1. Inner Structure Design NoS Explicit Learning

Teacher	Student
Encouraging students to use their prior knowledge to identify how scientists work and develop NoS.	Using their prior knowledge to identify how scientists work and develop science with creativity, socio and cultural embeddedness, empiric-based, scientific method, communication and collaboration, as well as subjectivity aspects.
Guiding students to collect evidence on how scientists work and develop NoS	Collecting evidence scientifically to prove scientists, when working and developing science, involve creativity, socio and cultural embeddedness, empiric-based, scientific method, communication and collaboration, as well as subjectivity aspects.
Organizing systematically students' new knowledge about how scientists work and develop NoS.	Analyzing evidence that when working and developing science, scientists are influenced by creativity, socio and cultural embeddedness, empiric-based, scientific method, communication and collaboration, as well as subjectivity aspects.
Confirming student comprehension of the newly acquired knowledge.	Concluding that the nature of science is influenced by creativity, socio and cultural embeddedness, empiric-based, scientific method, communication and collaboration, as well as subjectivity aspects.
Restating students' newly acquired knowledge.	Communicating their study on how scientists work and develop science, based on creativity, socio and cultural embeddedness, empiric-based, scientific method, communication and collaboration, as well as subjectivity aspects.

As the implementation of NoS explicit learning design is crucial, this research aims at investigating the effect of the implementation of the design on students' NoS comprehension. The aspects of NoS studied in this research are the aspects of creativity, socio & cultural embeddedness, empiric-based, scientific method, communication and collaboration, as well as subjectivity.

METHODS

This research employed a pre-experimental method through one group pretest post-test design (Gall, Gall, & Borg, 2010). The pre-experimental method is selected since the intervention was only conducted to one group, without the presence of a control group as a comparison. (Creswell, 2010). The initial stage of the research was the provision of pretest and treatment, while post-test was given in the later stage. The following table illustrates the one-group pretest-posttest design in this research.

Table 2. Research Design

Group	O ₁	X	O ₂
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(Creswell, 2010)

The research subjects, selected by *convenience sampling* (Gall et al., 2010), are 34 fifth grade students in one public elementary school in Bandung city. The instrument used to collect data related to student comprehension of NoS in the pretest and post-test was Likert-scale questionnaire (4, 3, 2, 1). Instrument validation is conducted through construct validity based on judgment from experts, peers, and teachers as practitioners. In the instrument, 25 items cover the aspects of creativity, socio and cultural embeddedness, empiric-based, scientific method, communication and collaboration, also subjectivity. The following is the overview of the questionnaire, the instrument, used to collect data regarding students NoS comprehension.

Table 3. The overview of students' NoS comprehension questionnaire

No	Aspects of NoS	Question Items	Total
1	<i>Creativity</i>	1, 2, 3, 4, and 5	5 items
2	<i>Socio & Cultural Embeddedness</i>	6, 7, 8, and 9	4 items
3	<i>Empiric-Based</i>	10, 11, 12, and 13	4 items
4	<i>Scientific Method</i>	14, 15, and 16	3 items
5	<i>Communication and collaboration</i>	17, 18, 19, 20, and 21	5 items
6	<i>Subjectivity</i>	22, 23, 24, and 25	4 items
	Total		25 items

A quantitative descriptive method, with SPSS and Microsoft Excel tools, was used to analyze the data collected from the questionnaire. In revealing the effectiveness of NoS explicit learning design implementation, the pretest and post-test results were processed by SPSS with independent sample two tests or t-tests. The significance of the design implementation was obtained from the tests. Then, the results were converted into a percentage to reveal the level of student comprehension of aspects of NoS taught in the lessons.

The learning activities of NoS explicit learning design implemented in this research were divided into five stages. First, the teachers played a video portraying how scientists work and develop science with aspects of creativity, socio and cultural embeddedness, empiric-based, scientific method, communication and collaboration, as well as subjectivity involved. Students were required to observe the video with guidance from teachers. Discussion on the content of the video followed. Lastly, teachers explained the connection of the content of the video with the next activities.

In the second stage, teachers provided tools, materials, and experiment manual to students working in a group. Students were asked to collect data proving that scientists, when working and developing science, involve aspects of creativity, socio and cultural embeddedness, empiric-based, scientific method, communication and collaboration, as well as subjectivity. Prior to the experimentation guided by teachers, students were required to prepare tools and materials, as well as study the experiment manual.

The third stage involved the preparation of students' analysis report (LKPD, *Lembar Kerja Peserta Didik*) sheet for the experiment. The experimentation activities aim to prove that the work and development of science involve aspects of creativity, socio and cultural embeddedness, empiric-based, scientific method, communication and collaboration, as well as subjectivity. Students were asked to study the report paper before analyzing the evidence from the experiment under teachers' guidance. The analysis process was conducted through in-group discussion.

In the fourth stage, teachers provided students with conclusion report sheet for the experiment that aims to prove that scientists work and develop science-based on aspects of creativity, socio and cultural embeddedness, empiric-based, scientific method, communication and collaboration, as well as subjectivity. Students were asked to study the report sheet before organizing the conclusion of the group experiment under teachers' guidance. Teachers then reviewed the conclusion made by students.

In the last stage, teachers provided the report form of the experimentation result for students to present their group work. Then, the report was presented to the class in turns. Teachers directed and gave feedback on students' performances.

RESULTS AND DISCUSSION

The result of the questionnaire about the effect of NoS explicit learning design implementation on students' NoS comprehension in the pretest and post-test is presented in Table 4. The descriptive statistic and Wilcoxon test on the data show the following result:

Table 4. Pretest and Post-test Analysis Result

Group	Descriptive Statistics					Uji Wilcoxon	
	N	Mean	Std. Deviation	Min	Max	Z	Asymp. Sig. (2-tailed)
Pretest	25	3.108	.3570	2.4	3.6	-4.385 ^a	.000
Posttest	25	3.648	.2064	3.1	4.0		

With significance value of $0.000 < \alpha = 0.05$, H_0 was rejected, while H_1 was accepted. The result indicates that there was a significant difference in NoS comprehension in the pretest and post-test. The average scores of the test show that score in post-test was higher than before.

Table 4 shows that the average score of the post-test was 3.65, higher than the average score of the pretest, which is 3.11. Hence, the finding indicates that students' NoS comprehension, after the intervention in the form of NoS explicit learning, improves. The finding is in line with some researchers (see, for example, Khalick et al., 1998; Lederman, Lederman, & Antink, 2013) stating that NoS explicit teaching is effective to improve students' NoS comprehension due to the focused and targeted instructions used. The instructions help students to attain knowledge from cognitive learning process similar to the learning of abstract concepts and advanced scientific knowledge (Khishfe & Abd-El-Khalick, 2002).

The data obtained from pretest and post-test then were converted into a percentage to reveal the complete result of students' NOS comprehension in each aspect. Students' NoS comprehension in each aspect is shown in Table 5.

Table 5. Students' NoS Comprehension Percentage

No.	Aspects of NoS	Pretest	Post-test
1	<i>Creativity</i>	85	95
2	<i>Socio & Cultural Embeddedness</i>	71	87
3	<i>Empiric-Based</i>	75	93
4	<i>Scientific Method</i>	81	89
5	<i>Communication and collaboration</i>	79	93
6	<i>Subjectivity</i>	74	88
	Average	78	91

Table 5 shows that students' NoS comprehension average score before the implementation of NoS explicit learning design was 78%. After learning commenced, there was an increase of 13% to 91%. This increase potentially occurred because of the implementation of NoS explicit learning design that emphasizes learning centered approach. When the intervention was conducted, students inquired actively to address empirically

contextual problems asked by teachers. Discussion connected to the inquiry task based on aspects of NoS selected then followed (Cil, 2014).

The aspect of creativity was the highest before and after the implementation of the learning design. Before the intervention, the comprehension score on this aspect was 85%. The questionnaire response regarding comprehension of this aspect increased by 10% to 95% after the lesson commenced. The percentage indicated that students understand how creativity is vital for scientists to work and develop scientific knowledge. The finding is consistent with Melville (2011) reporting that student comprehension on the aspect of creativity improved significantly after the learning.

The aspect of socio and cultural embeddedness has the lowest comprehension score before and after the intervention. Before the learning design was implemented, the student comprehension percentage was 71%, while after the intervention, the percentage improved by 16% to 87%. Despite having the lowest percentage, the finding related to this aspect indicated that students understand how socio-cultural contexts around scientists influence the work and development of scientific knowledge. In a similar vein, Ağlarıcı, Sarıçayır, & Şahin (2016) suggest that science is a cultural product strongly influenced by socio-cultural contexts where scientists experience various phenomena and conduct observation.

Furthermore, the students' response to the aspect of empiric-based was 75% before the intervention. After the implementation of the learning design, the percentage increased by 18% to 93%. This percentage suggests that students understand the importance of empirical facts on the work and development of science by scientists. As Eymur (2019) also suggests, science is a product from empirical observation. The aspect of scientific method had 81% of responses before the intervention. The percentage increased by 8% to 89% after the learning design was implemented. This finding shows that students potentially have understood that when working and generating scientific knowledge, scientist employs scientific methods (Miller et al., 2010).

The questionnaire result indicated that the aspect of communication and collaboration got 79% of responses before the intervention and 93% responses after the intervention. This increase suggests that students understand how communication and collaboration with peers and people around are vital in the work and development of science. Olson (2018) further suggests that science involves collaboration with various parties, disciplines, and culture.

Lastly, the aspect of subjectivity had 74% of response before the intervention, and 88% after the intervention. The result indicates that students understand how scientists are influenced by personal knowledge, experiences, thoughts, and skills when working and

developing scientific knowledge. This is in line with Khishfe. et al. (2017) reported that student comprehension on the aspect of subjectivity improved after the intervention.

The analysis of questionnaire responses shows that comprehension of all aspects of NoS improves. The highest improvement is on the aspect of empiric-based with 18% of the increase in responses, while the lowest improvement is on the comprehension of the aspect of scientific method with only 8% of the increase in responses. The improvement in comprehension of aspects of NoS, potentially, is caused by the explicit teaching of NoS, which explicitly direct students' focus to various aspects of NoS during the class. In this case, NoS is treated as the main component of the learning, not the appendage. (McDonald, 2010).

This research suggests that NoS explicit learning can improve student comprehension of NoS. The finding of this research corroborates the previous research, such as Eymur (2019), reporting that NoS explicit teaching improves high school student comprehension of NoS, as well as Nur & Fitnat (2015), stating that NoS reflective and explicit approach are effective to encourage students to perceive NoS more positively. Furthermore, Melville (2011) suggests that the two variations on NoS explicit teaching can improve student comprehension, adding to the plethora of research suggesting effectivity of NoS explicit teaching to improve students' NoS comprehension.

CONCLUSION

This research suggests that the implementation of NoS explicit learning design had a significant effect on the improvement of students' NoS comprehension. After the intervention in the form of explicit teaching, students' general NoS comprehension improved. The highest comprehension score was in the creativity aspect, while the lowest comprehension score was in the aspect of socio and cultural embeddedness. This research indicates that the implementation of NoS explicit learning design helped students to comprehend the nature of science holistically. This research is expected to contribute to the improvement of the learning process that aims to achieve the goals of science learning.

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