Development of scientific literacy instruments based on pisa framework for high school students on global warming topic

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Abstract. The purpose of this study is to develop scientific literacy instruments on global warming topic for senior high school students. The instruments were adapted from The Programme for International Student Assessment (PISA) framework. The method of this study is research and development used instructional models 4D (define, design, developed and disseminate) is constrained only to a point 3D (define, design and developed). (1) Define stage include literature studies and field study, (2) design stage include designing draft scientific literacy instruments based on PISA framework, and (3) developed stage include expert review and trial test for students. The instruments are consisted test for context, competence and knowledge aspects and non-test for attitude aspects. The test instrument consists of 22 essays and non-test instrumnet is a questionnaire. The subject of this research consisted of 37 students of XI MIA at a senior high school in Bandung. The Scientific literacy instruments were analyzed using expert review from 4 validators and classic test analysis include the validity of item, reliability, discriminating power and level of difficulty. The results showed that scientific literacy instruments have a good quality as instrumennts to measure scientific literacy of senior high school students for global warming topic.

1. Introduction

In The 21st century, Science and technology is developing rapidly. It has a positive and negative impact on human life and the world. The advancement of science and technology causes problems in human life and environment such as human welfare, job competence required, human population growth, economy, social, quality of life and environment such as; sufficient food and water, controlling diseases, global warming, energy crisis, pollution, adapting to climate change and environmental damage [1]. These are not just the problems faced by a particular individual, group or State but are a global problem. This issue is the responsibility of the global community and in its subscription requires global cooperation in order to be overcome. Thus, all citizens must have certain competencies to respond to the problem, it is called scientific literacy. Scientific literacy is the capacity to use knowledge, identify questions and draw evidence based conclusions in order to understand and help make decisions and acting as responsible person within society (at home, work, and community) [2]. Citizens who have good scientific literacy are expected to be able to use their understanding of the concept and process of science to solve personal and social problems [3]. Furthermore, scientific literacy can increase the knowledge needed for everyday life such as problem solving, cooperative skills, critical thinking skills
and technological [4]. Scientific literacy is an important character possessed by every citizen [5-6]. Scientific literacy has become the goal of science education [7-9]. Thus, scientific literacy is important ability for students as preparation for citizenship.

The importance of scientific literature makes this important ability to be measured as a picture of how successful the curriculum of a country’s education is to equip its citizens. One of the international assessments for measuring scientific literacy is the Program for International Student Assessment (PISA). PISA is coordinated by Organisation for economis Co-operation and Development (OECD). PISA is designed for measuring scientific literacy of the 15-years of students. One of notable feature of PISA is serves a conceptual underpinning for the project [10]. Indonesia has been following the PISA program since 2000. From the results of PISA from 2000 to the last in 2015, Indonesia is still at the bottom of the countries that follow PISA. Based on the results of PISA in 2006, the results obtained that the ability of scientific literacy Indonesia students are ranked 50th of 57 countries. The average science score that Indonesian students earn is 393 [11]. At PISA in 2009 the scientific literacy rate of Indonesian students is ranked 57th out of 65 participating countries with a score of 382 [12]. At PISA 2015 Indonesia is ranked 62nd out of 72 countries participating in PISA with 403 points [13]. It means that Indonesia’ students have low scientific literacy compared other countries.

The major change for improving literacy scientific students is proposed assessment of student achievement in science education [2]. Assessment is important part in learning. Many of assessments are only focus to measure science content and not related with daily life such as calculating use formulation or explaining theories. Whereas, relevance science content and student experience sis important for the enhancement of scientific literacy [2]. Based on those statement, The developing scientific literacy instrument is important. Thus, the purpose of our investigation was developing scientific literacy instrument adapted from PISA 2015 on global warming topic that can be used broadly by educators and educational researches.

2. Method
The methods of this study is research and developing (R&D) design. The design of this developing study is using 4D stage, which includes: 1) define, 2) design, 3) develop, and 4) disseminated [14]. But, in this development study step only from define and develop stage.

In the define stage includes the study of literature and field of study. The study literature as done by collecting and analysing the literature or data relating to scientific literacy which is adapted from PISA 2015 and facts about scientific of literacy high school students while doing field studies. In the design stage, the design of literacy scientific instrument test was developed. The develop stage, we conducted an instrument test through expert judgement and implemented test. The sample in this study is second year students at senior high school (SMA) in Bandung consist 37 students.

3. Result and discussion
3.1. Define stage
In this stage, we conducted field study and study literature to have facts or finding about scientific literacy high school student’s level. Field study and study literature show that literacy scientific of Indonesia’ student has low category. According to an interview with physics teacher, One of factors is mostly of instrument test that used as assessment is emphasize on memorizing and how using formulas to answer the question. Meanwhile, Literacy scientific is not just knowledge about science, scientific methods, or interpreted information but also how implemented them to solved real problem.

Literacy scientific in this study is adapted from PISA 2015 [15]. PISA is an assessment regarding the achievement of scientific literacy of students who aged above 15 years in international level. we analysed framework of PISA in the developing literacy scientific instrument tests. According framework of PISA, scientific literacy consists of 4 interconnected aspects, namely: context, knowledge, competence and attitude. On each of these aspects has each of competencies shown in figure 1.
Based on figure 1, all aspects have related each others. The context explain that the problem selected in the instrument test based on knowledge and understanding of the 15 year old student about issues related to science and technology. The problem in test instrument is taken from part of life so student can understand importance, usefulness and meaningfulness science concept in their life [16]. Aspects of competence is the ability needed to understand and engage on issues related to science and technology which it requires knowledge. Aspects of attitudes is a series of attitudes that identify that person has an interest to science and technology, concern for the environment and assess the scientific approach used in an inquiry. PISA is only measuring aspects of competence and knowledge while the context is used to select the issue that will be presented in the question. Aspects of attitude was measured separately using a questionnaire.

### 3.2. Design stage

In this stage, we made a blue print for design planning. Instrument test are consisted of an essay for knowledge and competences aspect and a questionnaire for attitude aspect. Essay form is chosen in order to avoid the possibility of students guessing answers and students can develop their own answers based on their knowledge. Reserved and developed a detailed questionnaire relating to the matter of global warming. After developing a problem, and then later also developed the assessment rubrics to assess student's answer. On the PISA 2015, things that are measured are aspects of competence and knowledge in which both these aspects have different competencies. Table 1 describes the distribution aspect of the competence and knowledge in scientific literacy instrument test which will be developed.

| Competency                                      | Knowledge               |
|------------------------------------------------|-------------------------|
| Explain phenomena scientifically                | Content: 8, Procedural: - | Epistemic: - |
| Evaluate and design scientifically enquiry      | Content: - , Procedural: 4 | Epistemic: - |
| Interperated data and evidence scientifically   | Content: 3, Procedural: 2 | Epistemic: 5 |

According to table 1, the amount of questions that will be developed are 22 essays. The Example of design scientific literacy instrument test show on figure 2.
Figure 2. Example of design scientific literacy.

Figure 2 shows there are 2 questions that need different competencies and knowledge aspect to answer them. To answer questions 1.a students must have the competence to interpret data presented on the problem and epistemic ability to synchronize between hypothesis statement and the data presented. As for answering 1.b students should have knowledge of the greenhouse effect occurring in Venus to explain why the temperature of Venus is higher than Mercury even though Mercury is closer to the sun.

On the attitude aspects, the questionnaire will be developed based on 3 competence, namely an interest in science, judging by the scientific approach to the investigation, and environmental awareness. The statement in question form consists of the statement is positive and negative. The statement is not only in positive form overall to avoid students guessing and students will focus to analyze each of the point statements. Each competency has a charge indicators will respectively. Table 2 show distribution statement for attitude aspects to be developed in questionnaire.

| No | Attitude areas                        | Indicator                                                                 | Amount of statement | Form statement |
|----|---------------------------------------|---------------------------------------------------------------------------|---------------------|----------------|
| 1  | Interest in science                   | Interest in learning science                                              | 3                   | 1              | 2              |
|    |                                        | Future oriented science activities                                        | 2                   | 1              | 1              |
| 2  | Valuing scientific approaches to enquiry | A commitment to evidence as the basis for explanations of the materials world | 2                   | 2              | -              |
|    |                                        | A valuing of criticism as a means of establishing the validity of any idea | 1                   | 1              | -              |
| 3  | Environmental Awareness               | Awareness of environmental issues                                         | 4                   | 3              | 1              |
|    |                                        | Environmental optimism                                                    | 3                   | 1              | 2              |

Based on table 2, there are 15 statements consisting of 9 positive statements and 6 negative statements that will be developed in the questionnaire. On Questionnaire design is not includes all indicators. It includes several indicators. Figure 3 show an example of a statement to be developed;
3.3. Develop stage

In this stage, the instrument that has been created in the previous stage is validated to 4 experts to assess the feasibility of the instrument. Based on the results of the assessment of 4 experts, they give some advice to some revision in the rubric assessment, concepts, writing and suitability of the questions on the indicators measured for the essay, while improvements to the questionnaire contained in the writing and improvement of sentence construction. After the instrument is revised in accordance with the advice provided by the expert, questionnaire can be used to measure attitude aspect while the essays that have been made are tested to 37 high school students while the questionnaires are not tested. The results of the students' scores were analyzed using Microsoft Excel to assess the validity, reliability, difficulty and distinguishing power. The result of the test analysis on the students is shown in Table 3.

**Table 3.** Analysis of literacy scientific instrument test quality.

| Number of item test | Validity | Discriminating power | Level of difficulty |
|---------------------|----------|-----------------------|---------------------|
| a                   | 0.71     | 0.74                  | Hard                |
| b                   | 0.65     | 0.88                  | Hard                |
| a                   | 0.67     | 0.70                  | Medium              |
| b                   | 0.61     | 0.94                  | Medium              |
| a                   | 0.27     | 0.17                  | Medium              |
| b                   | 0.61     | 0.94                  | Medium              |
| c                   | 0.64     | 1.00                  | Medium              |
| a                   | 0.66     | 0.88                  | Medium              |
| b                   | 0.65     | 0.94                  | Medium              |
| a                   | 0.69     | 1.00                  | Medium              |
| b                   | 0.71     | 0.70                  | Hard                |
| c                   | 0.62     | 1.00                  | Medium              |

Based on the test results in Table 3, 22 questions are valid. The reliability of the instrument test is 0.859 with very high category. So, 22 questions can be used to measure students' scientific literacy. The 22 problems consist of 1 easy question, 18 medium questions, and 3 difficult questions.
4. Conclusion
The literacy scientific test instrument developed based on PISA 2015 for senior high school level for global warming topic. This instrument included two instrument: a student test and a student questionnaire. In each items for student test developed based on 3 aspects, namely context, knowledge and competencies in PISA 2015\(^\text{[1]}\) and student questionnaire based on attitude aspect on PISA 2015. The scientific literacy test instrument has good validity and high reliability. So that, the scientific literacy test instrument can be used to measure scientific literacy for global warming topic in high school level.

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