3-dimensional scientific literacy assessment framework for senior high school science program students

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3-Dimensional Scientific Literacy Assessment Framework for Senior High School Science Program Students

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Abstract. Enhanced scientific literacy is the primary purpose of science education throughout the world, especially in Indonesia, where the students' scientific literacy capability is still far behind those of other countries. Achieving this requires an assessment instrument that can guarantee students' achieved scientific literacy capability at school. Based on many studies, we may conclude that there are at least three dimensions of scientific literacy, namely Scientific Reasoning Skill, Scientific Inquiry Skill and Nature of Science Knowledge. This study aimed at building the scientific literacy assessment framework for Senior High School Science Program Students based on Scientific Reasoning Skill, Scientific Inquiry Skill and Nature of Science Knowledge, here in after referred to as 3-Dimensional Scientific Literacy Assessment. This study was conducted by reviewing various concepts of scientific literacy, building indicators for each of the dimensions and carrying out validation by involving experts and practitioners. The validity used in this research is content validity and psychometric validity .The research results show: (1) The Scientific Reasoning Skill dimension consists of 25 indicators from distinguishing an object from the other correctly if a picture or data were given to making correct conclusion based on the relationship of two or more variables, (2) The Scientific Inquiry Skill dimension consists of 5 indicators from building the basic concept from one's own experience to delivering explanation of the phenomenon observed more realistically, (3) The Nature of Science Knowledge dimension consists of 8 indicators from distinguishing fact and explanation to distinguishing fact and belief.

INTRODUCTION

People's high scientific literacy significantly affects a country's advancement. The reason is that people's scientific literacy positively affects the quality of development of economy, democracy, culture and quality of individual's personality [1]. Therefore, in many developed countries, students' achieved scientific literacy is the main purpose of science education [2].

The scientific literacy dimension divides into three levels: cultural scientific literacy, functional scientific literacy, and true scientific literacy [3]. The true scientific literacy dimension contains mental quality that is called by John Dewey as scientific thinking habit and he had proposed it as the main reason of science education obligation almost a century ago (9). The indicators that an individual has scientific literacy are: (1) Understand scientific process of knowledge development, (2) Understand the importance of observation and experiment in science, (3) Capable of questioning, (4) Use logics for induction and deduction, (5) Rely on evidence, (6) Have appropriate understanding of the essence of science, and (7) Have the basis of understanding of history, value, and assumption of science [3].

Based on more than 25 researches on the nature of science, it have successfully formulated indicators of how an individual understands the nature of science, history, value and assumptions of science. The indicators are, among others: (1) Scientific knowledge Scientific knowledge is not completely objective, (2) Scientists use creativity, (3) Scientific knowledge is tentative but durable, (4) Scientific knowledge is instilled socially and culturally, (5) Law and theory are different types of knowledge, (6) Scientific knowledge is empirically based, (7) There is no scientific method of universal staging, (8) There is difference between observation and conclusion, (9) Science cannot answer

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all questions, (10) Cooperation and collaboration are part of scientific knowledge development, (11) There is difference between science and technology, and (12) Experiment plays role in science [4]. They were referring to the accurate scientific literacy dimension, according to measure the 5th-7th indicators.

Using the method of reviewing more than 20 research results, it arranges test indicators to measure scientific inquiry skills. The indicators that an individual is deemed skilled in scientific inquiry are: (1) Identify the problem to be inquired, (2) Use induction to formulate hypothesis or model, (3) Use deduction to produce prediction, (4) Design experimental procedure, (5) Conduct scientific experiment, (6) Observation, or simulation, (7) Collect, arrange, and analyze data, (8) Apply numeric and statistical methods, (9) Explain unexpected result, and (10) Use available technology to report, display, and maintain result [5]. Based on the latest literature, this inquiry literacy test can measure the 1st-3rd indicators of the accurate scientific literacy dimension.

The fourth indicator of true scientific literacy, namely logic for induction and deduction, is called scientific reasoning thinking [3]. Kind & Osborne (2017) develop scientific reasoning indicators, including (1) mathematic deduction, (2) experiment evaluation, (3) hypothetical model making, (4) categorization and classification, (5) probabilistic reasoning, and (6) history-based evolution reasoning [6]. Another research arranged a conceptual framework from scientific reasoning associated with inquiry skill level and Bloom's taxonomy [7]. Scientific reasoning, a process where logical principles are applied to scientific processes, namely search for an explanation, hypothesis formulation, prediction making, solution to problem, experiment creation, variable control, data analysis, and empirical law development [7]

Based on the relatively comprehensive studies related to scientific literacy, we may conclude that there are three dimensions of scientific literacy capability, namely: (1) Scientific Reasoning Skill, (2) Scientific Inquiry Skill, and (3) Nature of Science Knowledge. When combined, the three components can explain the profile of students' scientific literacy capability comprehensively.

None of the current studies of scientific literacy instrument development in Indonesia are capable of combining the three aspects of scientific literacy dimensions comprehensively. Indonesian researcher arranged scientific literacy tests for Junior High School based on science as the body of knowledge, way of thinking, way of inquiry, and interaction between science, technology, and people [8]. Some other researches only study one of the scientific literacy dimensions, but do not combine the three aspects [9][10].

The objective of this research was to build instrument development framework to measure the scientific literacy of Senior High School Science Program Students, covering scientific reasoning skill, scientific inquiry skill and nature of science knowledge. Hereinafter, the instrument was referred to as 3-Dimensional Scientific Literacy Test. The test was expected to become one of the criteria for graduation of Senior High School Science Program Students in Tegal City, thus all graduates would master science completely.

METHOD

This research is in the form of Research and Development [11]. The method used was the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model [12]. This research was limited to analysis and design phases. The research object was the assessment framework for students' scientific literacy of SCIENCE program of Senior High School, consisting of scientific reasoning skill, scientific inquiry skill and nature of science knowledge, here in after referred to as the 3-Dimensional Scientific Literacy Test. The validity of the content is done by asking the opinion of experts and teachers on the substance and content as well as the purpose of developing a 3-Dimensional Scientific Literacy Test. Psychometric validity is done by asking for the opinion of psychometric experts about the form of the test and the accuracy of the formulation of test indicators.

The analysis phase determined the objective of developing the instrument and instrument target user. The research product was instrument development framework for measuring scientific literacy competencies composed of three dimensions, namely scientific reasoning skill, scientific inquiry skill and nature of science knowledge for students of Natural Science Program of Senior High School. This test would measure the scientific literacy competence of Senior High School Science Program Students comprehensively and can serve as the criteria for graduation as the effort to enhance the standard graduation criteria for Senior High School Science Program Students. In the analysis phase, Focus Group Discussion (FGD) was also carried out with Senior High School teachers in the environment of SMAN 2 and SMAN 3 of Tegal City, involving 30 science teachers and principals. The activity was carried out on 28 March 2021.

In the design phase, the researchers started to conduct benchmarking related to the three dimensions of scientific literacy test, arrange and design test construct, determine the indicators, determine test form, develop items and

validate the content and carry out psychometric validation. Benchmarking was conducted by reviewing the research that had been conducted and consulting experts who were proficient in arranging scientific reasoning test, scientific inquiry test and nature of science knowledge and psychometricians. The benchmarking and content validation phases involved two professors in Natural Science education and one senior Natural Science teacher of Senior High School. The psychometric validation involved one professor in education assessment field. The form of test used was multiple-choice questions with one correct answer and five choices. The next phase was developing test items for the indicators and determining content validity and psychometric validation qualitatively. Upon review and some corrections, the reviewers agreed that the outline arranged could be developed further into scientific literacy test based on scientific reasoning, scientific inquiry and nature of science knowledge, referred to as 3-Dimensional Scientific Literacy Test. All reviewers have agreed that the formulation of indicators is in accordance with the competencies to be measured and the indicators are appropriate to measure the ability of high school students in grade XII science programs.

RESULT AND DISCUSSION

Based on the results of literature study and discussion with potential users and the results of review by experts, we can formulate that the instruments for measuring scientific literacy competencies consist of three dimensions, namely scientific reasoning skill, scientific inquiry skill and nature of science knowledge for students of Natural Science program of Senior High School. The test measured the scientific literacy competence of Senior High School Science Program Students comprehensively and can serve as an alternative graduation criteria as the effort to enhance standard graduation criteria for Senior High School Science Program Students. This scientific literacy test also serves as the reflection of success in Natural Science learning in Senior High School, especially for science program. Through this FGD, it is also proposed to name the literacy test to be developed as 3-Dimensional Scientific Literacy Test, in order to distinguish it from previously developed scientific literacy tests that measure scientific basic literacy competence (LISAPADU test/SLiSIS test) [13]. The framework of the 3-Dimensional Scientific Literacy Test is presented in Fig. 1.

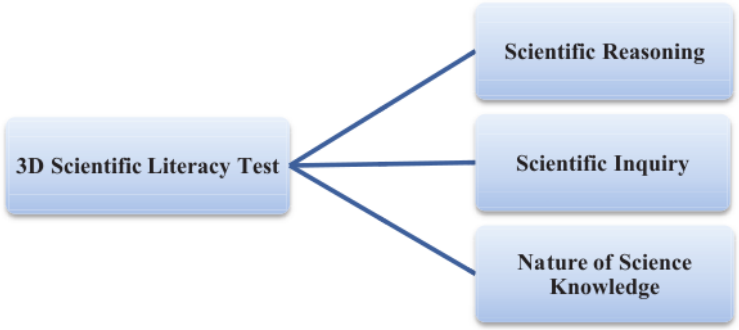

FIGURE 1. 3-Dimensional Scientific Literacy Test Framework

The scientific reasoning competency is formulated based on the theoretical framework developed by previous research and adopted pursuant to the context of the curriculum prevailing in Indonesia. The difference is that previous research divides scientific reasoning into six categories, namely Rudimentary, Basic, Intermediate, Integrated, Culminating and Advance, while this research only limits them until Culminating only. The reason is that the competence at Advance level, after analysis, is generally above Senior High School students' skill level in Indonesia. This analysis is also supported by the research conducted that measures scientific reasoning skills at the Senior High School level only until Culminating level [3]. With regard to scientific reasoning skill at rudimentary level there are eight competencies, at basic level there are five competencies, at the intermediate level there are five competencies, at integrated level there are three competencies and at culminating level there are five competencies. Each competency from Rudimentary level through Culminating level is explained in Table 1 through Table 5.

TABLE 1. Competencies and indicators of rudimentary level scientific reasoning test

Competency	Indicator
Classify	Picture or data were given. Student was able to distinguish an object from other object correctly.
Conceptualize	Picture that shows the cycle of a process was given. Student was able to mention one or more concepts in the picture.
Conclude	Experiment result was given. Student was able to make conclusion based on the result.
Contextualize	Student could show an example of the application of the concept in his/her daily life.
Generalize	Example was given, and student was able to make general statement from the example or give another appropriate example.
Sort	Data were presented, and student was able to sort the data.
Formulate the problem	Student was able to formulate the problem based on data or experimental data design

TABLE 2. Competencies and indicators of basic level scientific reasoning test

Competency	Indicator
Estimate	Student could calculate the data in question based on appropriate concept
Explain	Student could explain a process or event
Predict	A graphic or picture of illustration of an event was given. Student could predict one of the quantity values in the picture
Use conditional thinking	Student state a conclusion of one or more statements of previous requirements
Apply information	An application of a concept of Natural Science was explained. Student was able to explain the application further

TABLE 3. Competencies and indicators of intermediate level scientific reasoning test

Competency	Indicator
Explain relationship	Student could explain the relationship of two or more components in an event in the nature
Interpret quantitative data	Student could interpret quantitative data based on observation table
Use combinatorial thinking	Student was able to make the relationship of some variables based on data
Use relational thinking	Students was able to mention or draw a graphic of the relationship of two event variables
Correctly define problem for study	An event was presented. Student was able to correctly define the problem based on the explanation of the event

TABLE 4. Competencies and indicators integrated level scientific reasoning test

Competency	Indicator
Correctly define system to be used for learning	Student was able to choose appropriate statement pursuant to an occurrence.
Perform controlled scientific design and inquiry	Student was able to design scientific experiment in a controlled way
Interpret calculable data to determine the principle	Student was able to interpret data by calculating them principally

TABLE 5. Competencies and Indicators of Culminating Level Scientific Reasoning Test

Competency	Indicator
Determine whether statement of answer for problem or question is reasonable, including measurement and unit	Student was able to determine a statement pursuant to the problem, including measurement and unit
Summarizing aiming at logical justification, of conclusion based on empirical evidence	Observation results were presented, and student was able to choose logical conclusion based on observation result
Use causal reasoning to distinguish coincidence of cause and effect	Student was able to choose correct statement to distinguish something that is coincidentally cause and effect
Use causal reasoning to distinguish correlation of cause and effect	Student was able to explain the causal relationship based on an occurrence explained
Use proportional reasoning for decision making	Student was able to make correct conclusion based on the reason of relationship of two or more variables

Scientific inquiry competencies were made based on the theoretical framework developed. Scientific inquiry consists of Discovery Learning, Interactive Demonstrations, Inquiry Lessons, Inquiry Labs, and Hypothetical Inquiry skills. Using scientific narration pursuant to the Indonesian student context, the researchers arranged competencies and indicators of scientific inquiry test as presented in Table 6 below.

TABLE 6. Competencies and indicators of scientific inquiry test

Competency	Indicator
Discovery Learning	Student built the basic concept of his/her experience (focus on active involvement in knowledge building)
Interactive Demonstrative	Student was involved in explanation and making of prediction that allows teacher to obtain, identify, encounter, and complete alternative conception (discuss previous knowledge)
Inquiry Lesson	Student identified scientific principles and/or their relationships
Inquiry Laboratory	Student found empirical data based on variable measurement
Real-world Application	Student solved problem related to authentic situation while working individually or in group and collaborative group used problem based & project based approach.

Scientific inquiry instrument was planned to use theme or reading of actual scientific process. Students were engaged to follow example of identification of accident victims based on DNA test. The DNA test was used for forensic DNA and particularly to identify accident victims. After reading and following experts working in scientific process, students responded the problems through scientific inquiry questions.

Nature of science knowledge competency was made based on the competencies formulated as indicator that an individual understands the nature of science. There are seven basic competencies in nature of science knowledge. Based on the theoretical framework, the researchers tried to add 1 indicator, that is student's skill of distinguishing a phenomenon of fact from belief. This is very important since the skill of distinguishing fact from belief is the main indicator of the difference between science and non-science. The competencies and indicators of Nature of Science Knowledge test are presented in Table 7.

TABLE 7. Competencies and indicators of nature of science knowledge test

Competency	Indicator
Distinguish fact and explain	Given a scientific reading, student was able to distinguish facts and explain them correctly
Requirement of theory or partial subjectivity of Data	Given a scientific reading, student understood that observation was affected and guided not only by scientific theories, but also by a scientist's belief, value, attitude, commitment, training, previous knowledge, past experience, and expectation
Role of Creativity	Given a scientific reading, student understood that explaining was not only regarding collecting data and obtaining them logically, but this needed intuition, imagination and creativity.
Nature of Scientific method	Given a scientific reading, student understood that scientific method was a strategy of concluding an explanation of phenomena and evaluating the comparison of specific prediction from observation data with the data in real world
Determine explanation based on data	Given a scientific reading, student understood that an explanation was not determined by a datum, but some different explanations could explain a certain collection of data
Reason for accepting explanation	Given a scientific reading, student understood that a scientific explanation must meet some criteria, one of which was confirmation of observation of the prediction made
Tentativeness of scientific explanation	Given a scientific reading, student understood that a scientific explanation could be abandoned or even rejected for a better new explanation
Distinguish fact and belief	Given a scientific reading, student could distinguish fact and belief

The instrument for measuring Nature of science knowledge was planned using reading of research on how Covid19 appeared. Students were given reading of the pro and cons of the Covid19 appearance theories and also the history of pandemics in the past. Through fact based and tentative scientific principle, students were asked pursuant to the indicators determined using the reading material.

CONCLUSION

3-Dimensional Scientific Literacy Test is a scientific literacy test to measure the three main competencies, namely scientific reasoning, scientific inquiry and nature of science knowledge. The Scientific Reasoning Skill dimension consists of 25 indicators from distinguishing an object from the other correctly when a picture or data were given to making correct conclusion based on the relationship of two or more variables. The Scientific Inquiry Skill dimension consists of 5 indicators from building the basic concept of one's own experience to delivering explanation for the phenomenon observed more realistically. The Nature of Science Knowledge dimension consists of 8 indicators from distinguishing fact and explanation to distinguishing fact and belief.

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REFERENCES

1. E. A. Hanushek and L. Woessmann, Science **351**, 344-345 (2016).
2. J. L. Rudolph, and S. Horibe, Journal of Research in Science Teaching **53**, 805-820 (2016).

3. S. T. Hanson, *The assessment of scientific reasoning skills of high school science students: A standardized assessment instrument*. (ProQuest Dissertations Publishing, Normal, 2016).
4. W. F. McComas, and N. Nouri, Journal of Science Teacher Education **27**, 555-576 (2016).
5. S. Rönnebeck, S. Bernholt, and M. Ropohl, Studies in Science Education **52**, 161-197 (2016).
6. P. E. R. Kind, and J. Osborne, Science Education **101**, 8-31 (2017).
7. C. J. Wenning, and R. E. Vieyra, *Teaching High School Physics: The Nature of Physics Teaching* (AIP Publishing, USA, 2020).
8. A. Rusilowati, S. E. Nugroho, E. S. M. Susilowati, T. Mustika, N. Harfiyani, and H. T. Prabowo, Journal of Physics: Conference Series **983**, p. 012046 (2018).
9. A. I. P. Ariyanti, M. Ramli, and B. A. Prayitno, Preliminary Study on Developing Science Literacy Test for High School Students in Indonesia. In International Conference on Teacher Training and Education. (Sebelas Maret University, Surakarta, 2016).
10. S. Wahyuni, I. Indrawati, S. Sudarti, and W. Suana, Jurnal Pendidikan IPA Indonesia **6** (2017).
11. M. D. Gall, J.P. Gall, and W. R. Borg, Applying educational research: How to read, do, and use research to solve problems of practice. Pearson Higher Ed (2014).
12. M. Molenda, M. Performance Improvement **54**, 40-42 (2015).
13. P. Susongko, Y. Arfiani, and M. Kusuma, Jurnal Pendidikan IPA Indonesia **10**, 270-281 (2021).
14. L. J. Suzuri-Hernandez, "Exploring school students' views of the nature of science," Doctoral dissertation, University of York, 2010.

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