Design of scientific reasoning test instruments on simple harmonic motion topics

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Abstract. Scientific reasoning is one of the 21st century skills that is expected to be taught in science class as an effort to prepare students to successfully confront globalization and rapid technological developments. If student’s scientific reasoning skill is low, students will not be able to handle new problems and plan investigations to solve problems science, engineering and social in real-life [1]. Scientific reasoning is also considered as a set of basic reasoning skills that students need to successfully conduct a scientific investigation, including exploring problems, formulating and testing hypotheses, manipulating and isolating variables, and observing and evaluating the consequences [2]. Scientific reasoning (SR) is a set of abilities in carrying out scientific practices related to the collection and analysis of evidence, and then used to produce cohesive evidence-based arguments [3]. Therefore, scientific reasoning is the ability of thinking and reasoning that students need to construct a concept in a learning activity that is through a process of scientific inquiry so that students can hypothesize, determine variables, design experiments, collect data, analyze data, and draw logical conclusions.

1. Introduction
Scientific reasoning is one of the 21st century skills that is expected to be taught in science class as an effort to prepare students to successfully confront globalization and rapid technological developments. If student’s scientific reasoning skill is low, students will not be able to handle new problems and plan investigations to solve problems science, engineering, and social in real-life [1]. Scientific reasoning is also considered as a set of basic reasoning skills that students need to successfully conduct a scientific investigation, including exploring problems, formulating and testing hypotheses, manipulating and isolating variables, and observing and evaluating the consequences [2]. Scientific reasoning (SR) is a set of abilities in carrying out scientific practices related to the collection and analysis of evidence, and then used to produce cohesive evidence-based arguments [3]. Therefore, scientific reasoning is the ability of thinking and reasoning that students need to construct a concept in a learning activity that is through a process of scientific inquiry so that students can hypothesize, determine variables, design experiments, collect data, analyze data, and draw logical conclusions.

Based on the results of field studies that have been done in one of secondary school in Bandung shows that students’ scientific reasoning is relative low ie 22.32%. The students’ scientific reasoning is
low for all aspects. The Factors are less in practice in solving problems based on scientific reasoning, students used to memorize the formula to solve a problem so that less demanding students to high order thinking. So its important test instrument based on scientific reasoning to improved scientific reasoning of students.

A number of researchers assessing scientific reasoning test, such as Longeot Test [4], Group Assessment of Logical Thinking Test [5], the Test of Logical Thinking [6] and the Lawson’s Classroom Test of Scientific Reasoning [7], but the Lawson classroom Test has gained wide popularity in science education communities. The Lawson’s Classroom Test of Scientific Reasoning (LCTSR) is designed to examine conservation of matter and volume, proportional reasoning, control of variables, probability reasoning, correlation reasoning, and hypothetical-deductive reasoning [8]. Han modifies Lawson test into eight dimensions for assessment scientific reasoning is control of variables, proportions and ratios, probability, correlational reasoning, deductive reasoning, inductive reasoning, causal reasoning, and hypothetical-deductive reasoning [2].

Researchers modified Han’s scientific reasoning test by the content based on the concept of science that is simple harmonics motion. This study aims to design a scientific reasoning test instrument on simple harmonic motion topics.

2. Research method
The method utilized in this research is a research and development of instructional model 4D (define, design, develop, and disseminate) [9], but this research limited only to 2D (define and design). In the define stage is (1) literature study (2) field study (3) concept analysis (4) formulate instructional objective. In the design stage, the design of scientific reasoning test instrument to be developed.

3. Result and discussion
After conducting a review of scientific reasoning test instruments then determining the development design of the scientific reasoning test instruments. The following is the exposition of the design development process of scientific reasoning test instruments.

3.1. Define stage

3.1.1. Literature study. The first step in the define stage is by conducting literature studies on books, journals, and research that have been done related to scientific reasoning. The study is based on Han 2013 [2]. There are eight dimensions of students' scientific reasoning, namely control of variables, proportions and ratios, probability, correlational reasoning, deductive reasoning, inductive reasoning, causal reasoning, and hypothetical-deductive reasoning.

Control of variables is used to design and conducting experiments [10], to analyze the relationship between the dependent variables [2]. Proportional reasoning is used to the identification of two variables used in a problem and the application to find the relationship of adding variables or comparing variables [2]. A probabilistic is a situation in which we take a few numbers, then repeated to produce an accurate number by doing multiple repetitions [2]. Correlation is used to describe how relationship between two variables, proportional or inversely between variables. Furthermore, Correlation reasoning is fundamental to the establishment basic prediction and scientific exploration [11]. Deductive reasoning is a way to describe conclusions from statements or facts that are considered correct by using logic. Deductive reasoning can help students recognize cognitive conflict and resolve it [12]. Inductive reasoning is used when generate hypotheses, formulate theory and find relationships, and important in scientific discovery [2]. Causal reasoning is relate with establishing a causal relationship between phenomena [2]. The hypothetical-deductive is a very important method for testing theory or hypotheses [2].

3.1.2. Field study. Case studies are conducted to find out the profile of the scientific reasoning skills that students currently possess, where scientific reasoning is one of 21st century skills students must
possess. The question of measuring students' scientific reasoning is taken from the validated thesis on temperature and heat topics. And then, interview data obtained from open interviews of physics teachers, then the interview data, used to clarify results of student tests. Based on the results of data analysis of students scientific reasoning obtained as table 1. Based on the table 1 can be seen, students' scientific reasoning ability is low in all dimensions. The average score of students' scientific reasoning into the low category is 22.32. Therefore, required test instruments that can trace students' scientific reasoning on physics concepts.

| Dimensions of Scientific Reasoning | Percentage (%) |
|-----------------------------------|----------------|
| Control of variables              | 18.75          |
| Proportions reasoning             | 22.92          |
| Correlational reasoning           | 25             |
| Deductive reasoning               | 16.67          |
| Inductive reasoning               | 39.58          |
| Causal reasoning                  | 4.17           |
| Hypothetical-deductive reasoning  | 29.17          |

Average score 22.32

3.1.3. Concept analysis. Analysis of the concept aims to identify the subject matter in learning sets developed so that the concept of learning is more systematic and relevant between one concept with another concept. The interrelationships between concepts will form a concept map that can be used as a basis for developing learning objectives and means to achieve them.

The topic of this study is simple harmonic motion. Simple harmonic motion is divided into three subtopics namely pendulum oscillation, spring oscillation, and physical quantities on simple harmonic motion. Each subtopic consists of eight dimensions of scientific reasoning. So there are 24 items of scientific reasoning test instruments.

3.1.4. Formulate Instructional Objective. Learning objectives are goals that will be achieved students in a learning activity. Learning objectives are prepared based on conceptual analysis. In the curriculum there is basic competence used as a reference formulation of indicators of achievement competence. From the formulation of indicators of achievement of these competencies can then be determined what learning objectives will be achieved. Besides that we can develop the question indicator that is used to develop the test instrument design.

3.2. Design stage

Question of items use multiple choices form. Multiple choices can be presented in one tier, two tier, three tier, and four tier. This research use multiple choices test two tier, students choose some possible answers question followed by possible reason question [13]. The questions presented contain phenomena related to the simple harmonic motion topics. Eight dimensions of scientific reasoning was presented into 24 items based on paper and pencil test with mapping as in table 2.

| Dimensions of Scientific Reasoning | Number of items |
|-----------------------------------|-----------------|
| control of variables              | 1, 9, 17        |
| proportions and ratios            | 2, 10, 18       |
| probability                        | 3, 11, 19       |
| correlational reasoning           | 4, 12, 20       |
| deductive reasoning               | 5, 13, 21       |
| inductive reasoning               | 6, 14, 22       |
| causal reasoning                   | 7, 15, 23       |
| hypothetical-deductive reasoning  | 8, 16, 24       |
Figure 1 is an example of Lawson test instrument on control of variable dimension. That example can be used in simple harmonics motion topic. It can be seen from the picture, there are three pendulums have metal weights and different length of string. String and loads attached can be swung, moving back and forth, and the time it takes to make the swing adjustable. To see if the length of the string affects the time it takes to swing back and forth. Then the student is asked to choose the control of variable which supposed. Then students choose the right reasons. Student will get credit if answer dan reasoning is correct.

![Figure 1](image.png)

**Figure 1.** Example control of variable item from Lawson test.

The traditional scoring method of two tier item from the Lawson Test [2] is describe by Table 3. To define scientific reasoning skills, student will get credit for each items if his answer and reason are correct.

| Answer | Reasoning | Total Score |
|--------|-----------|-------------|
| incorrect | incorrect | 0           |
| incorrect | correct  | 0           |
| correct   | incorrect | 0           |
| correct   | correct  | 1           |

We believe each row of Table 3 represents a different level of understanding. The first three rows of the table represent equivalent skill levels. Getting both the answer and the reasoning incorrect certainly indicates the lowest skill level, then getting both correct indicates the highest skill level but the skill level when only the answer or the reasoning is correct is unclear.

This test is very useful to measuring students’ scientific reasoning skills, although it still based on concept of certain topics to be able to answer each item, so this test is difficult to measure students’ scientific reasoning skills who do not have knowledge of concept about that topics.
4. Conclusion

Instrument design of scientific reasoning test used refers to Han. It consists of 24 item, two tier, multiple choice test. Research is only at define and design stage of Han-based scientific reasoning tests for high school students on simple harmonic motion topics. Subsequent research is expected to reach the develop stage, that is the judgment stage by the experts, the revisions of test instruments from the judgment results, then testing on some samples. After that the disseminate stage. Researchers expect the development of scientific reasoning test instruments performed for other Physics topics so that the relationship between scientific reasoning with Physics learning can be known.

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