Case study: analysis of senior high school students scientific creative, critical thinking and its correlation with their scientific reasoning skills on the sound concept

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Abstract. This research aims to analyze the correlation between students scientific creative and critical thinking to their scientific reasoning skill related to sound concept. The participant of this research were 42 students from eleventh-grade of science in one of the Private School in Bandung. In this research we use one package scientific creative-critical thinking to solve sound problem and in term of open ended question and scientific reasoning skills instrument in term of multiple choice question related to sound concept. The result of this research showed that the students average score of scientific creative and critical thinking respectively is 23.67 and 17.36 from maximum score 64 and 48. Both of them are in low category achievement. And for average score of scientific reasoning skills is 36.70 from maximum score 100 and it’s in low category achievement. Meanwhile, for the correlation between scientific creative-critical thinking skills and scientific reasoning skills respectively are 0.57.

1. Introduction
The 21st century educational paradigm is increasingly aimed at providing a high level of cognitive ability to analyze, evaluate and synthesize [1]. The education sector is changing where learning not only focuses on knowledge but the integration among knowledge, application and its contribution. The 21st century skills are needed for students to grow in the future. Students are required to have the ability to apply knowledge that have been learnt to face the challenges of life outside school. Students are trained to solve problems by thinking critically and creatively in generating original ideas from various sources. Creative and critical thinking are both essential for students in all aspects of educational studies [2].

Scientific creativity is a type of intellectual nature or ability to produce or potentially produce a certain product that is original and has a social value or personal value, designed with a specific purpose of thinking using existing information. Creative thinking requires scientific knowledge and techniques in solving problems in order to create a new understanding and solution made based on a combination of knowledge and techniques [3].
At the same time, critical thinking skills are needed to develop an educated society which involves knowledge in terms of the ways in which thinking is used. In the ACTA (Assessment of Critical Thinking Ability) there are three critical thinking skills considered as important for an evaluation, that are Critical Thinking Ability 1: integrating conflicting studies into a unified conclusion; Critical Thinking Ability 2: designing experiments to resolve ambiguities in particular studies; and Critical Thinking Ability 3: conjecturing other interpretations of particular studies [4].

National education aims to create qualified human beings, who are able to think critically, creatively, logically, solve problems, and follow the development of science and technology. The curriculum is designed to realize the national goals and expects students to be able to process, reason, and conceptualize in concrete and abstract realms in solving problems. Reasoning in Physics is not only for success in learning, but also to shape the mindset, attitude and behavior of students as part of society. Then the mindset can be implemented in the learning activities including assessment activities which are the main activity of learning [5].

The way to teach science in Indonesia is not properly taught because most teacher are still positioning the student as fact’s observer rather than considering the learning process. In this case, that condition is called pseudo-science which generally emphasizes on matching than testing and reasoning.

Scientific reasoning is a process in which the logic of thought is applied to the process of science, seeking explanations, designing hypotheses, making predictions, solving problems, producing experiments, controlling variables, analyzing data, developing empirical laws through the development of meaning [6][7]. Scientific reasoning is a special domain and depends on content of knowledge and concept of science, the subject of procedural knowledge of standard methods and the epistemic knowledge of how the procedure guarantees the findings of previous scientists [1].

It is important to teach scientific reasoning skills in improving students’ educational outcomes on higher order thinking skills in this 21st century. Moreover, scientific creative skills and critical thinking skills are included in high-level thinking skills that can be trained through Physics learning in the classroom.

Based on these problems, a case study was conducted to investigate scientific creative skills and critical thinking skills of high school students on the Sound concept and to see its correlation with scientific reasoning of high school students. The concept of sound is chosen since it is closely found in everybody life and it is related to many disciplines. Thus, this research is the first step to see and provide follow-up solutions to the improvement of physics learning in the classroom. This article discusses the general profile of scientific reasoning, creative science and critical thinking of high school students.

2. Method
The method used in this study is a collective or multiple case study. It is a case study that uses many issues or cases in one study [8]. The study used only at one location but with many issues studied. The researcher then generalizes on each case and compares it at the end of the study. The research design used is holistic single-case study with multiple-case design. It is defined as a research that puts some cases as the focus of the research. The consideration of the selection of this study is because the case study design variables in this study more than one, namely scientific reasoning skills, scientific creative skills and critical thinking skills.

The research was conducted at Private Senior High School of Santa Angela Bandung in 2nd Semester of School Year 2017/2018 with the subject of research as many as 42 students of XI-MIA class with random student selection. In this research, the researcher employed one package scientific creative-critical thinking to solve sound problem and in term of open ended question and scientific reasoning skills instrument in term of multiple choice question related to sound concept. The aspects of scientific reasoning skills measured consists of twelve indicators with five categories (rudimentary, basic, intermediate, integrated, culminating). Meanwhile, each case consists of three aspects of scientific creative skills (fluency, flexibility, originality) and three critical thinking aspects (critical thinking ability 1, critical thinking ability 2, critical thinking ability 3).
The students' scientific reasoning skills are measured using an instrument of scientific reasoning based on Hanson framework [7] in which the framework has been developed by researcher and validated by 4 expert lecturers. The scientific creative skills are measured by Hu framework [3]; while the critical thinking skills are measured by ACTA framework [4]. Distribution of scientific reasoning skills test can be seen in Table 1 and for scientific creative-critical thinking can be seen in Table 2.

**Table 1. Distribution problem Scientific Reasoning Skills (SRS) test.**

| Category  | Aspect SRS                  | Question Number |
|-----------|-----------------------------|-----------------|
| Rudimentary | Concluding                  | 1               |
|           | Contextualizing             | 2, 3            |
| Basic     | Estimating                  | 4, 5            |
|           | Predicting                  | 6, 7            |
|           | Applying information        | 8, 9            |
| Intermediate | Describing relationship    | 10, 11          |
|           | Making simple sense of quantitative data | 12, 13          |
|           | Using combinatorial thinking | 14              |
| Integrated | Interpreting quantifiable data to establish laws using logic | 15              |
| Culminating | Determining if an answer to a problem or question is reasonable including size and/or units | 16              |
|           | Using data and math in the solution of real-world problems | 17, 18          |
|           | Using proportional reasoning to make decisions | 19, 20          |

**Table 2. Distribution problem SCS and CTS test.**

| Type Skills         | Aspects                          | Question Number |
|---------------------|----------------------------------|-----------------|
| Scientific Creativity Skills (SCS) | Fluency, Technical Product, Thinking | 1a, 2a, 3a, 4a  |
|                     | Flexibility, Science Knowledge, Thinking | 1b, 2b, 3b, 4b  |
|                     | Originality, Technical Product, Imagination | 1c, 2c, 3c, 4c  |
|                     | Fluency, Science Knowledge, Thinking | 1d, 2d, 3d, 4d  |
| Critical Thinking Skills (CTS) | Critical Thinking Ability 1 | 1e, 2e, 3e, 4e  |
|                     | Critical Thinking Ability 2 | 1f, 2f, 3f, 4f  |
|                     | Critical Thinking Ability 3 | 1g, 2g, 3g, 4g  |

3. Result and discussion

3.1. Scientific creative skills and critical thinking skills

Analysis of students' scientific creative skills (SCS) and critical thinking skills (CTS) in general can be seen in Table 3. Based on Table 3, it can be seen that scientific creative and critical thinking on the sound concept are still categorized as low achievement. In the first and second cases on the instrument of SCS and CTS were tested to students to design the best soundproofing products used to reduce noise critically and creatively. While the third and fourth cases, students were asked to design a simple musical instrument that utilizes the strings and air column principles. The low results of the test is caused by student's learning experience which has not yet facilitated to solve the real-world problems that related to Physics subject. Students are more familiar with the problem of applying the concept that solved mathematically.

Most students have not been able to propose ideas based on data and have not been able to design experiments that involve the concept of physics. Students also do not provide answers that are associated
with scientific data. The ability to think critically and creatively can be explored through direct experience, how students facing the real-world problems, finding alternative solutions, considering various factors, and testing the results through experiments.

### Table 3. Percentage of SCS and CTS.

| Score       | SCS  | CTS  |
|-------------|------|------|
| Ideal       | 64   | 48   |
| Maximum     | 32   | 23   |
| Minimum     | 10   | 6    |
| Average     | 23.27| 17.36|
| Percentage  | 36.35%| 36.17%|

#### 3.2. Scientific reasoning skills

Analysis of students scientific reasoning skills (SRS) in generally can be seen in Table 4. Based on Table 4, it can be seen that the result of scientific reasoning skills on the sound concept generally are still categorized as low achievement. This low result may be due to the fact that the teacher has not yet established the student's reasoning skills. The evaluation used in the lesson is still on the low-level cognitive process, so the students are still based on the formula used for problem-solving.

### Table 4. Score of scientific reasoning skills test.

| Score       | SRS  |
|-------------|------|
| Ideal       | 100  |
| Maximum     | 75   |
| Minimum     | 10   |
| Average     | 36.70|

The instrument that used in analyzing scientific reasoning skills are based on students’ experience in daily life. Since it can also show the students’ ability to solve Physics context. Thus, it requires practice to be able to have a habit of solving real-world problems. However, at the present time, the teachers barely established the test which has the point of high level reasoning.

### Table 5. Percentage of scientific reasoning skills each category.

| Category of SRS | Question Number | The number of students who answered correctly | Percentage |
|-----------------|-----------------|---------------------------------------------|------------|
| Rudimentary     | 1, 2, 3         | 14                                          | 34.12%     |
| Basic           | 4, 5, 6, 7, 8, 9| 14                                          | 34.12%     |
| Intermediate    | 10, 11, 12, 13, 14| 16                                        | 39.05%     |
| Integrated      | 15              | 21                                          | 50.00%     |
| Culminating     | 16, 17, 18, 19, 20| 13                                         | 32.38%     |
| Average percentage |                |                                             | 36.71%     |

Data analysis of student's scientific reasoning abilities of each category is presented in Table 5. Based on Table 5, it is obtained that students scientific reasoning skills on each category are still categorized as low achievement. The highest gain in category is integrated and the lowest category is culminating. As proposed by Wenning dan Vierya that Scientific reasoning is the process by which the principles of logic are applied to scientific processes-the pursuit of explanation, the making of prediction, the solution of problems, the creation of experiments, the control of variables, the analysis of data, the development
of empirical laws-all in logical manner-with the intent of developing meaning [7]. This varied gain can be due to the inequality of the number of questions in each of the categories tested.

3.3. Correlation scientific creative-critical thinking with scientific reasoning skills
This research using product moment correlation (Pearson) to find out the relationship of two variables (scientific creative-critical thinking and scientific reasoning) because the data in the form of interval or ratio. Based on the calculation of product moment correlation obtained correlation coefficient value of $r_{xy} = 0.57$ with a moderate level of relationship that indicates a positive correlation between scientific creativity-critical thinking with scientific reasoning skills. This shows that the variable of students' scientific reasoning skills contributes to the creative-critical thinking skill variable in the amount of 57%, and the rest is influenced by other factors.

Various learning strategies can be combined in problem or project based learning such as literacy strategy [9], various in non-traditional writing task which include writing types, authentic audiences, text production and content [11], conceptual change text [10], text based analogy [12], etc.

4. Conclusion
Based on the results of case studies that have been done, it can be concluded that students ability of scientific creative and critical thinking on sound concept is still in the low achievement as well as scientific reasoning skills. The findings also show a positive correlation between Scientific Creative-Critical Thinking and Scientific Reasoning Skills. So it is necessary to facilitated the students to achieve those three important skills (SRS, SCS and CTS) especially in Physics’ context.

Acknowledgments
The authors would like to thank the instrument validator, Mr. Rusli, Mr. Ahmad Samsudin, Mr. Ridwan Efendi, Mr. Dadi Rusdiana thank you so much for your willingness to make a judgement instruments. Gratuities also the authors convey to the principal SMA Santa Angela Bandung as well as physics teacher Mr. Eko, Mrs. Endah and all students involved in this research.

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