JIPF (JURNAL ILMU PENDIDIKAN FISIKA)
p-ISSN: 2477-5959 | e-ISSN: 2477-8451 *Vol. 8 No. 2, May 2023, Page 240-247*

The Effectiveness of Nature of Science-Based Learning Programs to Stimulate Complex Problem-Solving in Global Warming

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Received: December 28th, 2022. Revised: February 2nd, 2023. Accepted: February 5th, 2023

Keywords :
Nature of Science; Complex Problem Solving; Global Warming

ABSTRACT
This study aims to measure students' complex problem solving on the concept of global warming. This study used a quasi-experimental design with nonequivalent control group design. The research subjects were 52 grade 11 high school students in Pesawaran District using a purposive sampling technique. This study uses eight essay questions as complex problem-solving instruments with six skill indicators, namely 1) articulating the problem, 2) identifying the desired result, 3) brainstorming creative options, 4) analyzing and choosing the best option, 5) developing an action plan that will achieve the result desired end 6) establish a plan of action and adapt as needed. The results showed that there was an effect of learning using the nature of science on students' complex problem solving with an increase of 0.75 in the high category in the experimental class compared to the control class with an increase of 0.35 in the medium category.

INTRODUCTION

21st-century skills aim to train students to be successful in work and life [1] [2]. Subjects on 21st-century skills not only focus on the central theme but must include interdisciplinary subjects, the use of technology, and awareness of environmental issues [3]. One of the high school physics topics that do not only focus on the central theme is global warming material and has been included in curricula in various countries [4]. Studying global warming at school aims to train students to analyze symptoms and impacts and provide solutions to global warming [5]. However, many students are unaware of their role in tackling global warming [6] Research shows that a lack of basic scientific knowledge can reduce understanding and argumentation skills in solving problems based on concrete evidence [7].

Global warming is a complex problem [8] [9]. Global warming is a common problem that involves social, cultural, environmental, economic, and educational elements such as carbon emissions, the greenhouse effect, and the increase in the average temperature on earth, which is a problem that has not been resolved so far [10]. In education, we must prepare students to contribute to overcoming these complex problems, so students need to be trained in complex problem-solving.

Complex problem-solving is an interactive process that provides empirical access to detailed investigations [11]. Complex problems have interrelated factors, and students often ignore some small clues essential to solving complex problems [12]. Several cognitive processes are involved in solving complex problems [13]. There are six indicators of complex problem solving, namely 1) articulating the problem, 2) identifying the desired result, 3) brainstorming creative options, 4) analyzing and selecting the best option, 5) developing an action plan that will achieve the desired result 6) establishing an action plan and adapt as needed [14] [15].

One solution that is considered capable of overcoming this problem is the Nature of Science (NOS). NOS can increase students' understanding of science concepts [16] and enable them to make informed decisions about scientifically based personal and social problems [17]. This view is in line with the demands of world science education that NOS ideas must be included in learning [18] [19]. This trend has resulted in many researchers investigating the extent to which NOS has been applied in learning [18] [20] [21]. Understanding NOS helps students increase awareness of complex problems, scientific processes, and societal norms and appreciate science as an element of culture [22].

However, learning based on the nature of science is still a challenge for developing complex problem-solving skills in schools. Based on interviews with high school physics teachers in four provinces, namely Lampung, Banten, Jakarta, and West Java. Teachers have not integrated the nature of science into learning activities and teaching materials used. This is consistent with the study's results that the content of the nature of science in high school physics teaching materials is still in the implicit category [23].

Therefore, it becomes crucial to present problem-based learning, especially on global warming material [24]. The concept of global warming requires a dynamic focus with student-centered learning and the inclusion of relevant, challenging, and meaningful contexts. So, it needs to be packaged into a complete learning system as a NOS-based learning program.

This study aims to see 1) the effect of the nature of science learning on complex problem solving, 2) the improvement of complex problem solving using the nature of science and conventional learning, and 3) student activity when applied to the nature of science learning.

METHOD

This study used a quasi-experimental design with a non-equivalent control group design. Using a purposive sampling technique, the study subjects were 52 grade 11 high school students in Pesawaran District. It was decided that XI MIA 3, as the experimental class, used the nature of science learning while XI MIA 2, as the control group, used conventional learning.

The instrument used in this study is the description test instrument. The test instrument used to measure students' complex problem-solving with indicators 1) articulating the problem, 2) identifying the desired result, 3) brainstorming creative options, 4) analyzing and selecting the best option, 5) developing an action plan that will achieve the desired result 6) establish a plan of action and adapt as needed. Complex problem-solving test questions in the form of descriptions for eight questions. Complex problem-solving questions have been tested to determine the items' quality, validity, reliability, discriminatory power, and level of difficulty. The test results showed that four were in a significant category and four were very significant. The reliability coefficient is 0.86, with very high criteria.

Complex problem-solving data were analyzed with the help of SPSS 23 software. Normality test pretest and posttest through a One-Sample Kolmogorov-Smirnov Test. While the pretest and posttest homogeneity tests through a Levene Test. The pretest and posttest prerequisite tests show that the data are normally distributed and homogeneous, so the hypothesis test uses the t-test.

To determine the effectiveness of increasing complex problem solving, use N-gain with the following equation.

$$N - gain = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score} \quad (1)$$

Determination of the criteria for the N-Gain value is $0 < G < 0.3$ low category, $0.3 \leq G < 0.7$ medium category, and $0.7 < G$ high category [25].

RESULTS AND DISCUSSIONS

The data obtained in this study were students' complex problem-solving data. The data described are the results of data from the pretest, posttest, and N-gain in the experimental and control classes. The pretest results obtained from the control class and the experimental class before being given treatment are presented in Table 1.

Table 1. Measures of the Pretest Data Distribution of the Control and Experimental Group

Data Distribution	Control Group	Experiment Group
Average	24.19	22.07
The minimum score	3.00	3.00
The maximum score	47.00	47.00
Median	22.00	20.00
Modus	17.00	10.00
Standard deviation	12.80	10.36

Based on the results in Table. 1 average in the control class, 24.19, and the experimental class, 22.07. This shows that the average control class before treatment was more significant than the experimental class. However, the difference in the mean of the experimental and control classes was insignificant, indicating a similarity in the average initial ability. This was also supported by the minimum and maximum values obtained in the control and experimental classes obtaining the same score. The experimental class was treated using the nature of a science-based learning program.

After being treated with descriptive statistical analysis, the posttest results obtained from the control class and the experimental class obtained the value of the data distribution shown in Table 2.

Table 2. Measures of the Posttest Data Distribution of the Control and Experimental Group

Data Distribution	Control Group	Experiment Group
Average	51.77	80.04
The minimum score	40.00	67.00
The maximum score	67.00	97.00
Median	53.00	80.00
Modus	53.00	80.00
Standard deviation	7.09	7.63

Based on the results in Table. 2, the average posttest score in the control class is 51.77, and the experimental class is 80.04. This shows that complex problem-solving in the experimental class is higher than in the control class.

The normality test was carried out to determine the distribution of normally or not normally distributed data to determine the next statistical test. The normality test in this study used the One-Sample Kolmogorov -Smirnov test. The results of the pretest and posttest normality tests in the control class and experimental class can be seen in Table 3.

Table 3. Result of Normality Test

One Sample Kolmogorov-Smirnov	Kondisi	Sig.
Control group	Pretest	0.169
	Posttest	0.163
Experimental group	Pretest	0.200
	Posttest	0.105

Table 3. Shows the sig. The pretest and posttest in the control class and experimental class are more than 0.05. Based on these values, the pretest and posttest values in the control class and experimental class are normally distributed.

The results of the homogeneity test in this study used Levene statistics on the pretest and posttest. The homogeneity test results can be seen in Table 4.

Table 4. Result of Homogeneity Test

	Pretest	Posttest
Sig.	0.236	0.861
Levene's Test	Sig. ≥ 0,05 = H_0 accepted	
Result	homogeneous	homogeneous

Table 4. It shows the results of the pretest data homogeneity test of 0.236 ≥ 0.05 and posttest data of 0.861 ≥ 0.05, so it can be concluded that the variations in the two classes are the same or homogeneous. The hypotheses in this study include: 1) there is no effect of applying the nature of science learning program on complex problem-solving in the concept of global warming. The results of the pretest hypothesis test can be seen in Table 5.

Table 5. Result of Hypothesis Test

	Pretest	Posttest
Sig.(2-tailed)	0.515	0.000
Independent Sample T Test	Sig. ≥ 0,05 = H_0 accepted	
Result	H_0 accepted	H_1 accepted

Table 5. Shows the value of Sig. (2-tailed) pretest results of 0.515 ≥ 0.05, so it can be concluded that there is no difference in the mean pretest of complex problem-solving in the control class and the experimental class. The results of the posttest hypothesis test show that Sig. (2-tailed) posttest results of 0.000 <0.05 so that it can be concluded that nature and science-based learning programs have an effect on students' complex problem-solving in the control class and the experimental class.

The increase in complex problem-solving in the concept of global warming is calculated using the N-gain formula in the control class, and the experimental class can be seen in Table 6.

Table 6. Result of N-Gain

Group	N-Gain	Category
Control	0.35	Medium
Experiment	0.75	High

Table 6 shows the results of the control class getting an N-gain of 0.35 so that conventional learning treatment can improve students' complex problem-solving in the medium category. Meanwhile, the experimental class got an N-gain score of 0.75, which means that the nature of science-based learning can improve students' complex problem-solving in the high category. Based on the results of the average N-gain, the complex problem-solving of the experimental class with the nature of science was higher than the control class, which was given conventional treatment.

The increase in each indicator of complex problem-solving is obtained from the average n-gain for each group, which can be seen in Table 7.

Table 7. Result Average N-Gain Aspect of Complex Problem Solving

Aspect	Control Group		Experiment Group	
	N-gain	**Category**	**N-gain**	**Category**
Articulating the problem	0.39	Medium	0.71	High
Identifying the desired result, 6	0.48	Medium	0.81	High
Brainstorming creative options,	0.32	Medium	0.69	Medium
Analyzing and selecting the best option	0.48	Medium	0.78	High
Eveloping an action plan that will achieve the desired result	0.38	Medium	0.72	High
Establish a plan of action and adapt as needed	0.31	Medium	0.75	High

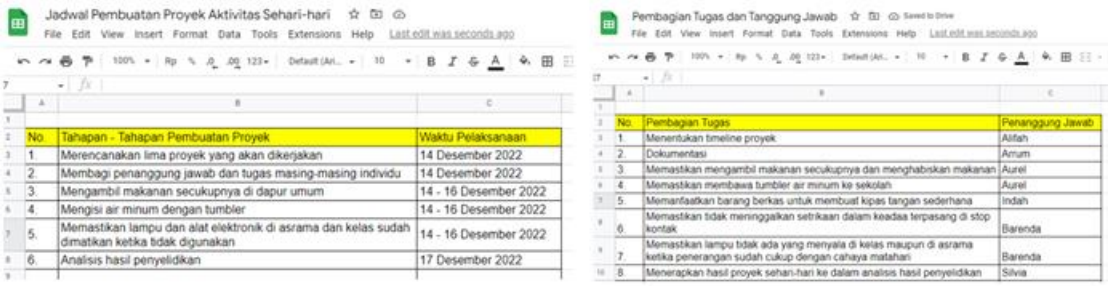
Based on Table 7. Students' complex problem-solving increased in every aspect. Six aspects of complex problem-solving in the control class increased in the moderate category. In the experimental class, only one aspect of complex problem-solving increased in the medium category, namely 0.69, and five aspects of complex problem-solving increased in the high category, with a range of 0.71 – 0.81. This increase occurs because the nature of the science learning process presents scientific knowledge based on empirical evidence so that student's understanding of science concepts increases, allowing them to articulate problems and make decisions based on scientific personal and social information [26].

The aspect of articulating problems in the control class increased by 0.39 (medium category), while in the experimental class, it increased by 0.71 (high category). The increase in the experimental class is superior because this aspect is trained through the nature of science learning which presents scientific problems based on empirical evidence so that a coordination process occurs to find patterns of evidence with theory to strengthen scientific arguments on the problems presented [27]. Scientific problems based on empirical evidence can be seen in Figure 1.

***Fig 1**. Aspects of articulating the problem on the e-worksheet*

Identifying the desired end result and brainstorming creative choices in the control class increased by 0.48 and 0.32 (medium category), while in the experimental class, it increased by 0.81 (high category). The increase in the experimental class is superior because learning the nature of science trains students to realize that scientific knowledge is probabilistic in nature, where knowledge is not only based on evidence that has been found but can also change based on new evidence so that students are able to make logical and creative choices [28].

Developing an action plan to achieve the desired result increased by 0.38 (moderate category) in the control class and by 0.71 (high category) in the experimental class. The aspect of establishing an action plan and adapting as needed to be increased by 0.31 (moderate category) in the control class, while it increased by 0.75 (high category) in the experimental class. It is trained at the everyday project investigation stage in Tackling global warming, which can be seen in Figure 2.



Jadwal Pembuatan Proyek Aktivitas Sehari-hari

No.	Tahapan - Tahapan Pembuatan Proyek	Waktu Pelaksanaan
1.	Merencanakan lima proyek yang akan dikerjakan	14 Desember 2022
2.	Membagi penanggung jawab dan tugas masing-masing individu	14 Desember 2022
3.	Mengambil makanan secukupnya di dapur umum	14 - 16 Desember 2022
4.	Mengisi air minum dengan tumbler	14 - 16 Desember 2022
5.	Memastikan lampu dan alat elektronik di asrama dan kelas sudah dimatikan ketika tidak digunakan	14 - 16 Desember 2022
6.	Analisis hasil penyelidikan	17 Desember 2022

Pembagian Tugas dan Tanggung Jawab

No.	Pembagian Tugas	Penanggung Jawab
1.	Menentukan timeline proyek	Alifah
2.	Dokumentasi	Arum
3.	Memastikan mengambil makanan secukupnya dan menghabiskan makanan	Aurel
4.	Memastikan membawa tumbler air minum ke sekolah	Aurel
5.	Memanfaatkan barang berkas untuk membuat kipas tangan sederhana	Indah
6.	Memastikan tidak meninggalkan setrikaan dalam keadaa terpasang di stop kontak	Barenda
7.	Memastikan lampu tidak ada yang menyala di kelas maupun di asrama ketika penerangan sudah cukup dengan cahaya matahari	Barenda
8.	Menerapkan hasil proyek sehari-hari ke dalam analisis hasil penyelidikan	Silvia

***Fig 2**. Daily project steps and responsibilities*

Based on Figure 2. The increase in the experimental class is superior because, through the nature of science learning, it trains students to gather up-to-date knowledge as a form of science is a way of knowing. Nature of science learning also forms students' awareness to deal with the symptoms and effects of global warming as an effort to maintain the order of nature. However, the efforts made must still pay attention to socio-scientific issues, scientific processes, and societal norms [29], So that students can make appropriate decisions, attitudes, and actions [30].

The increase in students' complex problem-solving is influenced by eight aspects of the nature of science, namely scientific knowledge based on empirical evidence, investigations using various methods, being open to receiving new evidence, the mechanism of science explaining natural phenomena, science how to know, science assumes alma regularity, science is a human endeavor, and science still pays attention to the social and cultural dimensions [31]. his study also corroborates previous studies that learning the nature of science can stimulate students' complex problem-solving [32] [33] [34].

CONCLUSION AND SUGGESTION

Based on the study's results, the nature of science learners influences students' complex problem-solving on global warming. The increase in complex problem-solving in the experimental class with N-gain of 0.75 is in the high category, while the increase in the control class N-gain is 0.35 in the medium category.

Based on the research that has been done, the researcher suggests that training students in complex problem-solving should be done continuously. The use of nature of science learning programs can also build a sustainable attitude towards the concept of global warming.

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