Analyzing Students Responses To Construct Open Ended Question To Assess Scientific Creative And Critical Thinking (SCCT-Test) Related To Hydrostatic Pressure

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Abstract. Information about students’ scientific creative thinking and scientific critical thinking skills is one of the important factor in order to ancillary students’ learning achievement in the subjects of physics, including hydrostatic pressure. Therefore, this study was conducted to identify students’ scientific creative thinking and scientific critical thinking skills profile through developing a diagnostic instrument test named Scientific Creative and Critical Thinking (SCCT) test in the open-ended questions form. The instrument SCCT-test consist of two scientific creative thinking test and three scientific critical thinking test related to hydrostatic pressure had been developed based on Scientific Structure Creativity Model (SSCM) and Assessment of Critical Thinking Ability (ACTA). In this paper, the instrument SCCT-test had been reconstructed three times on each times 10 eleventh grade students’ responses and model answers that constructed based on rubrics at SSCM and ACTA. The last constructed SCCT-Test have made students reveal their ideas and their critical reasoning related to the problems. From this result, we can consider SCCT-Test can be used to diagnose students scientific creative thinking and scientific critical thinking simultaneously related to hydrostatic pressure.

1. Introduction
The development of media and digital technology is growing rapidly. Students must have various ideas with logical thinking to solve problems in their daily life. Therefore two of he demands of the 21st century are the creative thinking skills and critical thinking [1]. Both skills are needed to solve problems that relate to students’ understanding and application of law of nature. Physics is one nature foundation in so many technology and application in life. According to observation which is done by Ika in 2017 on Indonesian students’ understanding of heat topic is still dominated by the definition written in the textbook [2]. Students only recall of what they have read when they solve a problem [2]. Whereas, the problem they face need a deep analyze and need activate scientific creative thinking skills and scientific critical thinking skills. Scientific Creativity and critical thinking is needed when student have to solve science problems in their learning process in class such as some learning design developed [3]. For learning, we can design a transformation from complexity of physics language to Middle school physics language and from an expensive and complex science investigation to a local material and simply hands activities [4].

Torrance (1990) said that creative thinking skills by using mental operations, such as fluency, flexibility, originality and disclosure of ideas to produce something original, new and valuable [5]. Hu (2002) explains that scientific creative thinking is part of scientific creativity that can be developed
and obtained through the learning process so that students are able to create new understanding, explore problems and imagine solutions that can be done to solve problems. Hu (2002) measure scientific creative thinking skills using test instruments with a combination of aspects based on the Scientific Structure Creativity Model (SSCM). Fasione (1990) explains critical thinking has been defined by experts in the field as purposeful, self-regulatory judgment that results in interpretation, analysis, evaluation, and inference as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. White (2011) said that critical scientific thinking skills are needed to develop an educated society which involves knowledge in terms of the ways in which thinking is used. To measure scientific critical thinking skills using ACTA (Assessment of Critical Thinking Ability).

In recently studies scientific creative and critical thinking skill has been considered as one of students achievement in physics subject. Based on previous research, the instrument to asses of creative thinking and critical thinking was done separately. But, when students study physics especially in problem based learning both skills can be increased simultaneously. Therefore, an alternative test to measure creative and critically thinking simultantly is needed.

Based of previous research, P Sinaga and S Feranie (2017) has implemented writing task strategy to enhance creative and critical thinking of third year physics students in modern physics course. So, this study, we reconstructed the instrument that simultantly measure creative and critical thinking simultantly related to hydrostatic pressure based on eleventh grade students responses in essay writing task. Response student is very important to plan learning reconstructions. Karim (2016) has implemented the learning reconstructions of particle system as well as linear momentum and provides positive impacts in achieving the physics conceptual understanding.

2. Method
This research tries to reconstructed the instruments of scientific creative thinking and scientific critical thinking skills. This research used mix method. Based on the design, procedure to reconstructed test instrument in this research was expressed by this chart below.

![Figure 1. Procedure to construct test instrument](image-url)
The design procedures in performing the instrument reconstruction test of creative thinking thinking skills and scientific critical thinking are made differently. The test was tested three times to 30 different students. The first test was tested on 10 students. Results of student answers are then analyzed and reconstructed for tested to 10 different students. Results of student answers are then analyzed and reconstructed for tested in 10 different students. Model answers that constructed based on rubrics at SSCM and ACTA.

3. Results and Discussions

The research was done to know skill scientific creative thinking and scientific critical thinking skills students after the reconstruction of the problem. First reconstruction there are four items about scientific creative question and three items about scientific critical question. On scientific creative items using a combination of aspects (thinking, fluency, science knowledge), (thinking, flexibility, science problem), (thinking, originality, technical product), dan (thinking, fluency, science phenomena) based on Scientific Structure Creativity Model SSCM) while scientific critical items used critical thinking ability 1, critical thinking ability 2, critical thinking ability 3 based on ACTA (Assessment of Critical Thinking Ability) with rules of essay making in the journal Developing Quality Essay Question (2000) [12]. Second reconstruction and the third reconstruction occurs the reduction of the problem into two items about scientific creative question and three items about scientific critical question. This Research is focused only to analyze one item about scientific creative using the combination of aspects (thinking, fluency, science knowledge) and one item about the critical scientific aspects of critical thinking ability 1 given simultaneously to the students. As an example of reconstructed test instruments scientific creative thinking and scientific critical thinking are presented as follows.

Item 1
Please make some dam wall designs that can withstand water pressure to prevent the dam from breaking down as in the previous picture! Explain the reason of the design you created!

Note for item 1 in the first reconstruction, the student's task is to express ideas in using an objects for a scientific purposes. Based on the Scientific Structure Creativity Model (SSCM) this covers science knowledge (in the product dimension), fluency (in the trait dimension) and thinking (in the process dimension), so three out of the 24 cells.

| Problem (a) | Scientific Creative Aspects | Students Responses |
|-------------|-----------------------------|--------------------|
|             | Thinking, Fluency,Science Knowledge |                     |

one of the students' responses which get scores three with making one design connected by a scientific reason

Figure 2. Students Responses
Above is sample student responses. We analyze all 10 students responses based on Hu rubric (2002) and the result in Table 1.

Table 1. Total Responses Scientific Creative

| Score Based on Rubric | Total Responses |
|-----------------------|-----------------|
| 1                     | 1 students      |
| 2                     | 8 students      |
| 3                     | 1 students      |

Analysis of student responses showed that only one student was able to make a design associated with the concept of hydrostatic pressure and density. One other student made only one design that was not related to the concept of hydrostatic pressure and the other eight students created a dam design connected to one of the concepts of hydrostatic pressure or density. Based on these analyzes, students have been able to make scientific reasons about the designs created but have not been able to draw the design as much as possible. Based on the rule of essay questioning found in the journal Developing Quality Essay Question (2000) in point 2 states "Related the questions as directly as possible to the learning outcomes being measured. One practical solution is to indicate the criteria (the rubric) to be used in evaluating the answer"[12] Therefore, the first reconstruction is done so that students are motivated to answer the questions by making the design as much as possible with scientific reasons.

**Item 2**

If you are required to make a embankments that is able to hold water. Try designing as many of these embankments! Approximately what factors will you consider when designing the embankment!

After analyzing the student response response, the second reconstruction was done. The purpose of this second reconstruction so that students express more ideas than in the first reconstruction with the Developing Quality Essay Question (2000) based journal in point 2. In the reconstruction of this issue, it combines more elements in the Scientific Structure Creativity Model SSCM includes science knowledge, technical product and science phenomena (in the product dimension), fluency and originality (in the trait dimension) and thinking (in the process dimension).

**Problem (a)**

**Scientific Creative Aspects:** Thinking, Fluency, Originality, Science Knowledge, Technical Product, Science Phenomena

**Students Responses:**

![Image of students' responses](image)

one of the students' responses which get scores four with making two different design connected by a scientific reason

**Figure 3. Students Responses**
Above is sample student responses. We analyze all 10 students responses based on Hu rubric (2002) as follows [3]:

| Score Based on Rubric | Total Responses |
|-----------------------|-----------------|
| 1                     | 1 student       |
| 2                     | 5 students      |
| 3                     | 3 students      |
| 4                     | 1 student       |

After the second reconstruction, an increase in student responses. One student is able to make one design without scientific reasons. Eight students are able to make one design with reasons connected to one of the concepts of hydrostatic pressure or density of the type to obtain scores of two. Three students were able to create two different designs that were connected to one of the concepts of hydrostatic pressure or density to obtain scores of three. Not limited to the scores of three, is one student who is able to create three designs with reasons that are connected to the concept of hydrostatic pressure and the density to get scores of four. The second reconstruction, there are still students who only make the design without scientific reasons. Therefore, a second reconstruction is done by making an essay question in accordance with the rules of essay questioning in the Developing Quality Essay Question (2000) journal on points 3 and 4 of the "Formulate question that present a clear task to be performed. Complex achievement is most apt to be called forth by such words as "describe" and "explain" and "provide ample time for answering and suggest a time limit on each question" [12]

**Item 1**

If you are required to make a dike that can hold water. *Try to make as many images of the embankment design as you know and think!* Approximately what factors will you consider when designing the embankment! Describe every image you create!

In the third reconstruction, item 1 changes according to the rules of the Quality Essay Question (2000) journal on points 3 and 4 by adding the affirmation and giving a longer time to answer the item. On this item, students are required to improve the technical product that is key to the creativity component.

**Problem (a)**

**Scientific Creative Aspects** : Thinking, Fluency, Originality, Science Knowledge, Technical Product, Science Phenomena

**Students Responses** :

![Figure 4. Students Responses](image-url)
Above is sample of student responses. We analyze all 10 students responses based on Hu rubric (2002) as follows:

| Score Based on Rubric | Total Responses |
|-----------------------|-----------------|
| 2                     | 1 students      |
| 3                     | 2 students      |
| 4                     | 4 students      |
| 5                     | 1 students      |
| 7                     | 1 students      |
| 12                    | 1 students      |

In the second reconstruction, students are able to design as much as possible. One student was able to make nine different designs along with the reasons associated with the concept of hydrostatic pressure and mass density. The other nine students were able to make one design up to four different designs accompanied by the reasons associated with the concept of hydrostatic pressure and the density of the species to obtain varied scores. There was one student who scores two, two students get scores three, four students get scores four, the students get scores five and one student scores seven.

**Problem (e)**

**Scientific Critical Aspects**: *Critical Thinking Ability 1*

**Question**: Suppose there are two construction of the dam is a dam created italics and bold at the bottom as shown in figure (a) and the dams built flat with deeper foundations as in figure (b).

What do you think? Which dam construction is able to withstand the hydrostatic pressure of a liquid? **Explain the reason for your choice!**
Above is sample of question and student responses. We analyze all ten students responses based on ACTA rubric (2011) as follows:

| Tabel 4. Total Responses Scientific Critical Score Based on Rubric | Total Responses |
|---|---|
| 1 | 2 students |
| 2 | 8 students |

Analysis of student responses shows that students have not been able to consider and explains the reasons for choosing a design. Therefore, reconstructed the problem by making a detailed problem with the scientific data follows the rules of making essay problems in the journal Developing Quality Essay Question (2000) that is "Relate the questions as directly as possible to the learning outcomes being measured"[12]

**Problem (e)**

**Scientific Critical Aspects**: Critical Thinking Ability 1

**Question**:
There are two embankment makers. Each embankment maker built the embankment construction as follows:

| Arah arus air | Arah arus air |
|---|---|
| (a) | (b) |

The construction of embankment (a) is made thin and the embankment construction (b) is made thick. **What do you think about the two constructions? What are the weaknesses and strengths of both constructs to hold water?**

**Figure 7. Second Reconstruction Scientific Critical Question**

**Students Responses**:

One of students responses get scores three because can explain the advantages and disadvantages of design but not choose the best design

**Figure 8. Students Responses**
Above is sample of question and student responses. We analyze all ten students responses based on ACTA rubric (2011) in table 5.

| Table 5. Total Responses Scientific Critical | Score Based on Rubric | Total Responses |
|---------------------------------------------|-----------------------|-----------------|
|                                             | 3                     | 7 students      |
|                                             | 4                     | 3 students      |

Based on the analysis of student responses on the second reconstruction. Students are able to explain the advantages and disadvantages of each design. But have not been able to choose which design is most appropriate. There were seven students get scores three for being able to give an opinion by mentioning the advantages and disadvantages of each dam design (a) and (b) but could not make a conclusion and choose which design would be best. There are three students get scores four because they are able to give an opinion by mentioning the advantages and disadvantages of each dam design (a) and (b) and can make a conclusion and choose which design is best. But some students not able to get scores four. Therefore, a second reconstruction is done so that students' answers can reach the measured aspects of critical thinking that is integrating conflicting knowledge into an integrated conclusion.

**Problem (e)**

**Scientific Critical Aspects**: Critical Thinking Ability 1

**Question**

There are two embankment makers. Each embankment maker built the embankment construction as follows:

(a)                               (b)

The construction of embankment (a) is made thin and the embankment construction (b) is made thick. **What are the weaknesses and strengths of the embankment construction (a) as well as the construction of the embankment (b)? Which construction do you think is strongest to hold water? Explain why you chose the construction!**

**Figure 9. Third Reconstruction Scientific Critical Question**

**Problem (e)**

**Scientific Critical Aspects**: Critical Thinking Ability 1

**Students Responses**

One of students responses get maximum scores four because can explain the advantages and disadvantages of design

**Figure 10. Students Response**
Above is sample student responses. We analyze all ten students responses based on ACTA rubric (2011) as follows:

| Tabel 6. Total Responses Scientific Critical Score Based on Rubric | Total Responses |
|---------------------------------------------------------------|-----------------|
| 3                                                             | 5 students      |
| 4                                                             | 5 students      |

On the third reconstruction. An increase in the total of students to get scores four based on the ACTA section. There were five students get scores four and five other students scores three.

4. Conclusion
Based on the above research, found a change in the pattern of student answers on the reconstruction of questions based on developing essay question principles. This proves the reconstruction of questions can improve the creative thinking of scientific and critical thinking of the students.

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