The Effectiveness of Science Learning Outcome Based on the Next Generations Science Standard

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Abstract. The significant effect of science learning outcome based on the Next Generations Science Standard (NGSS) was analyzed to improve constructing explanation-designing solutions skill (CEDS). CEDS is one of the main skills in NGSS. The research method used was a quasi-experimental design with non-equivalent group design. The populations of this research were all student of class VII SMP Negeri 8 Magelang. The sample of this research was selected through cluster random sampling, they were class VII G as an experimental class (30 students) and class VII H as a control class (30 students). The instrument used is a pretest-posttest questions. The analysis of data used is one-factor ANOVA at 0, 05 significance level and normalized gain score. The aspect of constructing explanation-designing solution skill in this research was claim, evidence, reasoning, design solutions, determine criteria and constraints, and evaluating potential solutions. The significance level result of CEDS skill with one-factor ANOVA is 0.00. It shows a significance level of < alpha (0, 05). It means that there was a significant effect of NGSS learning oriented towards constructing explanation-designing solution skills. The result of the analysis shows that the normalized gain score are 0, 29 (low category) in control class and 0, 55 (medium category) in experiment class. In conclusion, science learning based oriented to the NGSS that is effective to improve constructing explanation-designing solution skill in term in all CEDS aspects.

Keywords: Next Generations Science Standard, Constructing Explanation-Designing Solution

INTRODUCTION

Entering the 21st-century, technology and information develop more rapidly. The challenges faced by the people in this globalization era require a deeper knowledge reegarding the development of science and technology. Both science and technology play an important role to accelerate the development of a nation and meet various human needs [1]. Besides globalization as well as science & technology improvement, there are many changes happen in the world, including the increasing number of job opportunities which increases the workforce demands, and economic improvement which brings international competitiveness, which become 21-st century challenges. It demands a broader skill in which students need to be adequately prepared to participate in and contribute to today's society [2].

Despite having a demographic bonus in the form of a large productive population, the quality of human resources in Indonesia is still considerably low. This low quality of human resources is influenced by the poor quality of education. Education plays an important role to prepare future generations equipped with various skills to meet challenges in the 21st-century. However, NSTA recognizes the inherent and strong connection of many 21st-century skills with science education. Science education can offer a rich context for developing many 21st-century skills, such as critical thinking, problem- solving, and information literacy especially when the instruction addresses the nature of science and promotes the use of science practices. These skills not only contribute to the development of a well-prepared workforce of the future but also give individuals life skills that help them succeed [3].

Education is the most important factor to sustain country's development by creating more skilled and productive workforce. Various innovations and reforms in the field of education began to take on the challenges of globalization, both nationally and internationally. This change is done to prepare the next generation of quality. In the international sphere, one of the efforts made by various countries in the world is by preparing the Next Generations Science Standard (NGSS) [4].

The NGSS was developed through the collaborative effort of 26 the lead states in the United States to create a science education standard that reflects the knowledge and advances by enabling students to learn science by doing science. This standard was constructed based on three main dimensions. There are science and engineering practice, used by scientists and engineers to build the world through scientific inquiry and design, Disciplinary Core Idea that contains the main ideas in four disciplines, and the crosscutting concept, a concept or theme that bridges the scientific disciplines [5]. The NGSS present standards by expressing them as performance expectations (PEs). PEs integrate the three dimensions of NGSS to help students build an integrated and integrative understanding to enrich the relationship between concepts. The more connections developed, the greater the ability of students to solve problems, make decisions, explain phenomena, and make sense of new information [6]. A series of PEs is a first step in the development of lesson planning, curriculum, and evaluation in science learning to the NGSS [7].

The framework is designed to help realize a vision for education in science and engineering by ensuring that all students are college and career ready by the end of high school [8] and gain the vision for education in the twenty-first century [6]. The NGSS provide a strong science education that equips students with the ability to think critically, analyze information, and solve complex problems, the skills needed to pursue opportunities within and beyond STEM fields [4].

The Framework for K–12 Science Education and the Programme for International Student Assessment (PISA) emphasizes the importance of engaging students in scientific practices as they learn core ideas in science [5] [9]. However, science is not just a knowledge that reflects the understanding of the world today; but also a set of practices that are used to build, expand and improve that knowledge [5]. The importance of the engaging practice in science activity has been realized in the first dimension of NGSS-scientific and engineering practice.

Scientific and engineering practice emphasizes developing skills in science and engineering. The goal of science is to construct a theory that can provide an explanation of all phenomena in the world. While the goal of engineering is to solve a problem based on knowledge. However, to achieve the goal of science and engineering, students need to be involved in developing of constructing explanations and designing solution skills [4].

The scientific explanation practice goes beyond defining or describing a named process and links a chain of reasoning to the phenomenon to be explained [10]. The development of constructing scientific explanation plays an important role to enhance student's understanding of the nature of science and foster deeper understanding of important science concepts [11]. Although deemed as important, explanations are seldom becoming a part of classroom practice. Krajick identifies that the challenge of implemented CEDS practice is that students have difficulty using appropriate evidence and connecting evidence to a claim and typically discount data if the data contradicts their current theory.

The constructing explanations practice needs to be completed by designing solutions. The challenges emerging in the 21st century require innovative solutions based on scientific knowledge and scientific discovery [9]. Therefore, the people will need a prospective educated scientist to undertake the research and innovations in science and technology that are essential to meet the economic, social and environmental challenges to be faced in the future world. The integration of engineering process within NGSS is able to engage students in meaningful tasks ranging from defining problems to designing solutions [7] [12]. According to that challenges, the NGSS requires teachers to move away from simply presenting information to supporting students in building explanations of phenomena and proposing solutions to the problems [6].

The constructing explanations and designing solutions practice become an essential part of science literacy. This has been followed up by the PISA question, in the aspect of explaining the phenomena scientifically [9]. However, this CEDS skill has not been fully mastered by the students. PISA results show that the quality of students in Indonesia is in level 2 with the score of 403. At this level, students are able to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific inquiries and interpret data in some given familiar life situations that require mostly a low level of cognitive demand. They are able to distinguish some simple scientific and non-scientific questions and make some valid comments on the trustworthiness of scientific claims.

Students can develop partial arguments to question and comment on the merits of competing explanations, and proposed experimental designs in some personal, local and global contexts [13].

The Efforts within the national scope in addressing the challenges of globalization to achieve 21st-century skill is by formulating the 2013 curriculum. However, the framework of 2013 curriculum has not fully facilitated the realization of that vision. The low ability of students in developing scientific explanations and designing solutions is one caused by the standards competence in the 2013 curriculum which has not been specific to the development of scientific practice [14]. However, this requires the adoption of specific and measurable standards to integrate into the 2013 curriculum. NGSS presents an opportunity to improve the curriculum, teacher self-development, assessment, and student learning achievement [15]. This is supported by Nordman's research that science learning oriented to the NGSS can improve concept understanding by achieving 90% [16].

In this study, Science learning oriented to the NGSS is supported by learning tools on ecosystem materials. These learning tools are arranged towards NGSS and has been declared valid by the expert judgments. This research was conducted at SMP N 8 Magelang class VII. The purpose of this study is to know the effectiveness of Science learning oriented to the NGSS towards Constructing Explanation-Designing Solution skills.

METHOD

Type of Research

Type of research applied is quasi-experimental research. This research implemented two classes, namely experimental class and control class in which both classes were treated differently. The experimental class applied science learning oriented to the NGSS, while control class applied science learning based on the 2013 curriculum. Science learning oriented to the NGSS in experimental classes was using learning tools developed and declared valid by the expert judgments. Whereas the control class was doing the learning activity according to usual instructions applied in the school.

The Place and Time of the Research

This research was implemented in class VII G and VII H SMP N 8 Magelang. Class VII G was the experimental class, while class VII H became the control class. The study was implemented from January 22 to February 8, 2018.

The Populations and sample of the Research

The population in this research was all students of class VII SMP N 8 Magelang consisting of 8 classes with a total of 248 students. The sampling technique used in this research was cluster samplings, therefore, there were a total of 30 students in class VII G as the experiment class and a total of 30 students in class VII H as the control class.

PROCEDURE

The procedures implemented in this research were (1) giving a pretest to the control and experimental classes, 2) applying treatments by implement science learning oriented to the NGSS on experimental classes, and conventional learning on the control classes, (3) conducting a posttest to both classes to determine the improvement of CEDS skills after treatment.

The research design used was nonequivalent control group design. The format of this research can be seen in table 1 [17]:

TABLE 1. Research Design of Nonequivalent Control Group Design

Group	Pretest	Treatment	Postest
Experimental Class	O_1	X	O_2
Control Class	O_3	-	O_4

Note:
EC = Experimental Class
CC = Control Class
O1 = Early ability of Experimental class
O2 = Later ability of Experimental class
O3 = Early ability of Control class
O4 = Later ability of Control class

The process of science learning oriented to the NGSS was divided into three meetings with 8 hours lesson. This science learning was facilitated by student worksheets provided by the researcher for three meetings. The first meeting of science learning was about the interaction of living things with their environment. Through observation of ecosystem components in the environment, the students then created a mini ecosystem (eco-column) consisting of terrestrial and aquatic ecosystems. The second meeting was about the energy flow and cycle of matter within the ecosystem. The activity done by the student was identifying energy flow within food chain process and the trophic level. Then, they analyzed the cycle of matter through the ecosystem based on case study articles. The third meeting of science learning activity was designing the solution of the ecosystem problem in the previous articles. The main activity was building poster projects to be presented in the class.

DATA, INSTRUMENT, AND COLLECTING TECHNIQUE

The data used at this research was the result of student's CEDS skill. The instrument used in this research was six essay questions to measure CEDS skills on ecosystem topics. The instrument used was adapted from Mc.Neil & Krajick and SDCOE [18], [19]. The data collecting technique was conducted by taking student's pretest before the treatment and posttest after treatment score of CEDS skill. The CEDS skill question items given for pretest and posttest were the same, but the items are randomized at the posttest. The CEDS skill aspects were measured using essay questions consisting of 6 aspects with each indicator highlighted in table 2. Constructing Explanations-Designing solutions skill aspect.

TABLE 2. Aspect and Indicators of Constructing Explanations-Designing Solutions Skill

No	Aspect	Indicator
1	Claim	Articulate the explanation of phenomenon
2	Evidence	Cite evidence to support the explanation
3	Reasoning	Describe the reasoning that connects the evidence to phenomena
4	Generate Design solutions	Restate the original problem and propose solutions to each problem
5	Analyzing criteria and constraints	Describe criteria and constraints for the selected sub problems
6	Evaluating potential solutions	Analysis of the strength and weakness of the solutions with respect to each criterion and constraints

DATA ANALYSIS TECHNIQUE

1. Analysis Requirement Test

a. Normality Test

Normality test was applied to test the students' CEDS skill data distribution before treatment. The normality test applied was Kolmogorov-Smirnov test with SPSS 21. Normality test was applied upon pretest data of CEDS skill on class VII G as the experimental class and class VII H as the control class. The criteria applied was that if the value of significance was bigger than alpha (5%) then the data could be stated as a normal distribution.

b. Homogeneity Test

Homogeneity test was applied to find out whether the experiment and control class is homogeneous or not. Homogeneity test was applied upon pretest data of CEDS in both class groups using SPSS 21. The criteria applied as, if the value of significance > 0,05, the data could be assumed as homogenous and if the value of significance was < 0,05, the data could be assumed as not homogenous.

2. Hypothesis Test

The hypothesis test used was one way ANOVA statistic test. One way ANOVA test was used to analyze the significant effect of the science learning oriented to the NGSS towards the constructing explanation-designing solution skills in 2 groups, namely the experimental class and control class.

Hypothesis:

Ho: There was no significant effect of science learning oriented to NGSS on the constructing explanation-designing solution skill in SMP N 8 Magelang

Ha: There was a significant effect of science learning oriented to NGSS on the constructing explanation-designing solution skill in SMP N 8 Magelang

Criteria for decision making in this hypothesis test was Ho was rejected if the value of significance was < alpha (0,05)

c. Improvement Analysis

Improvement of students' CEDS skills can be analyzed using a normalized gain score calculation analysis [19]. The formula to calculate the improvement of CEDS skill with a gain score is:

$$g = \frac{postest\ score - pretest\ score}{maximum\ score - pretest\ score}$$

The normalized gain score can be categorized to determine the improvement of the CEDS skill shown in table 3 [19].

TABLE 3. Category of Normalized Gain Score

No	Normalized Gain Score	Category
1	g > 0.7	High
2	0.3 < g < 0.7	Middle
3	g < 0.3	Low

RESULT AND DISCUSSION

Constructing Explanations and Designing Solutions is one aspect of scientific and engineering practice in the first dimension of NGSS [5]. Science as a process of truth-seeking and engineering as the process of designing solutions to the problem has been rooted in various times and situations. The main purpose of science is how to use an evidence to construct a logical and coherent explanation of a phenomenon in order to form a theory. While the main objective of engineering is to produce a solution to the problem of the form of design obtained based on explanations or theories that have been owned [21] [22]. Thus, in order to realize the main goals of science and engineering, constructing scientific explanation skills need to be complemented by constructing designing solution skills as they complement each other.

Scientific explanation consists of three components: (1) claim, (2) evidence, and (3) reasoning. A claim is considered as correct when it is able to answer questions accompanied by appropriate supporting evidence and the reasoning provides a justification for that link between the claim and evidence [18]. Designing solutions emphasizes on how to use scientific knowledge to generate design solutions for each problem, then describe the criteria and constraints for the selected problems and solutions and, evaluating potential solutions by analyzing the strength and weakness of the solutions [19]. Based on constructing explanations framework by Mc.Neil & Krajick and designing solutions component by SDCOE, we can conclude that constructing explanations-designing solutions emphasizes on the development of several aspects. Constructing explanations designing solutions consist of 6 aspects they are (1) the claim, (2) evidence, (3) reasoning, (4) generate design solutions, (5) criteria and constraints, and (6) evaluating potential solutions.

This research was implemented in two classes, class VII G as experiment class and class VII H as control class. The experimental class applied science learning oriented to the NGSS, while control class applied science learning based on the 2013 curriculum. The science learning oriented to the NGSS in experimental classes was using learning tools developed and declared as valid by expert judgments. Whereas the control class was doing the learning activity according to usual instructions applied in the school.

The research was conducted from January 23, 2018, to February 8, 2018, which was divided into three stages: (1) pretest, (2) science learning process within three meetings, and (3) posttest. The pretest and posttest were performed using the test instrument in the form of essays questions to measure CEDS skills. The science learning process conducted in this study were taught in science in class VII with the interaction of living things with the environment as the subject matter.

Analysis requirement test consists of normality test and homogeneity test. The normality test applied was Kolmogorov-Smirnov test with SPSS 21. Normality test was applied upon pretest data of CEDS skill on class VII G as the experimental class and class VII H as control class.

Based on the normality test result, the significance value of the experimental class was 0.200 and the control class was 0.053. The result of the normality test in the control and the experimental class shows that the data pretest of both groups is normally distributed. This is indicated by the value of significance in both classes which is greater than the value of alpha (.sig> 0, 05).

Based on the homogeneity test result, the CEDS skill pretest score in the control and the experimental class resulted in a significance value of 0.093. This result shows that the value of significance is greater than the alpha value (.sig> 0, 05) therefore it can be assumed that both variants of the sample population in the control class and the experimental class are the same (homogeneous).

Based on the research that has been conducted, the data obtained regarding the CEDS skills of students in the control and experimental class is presented in table 4.

TABLE 4. Results of Descriptive Statistical Analysis of CEDS Skill in Control and Experimental Groups

No	Component	Control Class		Experiment Class	
		Pretest	Posttest	Pretest	Posttest
1	Total Student	30	30	30	30
2	Average of CEDS score	40,98	58,02	46,11	74,54
3	The highest score	73	83	80	87
4	The lowest score	23	37	17	53
5	Variant	147,65	148,45	286,65	78,68
6	Deviation Standard	12,15	12,18	16,93	8,87

The average CEDS skills pretest score in the control class was 40, 98 with the posttest score was 58, 02. While the average CEDS skill score in the experimental class was 46, 11 with the posttest score was 74.54. This indicates that the average CEDS skill at posttest was higher than the pretest score in both control and experimental class groups, which is shown in table 4. This result shows that there is an improvement of CEDS skills in both classes.

The score of CEDS skill in the control and the experimental classes based on pretest and posttest results can be explained by each aspect/indicator. The CEDS skill consists of six aspects: (1) claim, (2) evidence, (3) reasoning, (4) generate design solutions, (5) analyzing criteria and constraints, and (6) evaluating potential solutions. The CEDS skill value of both groups' score percentage recapitulation for the aspects concerned is presented in table 5.

TABLE 5. Recapitulations of the CEDS Skill Aspect Score Percentage

Aspects of CEDS Skill	Control Class			Experimental Class		
	Pretest	Posttest	Gain	Pretest	Posttest	Gain
Claim	33,62	59,17	0,38	32,50	68,33	0,53
Evidence	53,97	55,33	0,03	52,00	71,33	0,40
Reasoning	28,57	48,1	0,27	30,48	56,19	0,37
Generate Design solutions	54,02	80,56	0,58	65,00	95,56	0,87
Analyzing criteria and constraints	33,62	53,33	0,30	49,17	80,00	0,61

Evaluating potential solutions	41,38	51,67	0,18	47,50	75,85	0,54
Average	40,98	58,50	0,29	46,11	74,54	0,55

Where CEDS = Constructing Explanations-Designing Solutions Skill

The percentage of CEDS skills pretest in the control and the experimental class is shown by the table. 5. In both class groups, students get the highest score on indicator design solutions with a percentage of 54.02% in the control class, and 65% percentage in the experimental class. Both class groups also had the lowest score on the reasoning aspect with scores on the control class was 28, 57% and the experimental class was 30, 48%.

After treatment using NGSS-oriented science learning tools in experimental class and conventional learning in control class, there was an improvement in the posttest score of each indicator in both classes as shown by the table. In both groups, students get the highest score on indicator design solutions with the percentage of 80, 56% in the control class and 90, 56% in the experimental class. Both groups also had the lowest score on the reasoning aspect with a score of 48.1% in the control class and 56, 19% in the experimental class.

Based on the percentage score result of each indicator on pretest and posttest, the improvement of CEDS skills could be analyzed with the normalized gain score in each indicator. From the analysis result shown in table 5, it is known that CEDS skill aspect which gets the highest improvement in the experimental class is on the aspect of generating design solutions with high category improvement. While CEDS skills aspect with the lowest improvement is on the aspect of reasoning with a moderate category improvement.

The highest student improvement aspect of CEDS skill is in the generating design solution aspect with generalizing the problem and determining the solution to the problem as the indicators [19]. This increase is due to the fact that this aspect is the most basic aspect of the designing solutions skill. In this study, the students generalize the problems contained in the article and then provide solutions based on these problems.

The lowest improvement of students CEDS skills in this study was on the aspect of reasoning. This is caused by the fact that reasoning is the most difficult component of scientific explanation skills because it involves a justification that linking evidence to the claim [18]. Reasoning requires students' logical reasoning supported by their scientific knowledge. The development of scientific explanations at the middle school level is a difficult task and faces many challenges. Krajick describes that the greatest challenge in implementing constructing explanation practice is that students face difficulties to present appropriate evidence and relate it to claims [11]. This is supported by Wang's research that the main difficulties students face due to the weak understanding of scientific explanation and reasoning skills are still mistaken [22].

Based on the average normalized gain score, it was found that the improvement of CEDS skills in the control class was included in the low category with the gain score (g) of 0, 29. While the improvement of CEDS skills in the experimental class was considered to be in the medium category with the gain score (g) of 0, 55. The result of normalized gain score analysis can be seen from the following table:

TABLE 6. Average g normalization Percentage of CEDS Skill

No	Score	Class	
		Control	**Experiment**
1	Pretest	40,98	46,11
2	Posttest	58,02	74,54
3	Gain score	0,29	0,55
4	Categories	Low	Medium

After both class groups proved to be normally distributed and homogeneous, an ANOVA test was conducted to examine whether both groups had the same variance. Output ANOVA is the final calculation for determining the hypothesis analysis to be accepted or rejected. Based on one way ANOVA test result, F value is 30, 50 with significance value of 0.000. Based on the results of the significant value, the significance value is <0, 05. Therefore it is concluded that Ho is rejected then there is a significant effect of CEDS skill between control class and experiment class after treatment. The result of One Way ANOVA can be seen in table 7.

TABLE 7. Result of One Way ANOVA Test of CEDS Skill

	F	**Sig**
CEDS skill after treatment	30,50	0.000

The NGSS presents an opportunity to improve the curriculum, teacher self-development, assessment, and students learning achievement [15]. Based on this research, science learning oriented to NGSS is able to improve learning outcome and develop students' CEDS skills significantly. This result is supported by Nordman & Pinderi's research mentioning that students can actively engage in learning material through Project Based Learning and they had a good understanding of the topics being covered. Additionally, learning science Project Based Learning based on NGSS can help the students understand the material better and the test scores reflect that as well with a rate of 90% learning achievement [16]. In line with this, physic learning using PjBL oriented NGSS learning tools is able to facilitate students to achieve planning & carrying out investigation and constructing explanation-designing solutions skill [23].

The Science learning oriented to NGSS emphasizes the activity of scientific inquiry and engineering design [9]. For scientists, scientific inquiry activity emphasizes on observing a phenomenon, investigating matters to gathering evidence and then building or revising a theory based on fact or model, enabling the development of scientific explanations skill. While engineering activities emphasize on the design activities to solve the problem. The integration of design activities in NGSS allows students to be involved in defining problems and designing solutions [12]. Therefore, science learning oriented to NGSS can strongly support the development of CEDS skills.

The development of aspects practice in NGSS has been adjusted to the specific subject matter in the form of Performance Expectation. Based on the performance expectation of the NGSS standard, it can be seen that the ecosystem material is appropriate to develop CEDS skills. This has been listed in Performance expectations, one of which is the standard MS-LS2-2 with learning objective of "student can construct an explanation that predicts patterns of interactions between organisms across multiple ecosystems". That performance expectations have been integrating the three dimensions of the NGSS aspects of a) practice: constructing explanations-Designing Solution, b) crosscutting concept aspects of patterns and c) disciplinary core idea: the interaction of organisms in the ecosystem. Standard of NGSS in the form of Performance expectations allows teachers to design learning instruction and evaluation that are appropriate with the achievement of certain mastery of learning material along with the development of specific skills that might appear according to learning material characteristics.

Various forms of interaction and ecosystem dynamics stimulate students to explain the phenomenon based on what they see [4]. Ecosystem learning stimulates students to be able to develop constructing explanations skills. The ecosystem also brings up many problems that require understanding and need various preventive and solutive actions to keep the environmental sustainability in the future [4]. However, this ecosystem learning also stimulates students to develop designing solutions skill. Thus, constructing explanations-designing solution skills can be developed through science learning oriented to NGSS on ecosystem subject matter.

Science learning oriented to the NGSS that is implemented in science learning process can improve various aspects of scientific and engineering practice, one of them is the Constructing Explanations Designing Solutions skills. When students are involved in developing an explanation by integrating the scientific principles into thinking, speaking, and writing activities, it creates a class of scientists who use concrete evidence to support ideas and make connections to their daily experiences. The development of explanation skills is capable of supporting the learning process as well as writing ability to build a deeper understanding of the content, concepts, and nature of the science so that it leads to the achievement of science literacy [9], [11], [24]. The integration of engineering in the learning process encourages students to be able to link and be equipped with the ability to solve various social problems and challenges around them that they will face in the future [25]. Students can also understand the scientific principles when faced with a challenge and apply those principles when generalizing an idea, as well as implementing and designing problem solutions. Students can use the concept of science explicitly when discussing in writing or orally and present facts to support the design of problem solutions [12].

CONCLUSION AND SUGGESTION

Conclusion

Based on the research data obtained and undertaken, it could be concluded that there is a significant effect of science learning oriented to the NGSS towards constructing explanations-designing solutions skill. Science learning oriented to the NGSS is effectively improving the constructing explanations-designing solutions skill in term in all CEDS aspects with moderate improvement categories.

Suggestion

Science learning oriented to the NGSS is strongly encouraged to be integrated into the science-learning process because it contains specific and structural standard which integrate 3 dimensions of skills, understanding, and content to create meaningful learning for students. However, proper plannings and preparations are required by the teacher to implement science learning oriented to the NGSS starting from understanding the standards, characteristics, to the preparation of the learning process to fit the NGSS framework and goals.

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