DEVELOPING NEXT GENERATION SCIENCE STANDARDS (NGSS) ORIENTED-BASED ETHNOSCIENCE TEACHING MATERIALS: IMPROVING CONSTRUCTING EXPLANATION AND DESIGNING SOLUTIONS (CEDs) SKILLS FOR PROSPECTIVE ELEMENTARY SCHOOL TEACHERS

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ABSTRACT

This study aims to produce teaching materials oriented to Next Generation Science Standards (NGSS) that can improve the Construction Explanation and Designing Solutions (CEDs) skills of elementary school teacher candidates. This study uses the development research method (RnD) adapted from Borg & Gall. The 10 Borg&Gall development procedures were then modified into 8 stages which were adapted to the conditions in the field. The results of the study show that NGSS-oriented teaching materials are appropriate for use in learning with valid, practical, and effective criteria. The validation results obtained from the average value of the teaching material expert validator and learning media show that the teaching material is considered valid both in terms of construct and content. The results of observing the activity of lecturers and students increasing at each meeting indicate that practical teaching materials are applied in learning, as well as the results of student CEDs skills tests indicating that teaching materials are effective for improving the CEDs skills of prospective teacher students. The implication of this research is that the use of appropriate methods can affect the achievement of CEDs ability of prospective teachers to be able to present various alternative solutions to problems. The suggestions for further research are to develop NGSS-oriented teaching materials for elementary school students.

Keywords: NGSS, CEDs Skills, Teaching Materials, Prospective Elementary School Teacher

A. INTRODUCTION

The development of science and technology marks the 21st century which is increasing rapidly, emphasizing the combination of technology and human qualities. Thus, human resources are needed who can take initiative, think critically, be creative, skilled in problem solving, are also sensitive to changes in a more comprehensive and flexible education system (Santoso, 2019). Quality education certainly involves students to learn actively and make changes to better conditions. Science education which is the main focus plays a role in preparing students to understand the nature of science, think critically, and have the skills to face the challenges of the 21st century (OECD, 2019a; NGSS, 2013).

Human resources in Indonesia, which must be continuously improved, show the lack of quality education as a producer of skilled and quality generations. The results of the Program for International Student Assessment (PISA) in 2018 show the ability of Indonesian students, especially in science, with a score of 396 out of an international standard score of 489 (OECD, 2019b). This score shows that the ability of Indonesian students in science is at level 1, meaning that students can only identify information and solve problems according to very clear instructions and have not been able to carry out procedures properly, including methods that require sequential decisions. This condition causes low science process skills and affects students' ability to construct explanations and design solutions. This problem is in line with the study conducted by Puspita (2019) and Wardani et al., (2021) that one of the causes of students' science process skills, such as skills in explaining phenomena based on evidence and designing solutions to formulate conclusions (CEDs) which are still low is because so far students have only relied on textbooks as learning resources. Teaching materials are general in nature, because they are made for general purposes, so students need the help of other people such as teachers to explain the contents of the book. Based on the nature of the presentation, books tend to be informative and the presentation of teaching materials has a broad and general scope, so that communication takes place in one direction and students tend to be passive. To be able to develop and improve students' science skills, a teacher must carry out various innovations and reforms, including in teaching materials.

Teaching materials made can adopt educational standards from leading countries, namely the Next Generation Science Standard (NGSS). Regarding how to practice science, NGSS facilitates students through the integration and implementation of the three dimensions of NGSS, namely dimensions of *Science and Engineering Practice* (SEPs), *Disciplinary Core Ideas* (DCI), dan *Crosscutting Concepts* (CCs) (Krajcik et al., 2014; Fulmer et al., 2018). One of the goals of the NGSS is to optimize students' practical skills by constructing explanations and designing solutions (CEDs) (Chiappetta, E.L., & Koballa, 2010). NGSS allows students to develop creativity in designing and working on projects that are used to solve problems (Lattimer & Riordan, 2011b), thereby enabling students to become interactive learners and constructing knowledge through exploration enabling students to demonstrate organized learning outcomes to enhance their knowledge and progress in learning (Zarouk et al., 2020). This is consistent with the application of the NGSS-oriented learning model in science learning which is known to improve cognitive learning outcomes and science process skills (Pruitt, 2014; Hardy & Campbell, 2020). NGSS-oriented teaching materials will support the truth-seeking process through an inquiry process to answer questions about natural and engineering phenomena that are more focused on solving problems through a series of design processes, so that students can increase understanding with the knowledge found (Zajkov & Mitrevski, 2012). Thus, this process allows students to be involved in defining problems and designing solutions, so it is hoped that later these prospective teacher students will be able to design the same learning for their students in class.

Based on the explanation above, the researchers focused on the study on the Development of Science Basic Concepts Teaching Materials Oriented Next Generation Science Standards (NGSS): Efforts to Improve the Skills of Constructing Explanations and Designing Solutions (CEDs) for Prospective Elementary School Teachers.

B. THEORETICAL REVIEW

a. *Construction Explanation and Designing Solutions* (CEDs) Skills

Construction Explanation and Designing Solutions (CEDs) skills are one of the skills in the dimensions of scientific and engineering practice that describe the achievement of the main goals of science with the integration of engineering (Pellegrino & Hilton, 2013). Students involve themselves in a variety of practical activities which will understand that science and engineering are processes for developing explanations and formulating solutions to every problem (National Science Teacher Associations (NSTA), 2011). NGSS (Haverly et al., 2022) describes the CEDs skills into a single unit with the indicators shown in Table 1.

Table 1. Indicators of *Construction Explanation and Designing Solutions* (CEDs) Skills

Aspects	Indicators
Construction Explanation	1. Compile a scientific explanation based on facts obtained from various sources and the assumption that a theories and laws that explain the mechanisms of nature in the past and present 2. Applying ideas, principles, and facts to build and improve using scientific explanations to explain natural phenomena
Designing Solutions	1. Apply scientific reasoning to show why data can be used to draw conclusions 2. Implement ideas to design and test a design object. 3. Designing projects by implementing design steps to formulate solutions with criteria. 4. Optimizing the design of the way of work

(Haverly et al., 2022)

The development of constructing explanation skills provides an understanding of scientific concepts that will affect students in formulating a scientific explanation. The constructing explanation activity focuses on scientific explanations to describe the reasons for preparing a logical scientific explanation related to the observed phenomena

(Lattimer & Riordan, 2011a). The scientific explanation is organized into three main points. More detail in Table 2.

Table 2. Aspects of Scientific Explanation

Aspect	Descripti on
Claim	A statement that answers a question. Claims consider right when they can answer questions that are supported by sufficient evidence and logical reasoning
Evidence	Evidence of scientific data to support the claim. Evidence that is meant to come from observations or based on existing data, and is used to support the formulated scientific explanation
Reasoning	A reason for linking data as evidence supporting a statement using proper scientific principles based on scientific knowledge, theories, and models

The use of a claim, evidence, and reasoning (CER) framework in learning can support CEDS skills, which will have an impact on students regarding their understanding of a scientific explanation and students are able to compile a scientific explanation (McNeill & Krajcik, 2008). If the teacher applies the CER framework in learning, students will get a firm understanding in compiling scientific explanation based on their knowledge (McNeill & Krajcik, 2008). Based on the CER framework described above (SDCOE, 2007), the constructing explanation aspect in this research becomes more operational. In a science and engineering process, the NGSS standard has been integrated simultaneously as an example of constructing explanation, in this case, it is necessary to have skills in designing solutions as a compliment because these two skills are related and complementary (Metz, 2016). The NGSS framework describes solution designing skills to enhance design-related ideas, test a model, and determine the criteria and limits for the desired quality of the solution (National Research Council (NRC), 2012). Furthermore, SDCOE (2017) describes several aspects and indicators of designing solution skills. Therefore, Based on several descriptions of CEDS skills that have described, there are six aspects with each indicator. More detail in Table 3.

Table 3. Aspects of Scientific Explanation

Aspect	Indicator
Claim	1. Emphasizes the explanation of a phenomenon
Evidence	2. Presenting valid and reliable evidence to support a scientific explanation
Reasoning	3. Explain the reasons that link evidence to phenomena, based on scientific knowledge, theories, and models

Generate designing solution	4.	Applying a scientific idea or principle to design a solution to a problem
Criteria and constraint	5.	Describe the criteria and obstacles that may be faced in the selection of a problem
Evaluating potential solution	6.	Evaluating various solutions and selecting the optimal solution

b. Next Generation Science Standards (NGSS) Oriented Teaching Materials

To be able to develop and improve students' science skills, a teacher must carry out various innovations and reforms in the field of education. Such as adopting educational standards from leading countries, namely the Next Generation Science Standard (NGSS) (Pitaloka et al., 2021). NGSS is a minimum framework that must be achieved by students in learning science (Rousseau & Khomenko, 2011). Regarding how to practice science, NGSS facilitates students through the integration and implementation of the three dimensions of NGSS, namely the dimensions of Science and Engineering Practice (SEPs), Disciplinary Core Ideas (DCI), and Crosscutting Concepts (CCs) (National Research Council (NRC), 2012; Next Generation Science Standards, 2013). The adoption of NGSS can be realized in a teaching material as a student learning resource. With NGSS-oriented teaching materials, students will have an in-depth understanding of a small number of core disciplinary ideas, be able to demonstrate evidence of knowledge through scientific and engineering practice, and connect across concepts across disciplines. This will certainly affect students' ability to explain phenomena based on evidence from research, innovate, and design solutions to formulate conclusions based on investigations (Metz, 2016).

C. METHOD

This research uses the R&D (research and development) method adapted from Borg & Gall. According Borg & Gall (1989), R&D is a process used to develop and validate educational products. The results of development research are not only the development of an existing product but also to find knowledge or answers to practical problems. Through development research researchers try to develop a product that is effectively used in learning. The product produced in this study is in the form of teaching materials for Basic Science Basic Concepts oriented Next Generation Science Standards (NGSS) to improve Construction Explanation and Design Solutions (CEDs) skills for elementary school teacher candidates. This development procedure has 10 stages which are then modified by researchers into 8 stages that are adapted to the needs and conditions in the field. The steps include: (1) initial research and information gathering, (2) planning, (3) initial product format development, (4) initial trials, (5) Initial product revision, (6) Validation and field trials, (7) Revision of the final product, and (8) Dissemination and implementation. The trial design used a one group pretest-posttest design with a sample of 150 elementary school teacher candidates. The trial design is presented in Table 1.

Table 1. Research Design

Group	O_1	X	O_2

(Creswell, 2013)

The research instruments consist of; 1) expert validation sheet, 2) lecture teaching unit (SAP) implementation observation sheet, 3) Construction Explanation and Designing Solutions (CEDs) skills test sheet, 4) interview guide, and 5) product application response questionnaire. The data analysis technique used is qualitative and quantitative data analysis techniques. Qualitative data analysis consisted of data reduction, data presentation, and conclusions, while quantitative data analysis consisted of normality test steps, and t-tests for Construction Explanation and Designing Solutions (CEDs) skills tests.

The CEDs performance indicators in this study follow the CEDs indicators from the OECD (2019c) with the grid in Table 2.

Table 2. Construction Explanation and Designing Solutions (CEDs) Skills Test Grid

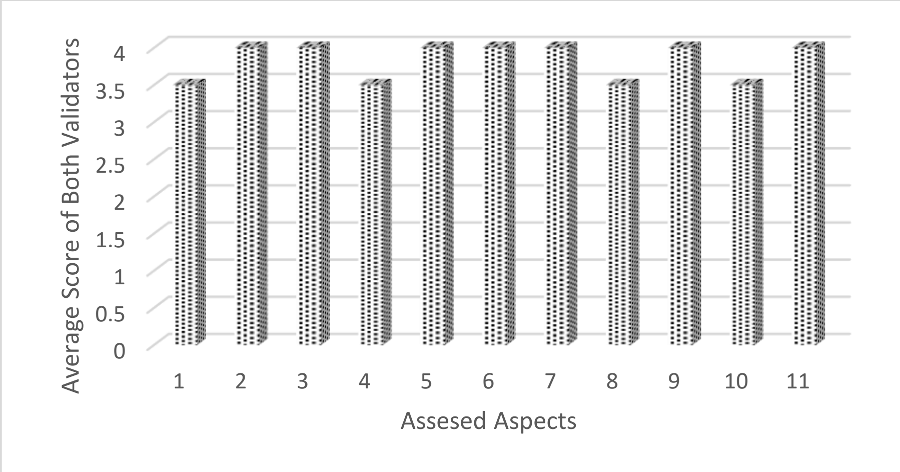
Aspek	**Indikator**	**No. Soal**
Construction Explanation	1. Emphasizes the explanation of a phenomenon	1,2
	2. Presenting valid and reliable evidence to support a scientific explanation	3
	3. Explain the reasons that link evidence to phenomena, based on scientific knowledge, theories, and models	4
Designing Solutions	4. Applying a scientific idea or principle to design a solution to a problem	5,6
	5. Describe the criteria and obstacles that may be faced in the selection of a problem	7
	6. Evaluating various solutions and selecting the optimal solution	8

D. RESULTS AND DISCUSSION

1. Results

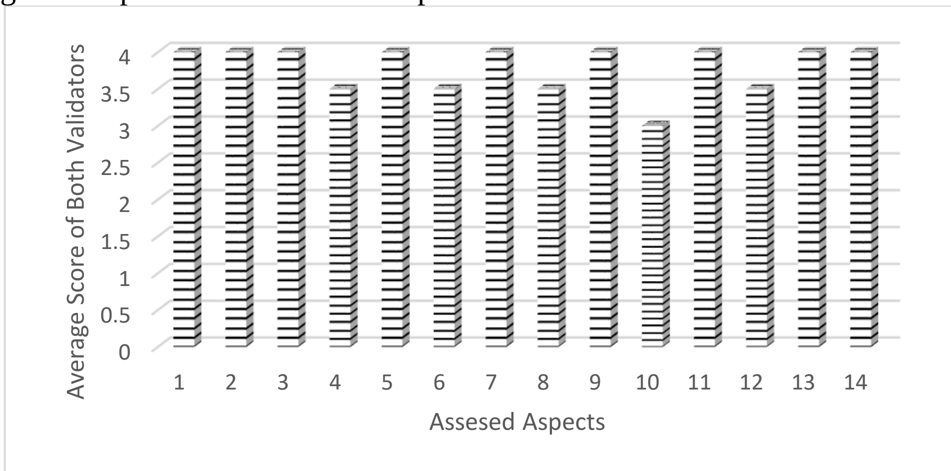
Teaching Material Validity

The validity of the developed teaching materials was obtained from the average scores of the two validators on the presentation, language, graphic, and content components. The results of the average validation score on the presentation aspect can be seen in Graph 1.



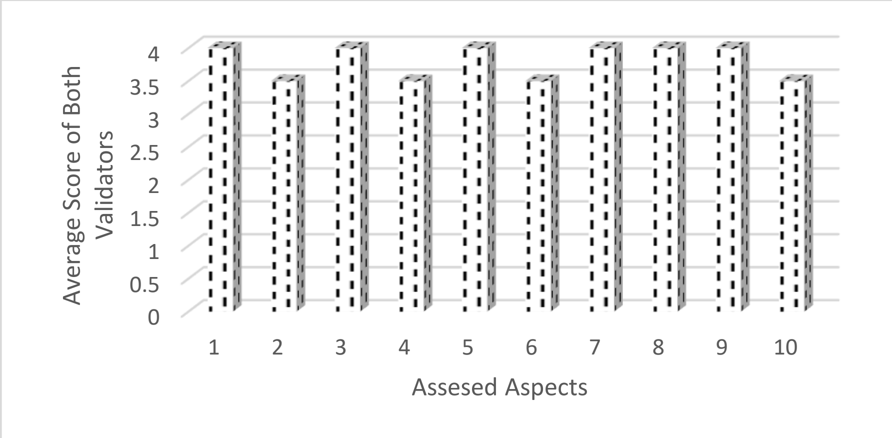
Graph 1. Average Result of Presentation Aspect Validation Score

Based on Graph 1, it can be seen that the development of teaching materials from the presentation aspect results in an average validation score of 4 with a valid category on 7 aspects of 11 aspects. Thus, the construct validity of the NGSS-oriented teaching material presentation components can be scientifically proven. Then for the results of the average validation score on the linguistic aspect can be seen in Graph 2.



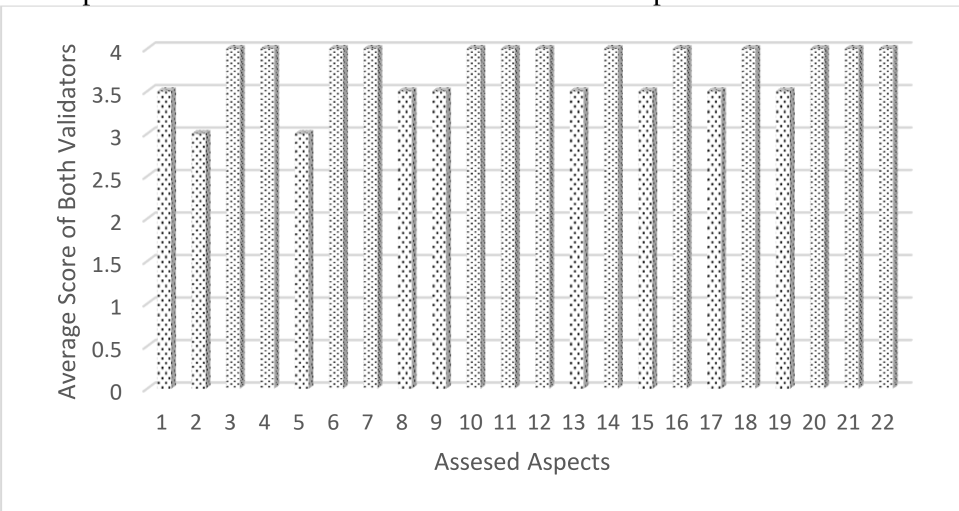
Graph 2. Results of the Average Score of Language Aspect Validation

Based on Graph 2, it can be seen that the development of teaching materials from the linguistic aspect results in an average validation score of 4 with a valid category on 9 aspects of 14 aspects. Thus, the construct validity of the linguistic components of NGSS-oriented teaching materials can be scientifically proven. Then for the results of the average validation score on the graphical aspect can be seen in Graph 3.



Graph 3. Results of the Average Score of Graphical Aspect Validation

Based on Graph 3, it can be seen that the development of teaching materials from the graphical aspect results in an average validation score of 4 with a valid category on 6 out of 10 aspects. Thus, the construct validity of the graphic components of NGSS-oriented teaching materials can be scientifically proven. Then for the results of the average validation score on the content aspect or content validation can be seen in Graph 4.

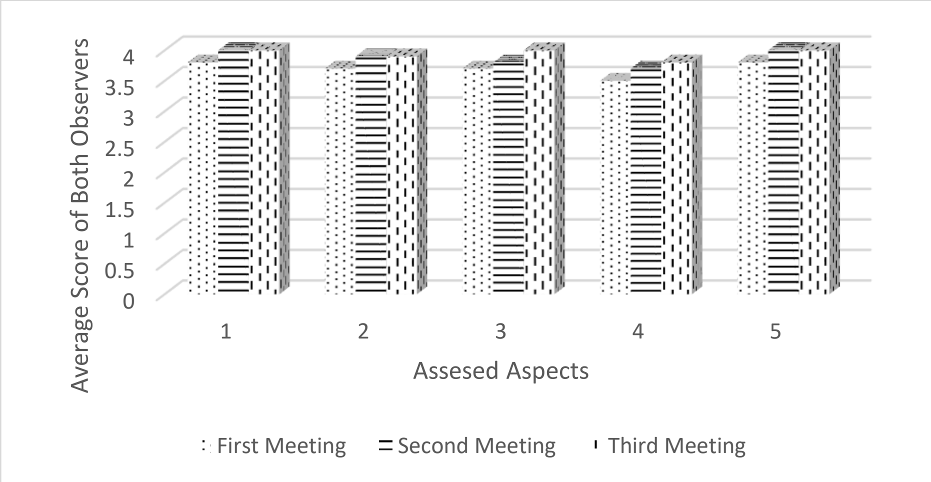


Graph 4. Results of the Average Score of Content Aspect Validation

Based on Graph 4, it can be seen that the development of teaching materials from the content aspect results in an average validation score of 4 with a valid category on 14 of the 22 aspects assessed. Thus, the content validity of the content components of NGSS-oriented teaching materials can be scientifically proven.

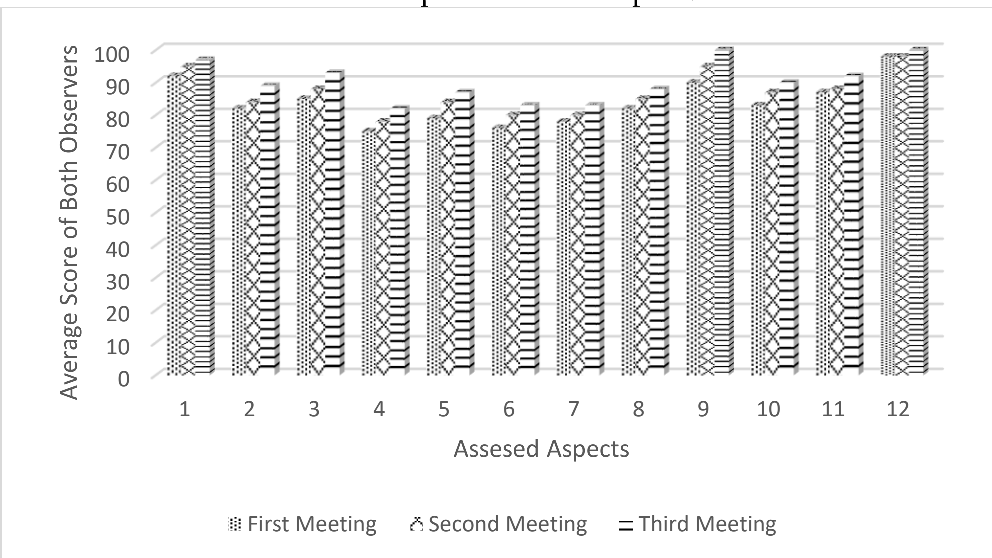
Practicality of Teaching Materials

The practicality of the teaching materials in this study can be seen from the results of the average scores of the two observers in the implementation of SAP (Lecture Program Unit) lecturer and student activities in lectures that apply NGSS-oriented teaching materials. The results of the average score of observers on the implementation of lecturer activities are presented in Graph 5.



Graph 5. Results of Mean Scores of Observers for the Implementation of Lecturer Activities in Three Meetings

Graph 5 shows that lecturer activities have increased from the first meeting to the third meeting, namely obtaining an average score of 4 in the "good" category in 3 of the 5 aspects assessed in the second and third meetings. Overall all the stages in SAP at all meetings can be carried out in the "good" category. The results of the average score of observers on the implementation of student activities are presented in Graph 6.



Graph 6. Results of Average Scores of Observers of the Implementation of Student Activities in Three Meetings

Graph 6 shows that all stages of student activity in the second and third meetings achieved an average score of >75 in the "active" category and experienced an increase in activity from the first meeting to the third meeting. Thus, the application of NGSS-oriented teaching materials can be scientifically proven in terms of practicality.

The Effectiveness of Teaching Materials

The effectiveness of applying NGSS-oriented teaching materials can be seen from the results of the pretest and posttest of the Construction Explanation and Designing Solutions (CEDs) skills. These are assessed using an assessment rubric and then presented in numerical form. The results of the students' pretest and posttest scores were then tested inferentially using a paired sample t-test which first tested whether the data was normally distributed or not using the Kolmogorov-Smirnov test with a Sig value of > 0.05, namely 0.231. These results indicate that the data is normally distributed. The output results of the paired sample t-test are then presented in Table 1..

Table 3. Results of the t-test for Construction Explanation and Designing Solutions (CEDs) Skills

Data	***Std. Deviation***	**Sig. (2-tailed)**	**Decision**
pretest and postest *Construction Explanation and Designing Solutions* (CEDs) skills	1.874	0,000	There are significant differences

The data in Table 1 shows that the t-test of students' creative thinking skills data at a significance level of 0.05 was obtained sig.(2-tailed) = 0.000 <0.05 (α) so that H0 was rejected and Ha was accepted. Thus there is a mean difference between the pretest and posttest results. This means that there is a significant increase in the results of the Construction Explanation and Designing Solutions (CEDs) skills before and after the implementation of NGSS-oriented teaching materials. So as the results above, it can be concluded that there was an increase in the pretest and posttest results of students' Construction Explanation and Designing Solutions (CEDs) skills by applying Next Generation Science Standards (NGSS) oriented teaching materials. Thus the application of Next Generation Science Standards (NGSS) oriented teaching materials can be scientifically proven in terms of effectiveness.

2. Discussion

According to Nieveen (1999), the quality of the development of a learning material product must meet the criteria of validity, practicality, and effectiveness. A product is said to be valid if it is developed in accordance with the material (content validity) and all components are connected to each other consistently (construct validity) and are declared fit for use with revisions or without revisions by the validator (Plomp, 2013). This NGSS-oriented teaching material is assessed in terms of validity from four aspects of feasibility, namely the feasibility of presentation, language, graphics, and content. Graph 1 shows that the development of teaching materials from the presentation aspect results in an average validation score of 4 with a valid category on 7 aspects out of 11 aspects. One aspect of the presentation component that is rated as valid is the support for the presentation of the material. The presentation of the material in this teaching material is supported by aspects in the NGSS which facilitate students through the integration and implementation of the three dimensions of the NGSS, namely dimensions of *Science and Engineering Practice* (SEPs), *Disciplinary Core Ideas* (DCI), dan *Crosscutting Concepts* (CCs) (National Research Council, 2012; NGSS, 2013). The ideal NGSS teaching materials will enable students to have an in-depth understanding of a small number of core disciplinary ideas, be able to demonstrate evidence of knowledge through scientific and engineering practice, and connect across cross-concepts from various disciplines (Metz, 2016). Graph 2 also shows that the linguistic components of NGSS-oriented teaching materials can be scientifically proven. The linguistic aspect of textbooks is one of the factors that determines whether textbooks are of good quality or not. This is in accordance with the statement Tegeh et al. (2015) that one of the characteristics of a good textbook is to use language that is good and easy to understand. Then Graph 3 shows that the graphical component is considered valid by the validator. The validity of the graphical components in the developed teaching materials is supported by the provision of appropriate illustrations and font sizes so that they can increase students' understanding of reading in teaching materials (Rizal, 2012). The same thing is also found in content validation. The content-developed teaching materials have met the requirements relevant to scientific principles, namely they are in accordance with basic education scientific principles, have provided a need for student learning outcomes and each component in the teaching materials has been based on strong theoretical arguments about integrating NGSS and CEDs skills.

The application of NGSS-oriented teaching materials has also been scientifically proven in terms of practicality and effectiveness. The results of observing the implementation of lecturer and student activities in Graph 5 and 6 show an increase in lecturer and student activity from the first meeting to the third meeting. The highest aspect of the lecturer's activities is shown in the core lecture activities, because in this core activity, the lecturer applies NGSS-oriented learning and CEDs skills using teaching materials that have been developed. Equally important is the data in Table 1 which shows the effectiveness of NGSS teaching materials which are proven to improve students' Construction Explanation and Design Solutions (CEDs) skills. This is because learning is carried out using two main approaches, namely process and product. In the process approach, the lecturer stimulates students to respond to problems and solve them using appropriate methods, in this case, the scientific literacy process starts from students knowing there is a problem to communicating the results of their thoughts (Kardoyo et al., 2020). Then in the product or result approach, Pitaloka et al. (2021) suggests that CEDs emphasize the aspect of compiling scientific explanations based on facts obtained from various sources and assumptions and applying ideas, principles and facts to build and improve using scientific explanations and apply scientific reasoning to design and test as well as formulate solutions.

NGSS supports learning through the application of science and engineering practice based on project-based learning, performance-based assessment and structured group work. In addition to providing opportunities for students to solve real problems scientifically. For each activity unit, creating a project allows students to 1) access various forms of information needed; 2) actively involved in learning that shows independent learning outcomes, and 3) reflecting on learning by making revisions based on peer and teacher assessments (McMahon & Clark Blickenstaff, 2020). As we discussed above, CEDS skills indicators are claims, evidence, reasoning, generating design solutions, criteria - constraints, and evaluating potential solutions. These indicators can be achieved by using project-based learning methods. As we discussed above, CEDS skills indicators are claims, evidence, reasoning, generating design solutions, criteria - constraints, and evaluating potential solutions. These indicators can be achieved by using project-based learning methods and supported by the use of appropriate teaching materials.

The use of NGSS-oriented teaching materials in improving CEDS skills allows students to be able to manage research, projects, or solve problems. In finding solutions to project assignments, students can construct knowledge from various sources (Kizkapan & Bektas, 2017). NGSS-oriented teaching materials meet the needs of students with different skill levels and learning techniques. One of the interesting things is that NGSS teaching materials are supported by important projects to be implemented as shown by several studies which show that students can implement projects with confidence and optimism that they can improve students' science process skills and creative thinking (Anazifa & Djukri, 2017). Also, it was found that 86% of projects implementing NGSS-based learning were more effective than implementing traditional teaching approaches (Balemen & Özer Keskin, 2018). It also has a significant effect on creative thinking skills and science process skills (Uswatun Chasanah et al., 2016). NGSS-oriented teaching materials can increase students' appreciation of the importance of science in life, involve students in science practices and increase students' confidence in communicating scientific topics (Engels et al., 2019). NGSS proves to be an interesting aspect for students in education, this is according to the statement Engels et al. (2019) that through the NGSS platform students can become more motivated and inspired in the formal education system. This motivation and inspiration enhances students' ability to learn and increases their desire to persist in their educational pursuits.

E. CONCLUSION

The development of NGSS-oriented teaching materials to improve the Construction Explanation and Designing Solutions (CEDs) skills of prospective teacher students is proven to be appropriate for use in learning with valid, practical, and effective criteria. The results of content and construct validity show that the developed teaching materials meet valid criteria in terms of presentation, language, graphics, and content. The results of observing the activities of lecturers and students that increase in each meeting show that practical teaching materials are applied in learning and are proven effective in improving the CEDs skills of prospective teacher students. Thus, valid, practical, and effective criteria indicate that the developed teaching material product is suitable for use in learning. What can be developed as a follow-up study from this research is the development of NGSS-oriented teaching materials for elementary school students..

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