KTG-SESC: Development of scientific explanation skills test instrument

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Abstract. A scientific explanation is one of the main goals in science learning, including physics. But, nowadays it is still rare that instruments can to develop the scientific explanation skills, so it requires specific test to measure it. This research aims to develop scientific explanation skills test instrument on kinetic theory of gases material named KTG-SESC (Kinetic Theory of Gasses-Scientific Explanation Skills Checker). The test instrument was prepared based on the adaptation and modification of Chaimala's scientific explanation skills test. The method used is a method of research and development of instructional models 4D (define, design, develop and disseminate) is constrained only to a point 3D (define, design and develop). Question was developed as many as six questions in the form of essays that allow students to provide scientific explanations freely. So that, can be seen categories of students explain scientifically through the answer. Based on the trial, scientific explanation instruments have been high category reliability and good validity. Through the define, design and develop stage, a scientific explanation skills test instrument for high school students has been developed in the kinetic theory of gasses based instrument of SESC test by Chaimala.

1. Introduction

In the contemporary nations, there has been an increasing emphasis on industrial, scientific and technological advancements because of the obvious effects of science and technology on today’s world and the future. It is observed that scientific methods influence all human interaction and has a fundamental role in all countries’ national growth and economic and scientific development. Thus, science education has been regarded as being central for knowledge economy and intellectual development especially in emerging societies [1]. Science has two basic functions, namely to describe phenomena or natural events that become objects in a scientific research and to understand a phenomenon based on law or scientific principles. In the context of physics learning, most of the physics learning materials are still closely related to real life. Consequently, in physics learning, learners are expected to have the skills in explaining scientifically (scientific explanation) to the phenomena or natural events that occur. The involvement of learners in building scientific explanation skills is an important issue in recent research and education on science [2-5]. With the result that, researchers and educators have paid much attention to scientific explanation as it is regarded as one of the important skills in physics learning.

Scientific explanation skills become one of the important competencies students must possess. There are two reasons why scientific explanation skills are necessary, first to prove that science is a science that is closely related to everyday life and enhances understanding of the world, secondly because
science continues to grow so that it can be compared to the thinking of scientists then with today's scientists so as to predict what will happen in the future. Scientific explanations go beyond being merely descriptions of a phenomenon and should commonly provide reasoning, and answers to ‘why’ questions. Scientific explanation activities not only help students to acquire a deep understanding of scientific concepts but also promote scientific literacy. Even though the positive effect of scientific explanation activities, various studies have also identified a variety of difficulties including misconception explanations, missing articulation about claims, and incorrect use of evidence [6,7].

Scientific explanation is a way of answering questions about cause or giving reasons for the occurrence of a scientific phenomenon. The ability to make scientific explanations is one of the most important skills in defining scientific thinking, which is a combination of a number of complex skills, including the ability to articulate theories, to understand evidence [8-10] or contrary to theory, and to justify the truth of a theory that explains a phenomenon. To know the scientific explanation skills category of a person, it is necessary to measure scientific explanation skills. So far, scientific explanation skills instruments that are widely used to determine the quality of scientific explanation skills are based on claim, evidence, and reasoning [6,11].

The scientific explanation skills instrument designed by Katherine L, McNeill and Joseph Krajcik [11] gives students a framework to build scientific explanation skills of students covering evidence and reasoning to support their ideas. Then ask students to use their own data, or data they get from other sources to form conclusions or claims. Meanwhile, Chaimala [12] designed scientific explanation skills instruments based on categories such as proper explanations, appropriate explanations, inappropriate explanations, no explanation with justification, and no explanation. Associated with measuring instruments that can be used to measure scientific explanation skills, researcher consider still require development.

This study aims to develop scientific explanation skills measurement tool students or namely scientific explanation skills checker (SESC). The measuring instrument has been developing in this study combines the scientific explanation skills component of claim, evidence, and reasoning in the scientific explanation skills category that refers to Chaimala [12] by inserting the material of kinetic theory of gasses.

2. Method
The method utilized in this study is a research and development (R&D) design. The research focused on the development of instruments test to measure scientific explanation skills in high school physics material. The development step using 4D stage, which includes: 1) define, 2) design, 3) develop, and 4) disseminate [13], but in this research the development step only from define to develop stage. In the define stage analysis of scientific explanation skills test instrument developed by Chaimala [12]. In the design phase, the design of scientific explanation skills test instrument was developed. Then at the stage of the development, the researcher conducted an instrument test through expert judgment and reliability test with test-retest method.

In the design phase, the scaffolding for construction scientific explanation skills instrument test consist of a five phases of construction activity developed by Arif [14]. The matrix using scaffolding during the construction process of the scientific explanation skills instrument test item, used the following provisions:1) the column test form filled in an essay test questions form, 2) the column component of scientific explanation is filled with claim, evidence and reasoning, 3) the column description of the component filled in as indicators of scientific explanation that will be measured in accordance described, 4) the column content filled with physics content that is kinetic theory of gasses material and Boyle Law, Charles Law, Gay-Lussac Law and equation of ideal gasses concept, 5) the column operationalization of aspect indicator is filled with the elaboration of indicators in a more specific aspects which include the concept being evaluated. Then, next step making the construction of frame is filled with the exposure of each part consisting of questions about the stimulus and STEM. In stimulus step, a phenomenon given to students about kinetic theory of gasses according to the indicators were evaluated. In STEM step, student giving explanation about kinetic theory of gasses
according to the indicators were evaluated. The last stage, construction of scientific explanation skills instrument test item. The data obtained in this study is a quantitative data of scientific explanation skills test instrument results is the form of students’ essay test score. The population in this study is the eleven grade students of Senior High School (SMA) in Bandung, which consists of six classes with the average number of students in each class are 40 students, while the sample is two of grade XI in the school with 62 students.

3. Results and discussion

Researcher conducted a study related to scientific explanation skills test instrument, then the researcher determine the development design of the scientific explanation skills test instruments, the following is the exposure of the design process of development of scientific explanation skills test method.

3.1. Define stage

Scientific explanation refers more to the explanation of the question of why or how a phenomenon occurs. Scientific explanation has three main components: claims, evidence and reasoning [6,11]. Claim is the answer or the initial explanation of a question. Claims can be short answers such as approval, rebuttal, or core answers. Can also be classification, grouping, and numbering. Evidence is an example or data that can support a claim. Examples and data can be obtained from learning, experience, or everyday events, can also be obtained from an experiment. Reasoning is an explanation that links claims and evidence. In this case, good reasoning is a reasoning that many include supporting knowledge such as images, graphics, and mathematical formulas.

There are three components of scientific explanation, then the three components are incorporated into four categories in general and in category 1 is divided into three forms of categories based on student explanations. Each item can include either a scientific explanation component or a three-component scientific explanation directly. Each item refers to the category compiled by Chaimala [12]. The first step on the analysis of students’ scientific explanations involved their classification in terms of scientific reasoning content. For each one of the six items of the questionnaire, students’ responses were classified in four broad categories: a) Appropriate explanations: they include scientifically accepted ideas about the phenomena; b) Inappropriate explanations: they include student’s alternative ideas about phenomena; c) No explanations with justification: the students comment that they do not know and explain the reasons; d) No explanations: no explanation is given or the response is irrelevant to the question asked.

Then, attention was turned to the appropriate explanations, which were classified in terms of their quality (defined as the degree to which the information provided by the student is enough to back up the explanatory conclusion reached). As exemplified in the following lines of this section, the properties of this category varied, in relation to the different content of each item. Yet, for all the items the categories that were formed involved the following: a) Category 3: It stands for the most complete appropriate explanations, where all the needed information is provided by the student to back up the explanatory conclusion; b) Category 2: It involves the cases where more information is needed to back up the explanatory conclusion; c) Category 1: It refers to appropriate explanations, where only the correct claim is provided by the students. The following lines present the categories that were formed from students’ responses to the six items of the questionnaire. A brief discussion on how students’ responded to each item is provided, while extracts from students’ answers exemplify the attributes of each category.

This test is very useful in measuring scientific explanation skills of students, although it still requires knowledge of certain materials to be able to answer each question, so this test is difficult to measure scientific explanation skills of students who do not have knowledge about the material. This study examined all the explanations produced by the students to identify the main explanation patterns that the students applied to construct explanations according to the main approaches reported by Chaimala [12].
3.2. Design stage

This step was known as making blue-print, similar with the building before it is built there should be a design on paper first [15]. Questions in each item are developed in essay form. So that students can provide answers freely based on the knowledge and experience they have. The questions presented contain phenomena related to the kinetic gas theory material. Then students are asked to explain their answers based on the question. The base explanation rubric includes the three components that we then adapt to create a specific rubric to address the particular content and task. To characterize how students defined scientific explanation, we gave each students a score from 0 to 5 for each of the four category of scientific explanation. In Table 1 shows the distribution of the items of the development design by including the three components of scientific explanation skills.

| Physics subject     | Claim | Evidence | Reasoning |
|---------------------|-------|----------|-----------|
| Boyle Law           | 5     | 2        | 3         |
| Charles Law         | -     | 6        | -         |
| Gay-Lusac Law       | -     | 2        | -         |
| The ideal gas equation | 1   | -        | -         |

Note: Nothing item in the physics subject

For example in the design of scientific explanation skills test, when the kinetic-molecular theory of gases explains why Boyle’s law holds, many specific character of the fundamental laws governing the interactions between gas and container molecules make no difference to the explanation. The only features of the laws that remain, once the model has been optimized, are that the gas container interactions are short range and elastic. Thus, only these characteristics help to explain Boyle’s law. Students may understand the importance of using explanation, but if they do not have strong conceptual knowledge they might not understand what counts as evidence in a particular domain. When students reason about a phenomenon, they rely on their theories about that phenomenon. This is example the modification design of instruments test to measure scientific explanation skills:

**Item 1:** A student blows a rubber balloon up to a certain volume. Students are watching slowly the walls of the balloon increasingly tense. According to the incident, how do you think the number of gas particles (when the balloon is constantly blown) to the gas pressure inside the balloon and the balloon's wall tension? Explain your answer by including the underlying concept of the phenomenon and conclude!

As illustrated there, in the appropriate explanations category 3 in this item the students state that the gas pressure in the balloon arises from the impulsive force due to the collision of the gas particles to the inner wall surface of the inner balloon. When the balloon is blown continuously the pressure value is still constant as the number of particles of gas increasing is proportional to the volume increase to the maximum volume of the balloon, then the pressure will increase as the balloon continues to be blown at a constant volume. This is due to the impulse force when the gas particles pounding the walls of the balloon get bigger as the number of particles increases. If the impulse force gets bigger than the gas pressure gets bigger. In addition, the more the amount of gas particles added into the balloon the collision of gas particles against the walls of the balloon more frequent so that the balloon wall voltage is getting bigger (Claim). The underlying concept is the gas kinetic theory of the relationship of the amount of gas particles to the gas pressure (Concept). So it can be concluded that the more the number of gas particles the greater the balloon wall voltage. While the pressure remains to the point of constant balloon volume, then the gas pressure gets higher when the balloon volume is constant (Conclusion). In category 2 students only explain concepts and conclusions and in category 1 the students only explain the conclusion.
Students state in the appropriate explanations in this item that if the balloon continues to be blown then the number of particles the more and the greater the pressure then the greater the balloon wall voltage due to the greater volume. Inappropriate explanations in this item include responses containing misconceptions. In terms of the quality of appropriate explanations, the most complete explanations (Category 3) include the cases where the students provide the correct claim, a correct principle or law, the appropriate data to back up the claim and the conditions under which the claim is correct.

3.3. Develop stage
In this step the researcher undertakes the development of the instrument through an instrument test to see the feasibility of the instrument. Based on the results of expert judgment found that the six items are prepared in accordance with the material indicators and scientific explanation skills competency indicator that will be measured. Although the results of the validation have met the criteria, there are some suggestions for improvement given by validator that are associated with changes in answer options and the category of scientific explanation skills because it does not appropriate, and improvement in writing the questions. The researcher has done a trial twice of the test instrument to 62 students in one senior high schools in Bandung. Based on analysis using the Anates V4 software, the value of validity of the item, level of difficulty and discriminating power presented in Table 2.

### Table 2. Analysis of the scientific explanation skills items instrument test quality.

| Number of item test | Discriminating power (%) | Level of difficulty |
|---------------------|---------------------------|---------------------|
| 1                   | 30.59                     | Moderate            |
| 2                   | 23.53                     | Easy                |
| 3                   | 35.29                     | Easy                |
| 4                   | 24.71                     | Easy                |
| 5                   | 31.76                     | Moderate            |
| 6                   | 36.47                     | Moderate            |

Based on the analysis of the 6 items shown that discriminating power: 2 item in enough category (item 2 and 4) and 4 items good category (item 1,3,5,6). For level of difficulty: 3 items easy category and 3 items medium category. Furthermore, analysis result found that the value of reliability test is 0.87, which mean very high category that indicates the reasoning developed test is reliable for use in assessing the students. Then, it can be seen that the scientific explanation developed instrument test has good quality as a test instrument to measure scientific explanation skills.

4. Conclusion
The scientific explanation skills test instrument has been developed at the high school level by inserting the kinetic theory of gasses material namely scientific explanation skills checker (KTG-SESC). In each item the measured component of scientific explanation skills is claim, evidence, and reasoning based on student explanation category. The scientific explanation skills test instrument has good quality validity and high reliability. So that scientific explanation skills test instrument can be used to measure scientific explanation skills in students.

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