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Scientific Reasoning Profile of Pre-service Elementary Teachers

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Abstract. Scientific reasoning is one of the 21st-century skills that pre-service elementary teachers should face global challenges. Scientific reasoning has a high correlation with the ability to explore science contents of pre-service elementary teachers. This research aims to find out the scientific reasoning profile of pre-service elementary teachers. The research methods used are quantitative descriptive. This study's subject was a pre-service elementary teacher of 109 students of the primary teacher Education Program at the University of Muhammadiyah Sidoarjo. This research instrument in the form of a cognitive ability test consisting of five questions and descriptions to measure a pre-service elementary teacher's scientific reasoning in the 4th semester. Tests were conducted through an online scoring system. The results showed that the scientific profile reasoning pre-service elementary teacher was 10%, including quite complex, 38% including complex, and 52%, including very complex. The results show that the most significant percentage of a pre-service elementary teacher, including very complex ones, reflects the ability to classify, consider, interpret, investigate, and predict. The implications are that most of the pre-service elementary teachers have been ready to learn a variety of science and skills in elementary school. This research also provides several recommendations related to the scientific reasoning of pre-service elementary teachers.

INTRODUCTION

Scientific reasoning is one of the indicators thinking skills. Scientific reasoning is essential for teachers because there are increasing challenges for them to continue to improve the quality of learning due to the flow of globalization and increasingly intense competition to the international level. To develop scientific reasoning, students, of course, teachers must have sound scientific reasoning. In order for students to use the quality of their reasoning, teachers must be able to provide the opportunities and support required by students [1]. Teach are also required to have competencies that suit their needs in the field so that students have reasoning skills such as working with models and design empirical approaches to test hypotheses [2]. Oriented to support scientific reasoning teachers' development, then various dimensions need to get attention to both cognitive dimensions, metacognitive dimensions, social dimensions, and moral dimensions.

Scientific reasoning is an essential part of making students have knowledge, skills, and attitudes and the goal of developing students' competencies in learning following the demands of the 21st century [3]–[5]. It is a challenge for both teachers and pre-service teachers to implement educational innovation, use the benefits they offer to optimize learning, and develop cognitive skills to face their future and time [3], [6]. Previous research has shown that scientific reasoning is a substantial part of supporting the development of pre-service teachers [7]–[9]. Besides, scientific reasoning is also required for students / pre-service teachers in problem-solving [10]. These results are also supported by the results of other studies stating that pre-service science teachers must be competent in reasoning to help their future students solve problems in science [8].

Scientific reasoning teachers support the change in knowledge and development of students' epistemology [11]. Due to the importance of scientific reasoning to gain knowledge about the surrounding world, the OECD has identified scientific reasoning as the normative purpose of science education [12]. There are research results that state that the primary purpose of science learning is to develop scientific reasoning. Scientific reasoning development can be done through various activities. In Maximilian & Moritz's research, pre-service science teachers' analysis was conducted in scientific reasoning modeling strategies. The result is that there are six types of scientific reasoning process modeling strategies namely (1) exploration, (2) exploration and development with a focus on exploration, (3) exploration and development with a focus on development, (4) balanced exploration and development, (5) exploration, development, and drawing once predictive models, as well as (6) exploration, development, and repeatedly drawing prediction models.

Scientific reasoning has various levels according to the age and development of one's thinking. Research in measuring scientific reasoning levels from Chili, the United States, China, and India shows different abilities [13]. The results revealed that the scientific reasoning level includes three levels of reasoning: concrete, transitional, and formal. The results also showed the lowest level of formal reasoning compared to other levels of reasoning. The various scientific reasoning levels explain how a person uses his or her thinking skills to create reasons that impact their reasoning skills. Reasoning skills are emphasized in standard documents for the education of science teachers in various countries around the world [8], [9], [14]. Science plays a huge role in preparing superior human resources, soft skills, and hard skills. This role can be known through numerous studies measuring the scientific reasoning of teachers and pre-service science teachers [3],

[8]–[10], [15]. Scientific reasoning is part of the cognitive skills and professional competencies of science teachers as a whole [16], [17], so it is strongly emphasized in the new science education standards [18], [19].

The measurement of scientific reasoning in various countries with various levels shows the need to bring up scientific reasoning, starting from elementary school-age students. This measurement has to do with preparing scientific reasoning pre-service primary school teachers as part of their competence. Pre-service primary school teachers are expected to master the competencies of various areas of expertise, one of which is Natural Sciences. Natural Sciences is part of science with learning activities that can utilize various literature and various sources online, both print and non-print, to support the achievement of learning competencies. Skills in the 21st century, when associated with Natural Sciences learning, are better known as strands of scientific proficiency, which refers to expertise or skill in using knowledge and reasoning to explain a phenomenon or event that occurs both internally and externally [20], [21]. In mastering science expertise as part of the competency of pre-service primary school teachers, scientific reasoning measurement is required.

Education today also emphasizes the importance of scientific reasoning, such as producing hypotheses and evaluating evidence [6], [22]. Scientific reasoning correlates with the ability of pre-service primary school teachers to learn about the content of knowledge as well as to gain knowledge about the surrounding world [20] [21] [23]. There are two kinds of scientific reasoning patterns, namely concrete patterns and formal patterns [21]. Scientific reasoning patterns that correspond to the cognitive development of pre-service teachers are formal. Indicators for formal scientific reasoning patterns include theoretical reasoning, combinatorial reasoning, functionality reasoning, control variables, and probabilistic reasoning [21]. Furthermore, it can be said that scientific reasoning is one of the skills of the 21st century that can be measured in science learning as an effort to prepare pre-service primary school teachers in the face of the challenges of globalization.

Although there has been much research done to measure teachers and pre-service teachers' scientific reasoning, there has been no research to find out the scientific reasoning of pre-service elementary school teachers, especially in the field of scientific expertise. Based on this, this research was conducted to prepare pre-service primary school teachers to have scientific reasoning so that they can give students opportunities using scientific reasoning in learning. This research was conducted to know how to profile scientific reasoning pre-service elementary school teachers through the provision of scientific reasoning tests. The test was adopted by referring to scientific reasoning indicators with formal patterns (Shofiyah, Setiyawati, & Nurdyansyah) in their research [15].

METHODS

The research method used is quantitative descriptive. This study's subjects were pre-service primary school teachers in semester four at Universitas Muhammadiyah Sidoarjo, which numbered 109 people. The data in this study was obtained through scientific reasoning measurements with indicators adopted by researchers from Shofiyah, Setiyawati, & Nurdyansyah [15] and further adapted to the concept of NATURAL SCIENCE in the early grade elementary school education courses shown as shown in Table 1 below:

Table 1. Scientific Reasoning Assessment Indicator with Formal Pattern

Scientific Reasoning Pattern	Description	Questions of scientific reasoning (question number)
Theoretical reasoning	The ability to apply binary classification, conservation logic, chain sequences, and other reasoning patterns to relationships and traits that are not directly observable.	Give a scientific explanation of facts, concepts, symbols, and conceptions on "Heat"! (Question number 4)
Combinatorial Reasoning	The ability to consider all possible alternative solutions in ideal situations.	"Through field observations, all animals named insects such as ants, locusts, crickets, wasps, flies, and mosquitoes have six legs (3 pairs") What are the scientific concepts in the explanation! Is there any conception made by scientists on that explanation! (Question number 3)
Functionality and Proportional Reasoning	The ability to interpret states and interpret functional relationships into mathematical forms or vice versa.	It says the current air temperature is a 27-celsius degree or 300 kelvin. Where the comparison of celsius and kelvin scales is expressed with: $^0C = K - 273$ Based on the scale comparison, determine which is correct to state the current air temperature! (Question number 2)

Control variables	Ability to recognize the needs required in an experiment and the variables to be investigated	Make three fundamentally scientific questions related to Lapindo mud bursts that have not stopped until now! (Question number 1)
Probabilistic and Correlational Reasoning	The ability to interpret observations that present unpredictable variables and recognize relationships between them.	Make observations through learning videos capable of exploring students' thinking skills. The categories of observable learning videos are constructivist-based. Learning videos can be obtained and found from youtube, and then explain the content of constructivist material based on the video! (Question number 5)

Scientific reasoning tests are administered online through the Moodle Docs system. The characterization of the test includes five field questions consisting of creating questions to find facts related to the concept of natural science, connecting facts with natural science concepts, linking concepts and conceptions to find solutions to specific situations encountered, conducting theoretical studies as a first step in scientific reasoning, and making observations to predict and interpret the results. Research is conducted online to be a medium of rapid delivery of valuable information and can be accessed easily so that it becomes more efficient and efficient in finding information about the value [24]–[26]. This study's data is quantitative data obtained from 109 students and calculated using individual ate formulas [26]:

$$P_{individual} = \frac{\Sigma \text{Achievability of indicators}}{\Sigma Score\ \ indicator\ \ total} \times 100\%$$

The ability of individual scientific reasoning is calculated following the classification of reasons given by the following provisions:

Table 2. Classification of Reasons [26]

Score	Form Description
2	Related reasons and support selected answers
1	Related reasons, but does not support selected answers
0	Reasons not related to the selected answer
0	Reasons not submitted

Once individual scores are obtained, the data is then categorized based on the following criteria:

Table 3. Criteria of Individual Scientific Reasoning [27]

Score Interval	Scientific reasoning
0% < P < 25%	Less Complex
25% ≤ P < 50%	Quite Complex
50% ≤ P < 75%	Complex
75% ≤ P ≤ 100%	Very Complex

RESULTS AND DISCUSSIONS

To find out how scientific reasoning pre-service primary school teachers are, researchers provide cognitive tests to measure aspects that include theoretical reasoning, combinatorial reasoning, functionality and proportional reasoning, control variables, and aspects of probabilistic and correlational reasoning. The materials studied are "concepts and misconceptions in natural science" and "natural science in constructivist traditions." The two materials are interconnected because the highest competency achievement is in the mastery of natural science learning with the basic competency "The Nature of natural science and Natural science Learning." To achieve this competency, pre-service primary school teachers are expected to master the concepts of science with the scope of living materials, objects and their nature, energy and changes, earth and solar system, and science and technology. Another competency is the management of natural science learning supported by classroom and student mastery skills through approaches, models, methods, strategies, and learning techniques. Therefore in this study, the provision of scientific reasoning tests is conditioned based on material and the achievement of competencies taught.

The results of individual scientific reasoning score scoring based on score range and category are seen in the following table.

Table 4. Scientific Reasoning Score Of Pre-Service Primary Teacher

Score interval	Individual achieve	Category
< 25	0	Less Complex
25 - 49	1	Quite Complex
50 – 74	41	Complex
75 - 100	67	Very Complex

In Table 4, it can be known that the scientific reasoning scores of pre-service primary school teachers through the online assessment system shows that the three categories of reasoning are quite complex, complex, and very complex. The scientific reasoning pattern measured is formal scientific reasoning in the material "concepts and misconceptions in natural science" and material "natural science in constructivist tradition." The number of individual reaches showed a highly complex reasoning category of 67 students, a complex reasoning category of 41 students, and a reasonably complex category of only 1 student. The trend of reasoning categories shown by pre-service primary school teachers is a highly complex category that reflects the ability to classify, consider, interpret, investigate, and predict capabilities. The ability to classify is demonstrated through the ability to conduct theoretical studies as a first step in scientific reasoning. Pre-service primary school teachers have been able to conduct theoretical studies related to the concept and conception of Natural Science from several experts or scientists. The ability to consider is demonstrated through the ability to connect concepts and conceptions to find solutions from specific situations encountered. Pre-service primary school teachers have been able to consider various facts related to animal concepts and conceptions about animals from scientists. The ability to interpret is demonstrated through the ability to associate facts with the concept of Natural Science. Pre-service primary school teachers have been able to find a link between the fact about the surrounding temperature and the concept of temperature conversion. The ability to investigate is demonstrated through the ability to create questions to find facts related to the concept of Natural Science. Pre-service primary school teachers have been able to make three questions scientifically related to Lapindo mud in Sidoarjo. The ability to predict is demonstrated through the ability to make observations to predict and interpret the results. Pre-service primary school teachers have been able to make observations of constructivist-based learning videos that they are looking for themselves through youtube. Furthermore, pre-service primary school teachers interpret the content of constructivist material based on the video.

The percentage of scientific reasoning categories of pre-service primary school teachers can be seen in Figure 1 below.

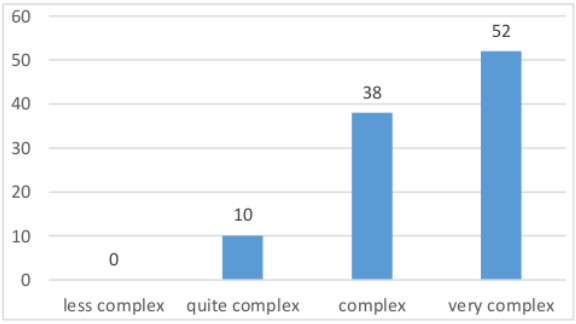

Figure 1. Percentage of Scientific Reasoning Category

Through Figure 1, it can be known that the scientific reasoning profile of pre-service primary school teachers is quite complex at 10%, categorized as complex at 38%, and categorized as very complex at 52%. Scientific reasoning can be broadly defined as a knowledge search [11]. Scientific reasoning guides the process of information search in disciplines and supports conceptual changes in science learning. Conceptual changes can describe a person's competence and measure their science learning [28]. The change in primary school students' knowledge demonstrates a change in their competence in the scientific reasoning component [27], [28]. In order for elementary school students to have 21st-century skills, one of which is scientific reasoning, pre-service primary school teachers need to be faced with various scientific reasoning developments in science learning through exploration, intervention, and prediction activities [9]. Exploration, intervention, and prediction activities in Natural Science learning are demonstrated through the ability to classify, consider, interpret, investigate, and predict the ability to predict what pre-service primary school teachers have in this study. Based on the percentage of scientific reasoning categories of pre-service primary school teachers in Figure 1 also shows the formal pattern which is largely categorized as very complex. This pattern according to Jean Piaget, appears in someone who is 11 years of age or older. In this case, pre-service elementary school teachers in semester 4 are appropriate if given formal scientific reasoning to know the aspects in him consisting of theoretical reasoning, combinatorial reasoning, functionality, and proportional reasoning, mostly categorized probabilistic and correlational reasoning. Scientific (formal) reasoning tests are used to assess students' scientific reasoning abilities at the formal operational stage [29].

Thorough knowledge of natural science concepts in the scope of living matter, objects and their properties, energy and changes, earth and solar system, and science and technology, pre-service elementary school teachers can classify, consider, interpret, and invest. Meanwhile, the ability is seen and measured when pre-service primary school teachers make constructivist-based learning video observations and interpret constructivist material based on the video. When making predictions in these observations, pre-service elementary school teachers search for various learning videos through youtube to further determine the learning videos based on constructivist. Next, they observed the video to interpret the observations in the form of conclusions in the form of the findings of materials in the video containing constructivist content based on the pedagogy's dimensions.

The scientific reasoning study results using a student activity sheet based on the image-based modeling approach in the Biological Education Study Program of the Muhammadiyah University of Bengkulu showed the percentage of student achievement in each category of low reasoning moderate reasoning, and high reasoning [30]. The results also mentioned that student activity sheets based on image-based modeling could provide scientific reasoning students in the high category of 78% and scientific reasoning in the low category of 22% [30]. In his research, Hidayat, et al. using multiple-choice tests so that it can be concluded that this type of test does not affect a person's scientific reasoning measurement results. The results of different scientific reasoning measurements were shown in the study conducted by Susilowati and Anam, with the most significant scientific reasoning category being the medium category. The results showed that the increase in MIA 3 grade XI students' scientific reasoning ability was 69.77% and 66.27% for grade XI MIA 4 students [10].

Different things are shown through the results of research conducted by Mambrey & Schreiber, factors that impact a person's scientific reasoning, including knowledge, conception, and exploration [7]. Therefore, students between the ages of nine and twelve show mixed reasoning derived from their system thinking skills, knowledge, conception, and personal understanding. Further, they revealed that students are influenced by factors under the individual cognitive requirements of the thinking skills system independent of their thinking abilities based on their age and system. Also, students partially demonstrate the level of complex reasoning can be identified from specific knowledge systems, conceptions, and representations to investigate the advancement of their knowledge of how the system's nature affects their scientific reasoning.

The overall comparison of scientific reasoning measurements shows the number of categories that are increasingly in the direction of a person's age. Boon's scientific reasoning measurements in grade IV elementary school children showed a change of competence in the scientific reasoning component. In grade XI students conducted by Susilowati and Anam, scientific reasoning measurements show the largest scientific reasoning category is the medium category. While the research conducted by Hidayat, et al., in pre-service biology teachers shows scientific reasoning students in the high category with the highest percentage.

From the results of discussions and discussions, there are research results that, through scientific reasoning can be used to measure a person's ability based on the level of thinking according to the theory of the development of Jean Piaget, especially at the formal operational stage. A person's scientific reasoning is determined by his linear level of thinking with one's age. At the formal operational stage, a person has a very complex scientific reasoning ability because it has been supported by sufficient cognitive abilities. The results also showed that a person's scientific reasoning in a very complex category is supported by related Natural Science knowledge. Such knowledge includes cognitive abilities, namely the identification of facts about Natural Science, concepts, and conceptions of the scope of living matter, its objects and properties, its energy and changes, the earth and solar system, and science and technology. Such knowledge becomes the basis of one's reasoning ability, which further through the stages of scientific activities can make pre-service elementary school teachers who in this study are in the 4th semester have the largest category of very complex reasoning. This finding also gives an overview of lecturers to conduct scientific reasoning research with other patterns, especially in the field of science science science. Pre-service primary school teachers are prepared to master one of the leading scientific fields, namely science.

CONCLUSION

Scientific reasoning correlates with the ability of pre-service elementary school teachers to learn about the content of knowledge. There are two kinds of scientific reasoning patterns, namely concrete patterns and formal patterns. Scientific reasoning patterns that correspond to the cognitive development of pre-service teachers are formal. Indicators for formal scientific reasoning include theoretical reasoning, combinatorial reasoning, functionality reasoning, control variables, and probabilistic reasoning. To measure scientific reasoning, the researchers used five cognitive tests. The analysis results showed that the scientific reasoning profile of pre-service primary school teachers is quite complex at 10%, categorized as complex at 38%, and categorized as very complex at 52%. The results of this study show that the most significant percentage of pre-service elementary school teachers is highly complex, reflecting the ability to classify, consider, interpret, investigate, and predict capabilities. The implication is that most pre-service elementary school teachers are ready to learn various sciences and skills in elementary school.

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