The influence of scientific creativity and critical worksheets (SCCW) on creative thinking skills and critical scientific as well as students’ cognitive abilities on project-based learning work and energy concepts

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Abstract. This study describes the influence of scientific creativity and critical worksheet (SCCW) to the creative thinking and scientific critical as well as students' cognitive ability of Work and Energy concept. The aim of this study was to find out the improvement of cognitive ability, creative thinking skill and critically scientific students with applied model of project-based learning integrated with SCCW and conventional student worksheet (CSW). This study is based on one of the 21st Century Partnership Learning Framework which contains the skills that must be possessed by learners in the 21st century, which is focused on scientific creative thinking skills and critical scientific thinking skills. The research method used is pre-experimental research with randomized control group pretest-postest design. Implementation of SCCW on project-based learning can improve creative thinking skills and critical scientific and cognitive abilities of students with greater improvement than the application of SCW on project-based learning.

1. Introduction
Based on the 21st century partnership framework, there have been three skills that must be possessed in the 21st century, such as (1) life and career skills, (2) learning and innovation skills, (3) information, media and technology skills [1]. This study is focused on the second point about learning and innovation skills. The learning that fits with 21st century was a 4C learning that was critical thinking, collaboration, communication and creativity [2]. This 21st century skill should be able to be implemented in our education system.

Based on the Indonesian 2013 curriculum revision it was said that learning process should be oriented to students rather than teachers. It is implied that the role of the student was more dominant in the learning activities and the teacher was only a facilitator [3]. Permendikbud No. 56 of 2013 “process standards” mentioned that the learning process in the educational unit held interactively, inspirational, fun, challenging, motivate learners to participate actively, and provide sufficient space for initiative, creativity, and independence in accordance with the talents, interests and development physical and psychological learners [4]. The meaning of participate actively is using the senses such as assembling tools in practicum activity while active in thinking determined based on creative thinking skill and critical thinking skill [5]. Since 21st century skills must be compatible to the demands of the revision of
the 2013 curriculum appraisal, an assessment of cognitive ability in addition to scientific and scientifically creative thinking judgments can be assessed. Cognitive abilities were measured through instruments based on Bloom's revised taxonomy. There were 4 cognitive levels used in this instrument that is C1 (remember), C2 (understand), C3 (apply) and C4 (Analyze) [6], the cognitive level based on Indonesian 2013 Curriculum basic competence 3.9 Analyse the concepts of energy, effort (work), business relations (work) and energy changes, energy conservation laws, and its application in everyday events.

Creative thinking skills are the cognitive skills to come up with and develop new ideas, new ideas as the development of previously born ideas and the skills to solve problems diverging [7]. Creativity has a specific domain component so there is a need to distinguish the scientific creativity from creativity in general. Scientific creativity is a type of creativity that is intellectual or produces a product that is original and has social value or personal value and is designed with a particular idea using existing information [8]. Creative thinking skills require knowledge and techniques to solve a problem in order to create a new understanding and solution to the problem based on the knowledge and techniques that have been previously owned [9]. The creative thinking skills are limited by a combination of aspects that combine process (imagination, thinking), trait (fluency, flexibility, originality) and product (technical product, science knowledge, science phenomena, science problem) according to Scientific Structure Creativity Model (SSCM). White states that critical thinking skills are needed in order to develop an educated society in which that ability involves knowledge that is based on the ways in which thinking is used. Critical thinking skills are not indispensable in Physics learning. Therefore, in learning ideally students can think critically so that students can process their own any received information. White, et al developed an instrument to measure critical thinking skills. This instrument is called Assessment of Critical Thinking Ability (ACTA). This instrument evaluates three students' thinking skills using essay-shaped questions. ACTA assesses three essential critical thinking skills considered critical for an evaluation of Critical thinking ability 1 (CTA-1): the ability to integrate conflicting knowledge into an integrated conclusion, Critical thinking ability 2 (CTA-2): the ability to design an experiment to answer any doubt in certain knowledge, Critical thinking ability 3 (CTA-3): is the ability to estimate other interpretations of a particular knowledge [10].

Based on the description of the creative and scientific critical thinking skills, one of the models of learning that can drill 21st century skills are Project-Based Learning (PjBL), because in this learning model, teachers can apply various learning strategies so that 4C skills can be trained and learning objectives achieved [11]. Project Based Learning is a learning model that uses the project as the core of learning [12]. This learning model is also an innovative learning model that emphasizes contextual learning through complex activities, there are five criteria of learning can be categorized as project-based learning such as (1) the project are central, not peripheral to the curriculum, (2) Project based learning are focused on question or problem that “drive” student to encounter (and struggle with) the central concepts and principles of a discipline, (3) Project involve students in a constructive investigation, (4) Project are student-driven to some significant degree, (5) Project are realistic, not school-like [13]. The project-based learning phase was developed by two experts The George Lucas Education and Dopplet consists of 5 phases that were start with essential question, design project, create schedule, monitoring progress of project and evaluation [4].

2. Methods
The research method used in this research was pre-experimental research with quantitative approach. According to Arikunto, Experimental study is a study which aimed to know there is or not the effect of the variable studied [14]. A quantitative approach is one of the investigations which primarily uses postpositive claim for developing knowledge (i.e., cause and effect thinking, reduction to specific variables and hypotheses and question, use of measurement and observation, and the test of theories) employs strategies of inquiry such as experiment and survey and collect data on predetermined instrument that yield statistics data [15]. The research design used was randomized control group pre-test-post-test design. In this study a number of subjects taken from a certain population grouping into
two classes, namely experimental class and control class. The experimental class is subjected to a certain treatment within a certain time to use SCCW in project-based learning and control group only use scientific conventional worksheet (SCW) in the same learning model, then the two classes are subjected to the same measurement, the difference being considered as the result from the treatment [16]. Subject for this research are 65 student second grade senior high school in Cimahi city, 65 students divided two group there are 35 students in experiment group and 30 students in control group. The research procedure used were (1) Preliminary study and literature review, (2) Formulate the problem, (3) Making instruments and learnings tools, (4) Expert judgement and instrument trials, (5) Instrument analysis and revision, (6) Pre-test, (7) Treatment, (8) Post-test, (9) Processing and analysis of data, (10) Conclusion.

3. Results and Discussion

3.1. Improved cognitive abilities

Figure 1 shows that the results of cognitive abilities. There are 20 items of cognitive tested that are two questions C1, eight questions C2, seven questions C3 and three questions C4. Maximum score is 20, with 1 for correct answer and 0 for wrong answer or no answer.

![Graph of cognitive ability improvement at every level from C1 to C4 for control group and experimental group.](image)

Figure 1. Graph of cognitive ability improvement at every level from C1 to C4 for control group and experimental group.

Table above is showing n-gain values. In control group the most significant improvement amongst the four cognitive levels is at C-3 level. This happened because the level of C-3 which means applying knowledge to the context or the new problem is strongly influenced by the project-based learning model, where in this learning model learners are required to be able to apply the knowledge, they have into the project to be made in order to solve a problem [17]. As a whole, the cognitive ability of the control class increases, this result was in line with Yance's research on "implementation of project-based learning in
improving student's learning achievement" in which the achievement is student's cognitive ability [18]. For the experimental group, the n-gain value was greater than the control group's n-gain. Based on these results can be concluded that SCW affects the overall cognitive abilities of students. Although the main focus of SCCW is to improve students 'creative and critical thinking skills but indirectly can improve students' cognitive abilities. This is because based on the scientific structure creativity model (SCCM) said that there are two involved processes of thinking and imagination. Both processes are related to cognitive processes [19]. The results are in line with previous research conducted by Wibowo which states that project-based learning integrated with SCL (Scientific Creative Learning) can improve the cognitive abilities of middle-class students [20].

Different test performed because the n-gain of the two classes is categorized into the same category of moderate [21]. Then a different test was done to see the significance of skill enhancement between the two groups. After the Kolmogorov-Smirnov normality test and variance test (homogeneity test) the data are stated normal and homogeneous distributed then t-test to see the difference between experimental class and control class [22], the result is shown at table 3:

Table 2. Recapitulation of cognitive ability T-test.

| Group       | N   | Dk  | T_count | t_table (α=0.95) |
|-------------|-----|-----|---------|-----------------|
| Experimental| 35  | 63  | 2,996   | 1,669           |
| Control     | 30  |     |         |                 |

Based on the above results, t_count > t_table which means the null hypothesis (no difference between the two groups) is rejected. This means that there was a significant difference in the improvement of cognitive ability between the two classes. Therefore, the use of SCCW on project-based learning is more effective than the use of SCW in project-based learning in improving students' cognitive ability. It is caused by SCCW’s question which is more associated with connecting between concepts that students had learned. In SCCW, students were required to understand the concept through the project’s aim as they asked to fully comprehend every step they’d been doing in Project-Based Learning processes.

3.2. Improved Scientific Creative Thinking Ability

there are three aspects of scientific creative thinking skills tested namely fluency, flexibility and originality. Fluency related technical product (maximum score 3 for each point) is translated into question 1a and 2a with indicator to make design variation of project to be made. While the fluency related science knowledge is described on the matter of no 1d and 2d with indicators linking the design made with work and energy concept. Aspects of flexibility (maximum score 2) related to science knowledge are described in Problems 1b and 2b, with an indicator about proposing ideas freely. and the last is the aspect of originality (maximum score 2) related to technical product spelled out in Problems 1c and 2c with indicators of choosing a new and unique design [9]. Graph of improving the creative thinking skill of each aspect is presented in Figure 2 below.

Figure 2. Graph of scientific creative thinking ability improvement each aspect for control group and experimental group
Figure 2 shows the average score of scientific creative thinking skills of every aspect for both groups. Based on the graph above, it is seen that the improvement of every aspect of experiment group creativity is greater than the control group. This was happened because SCCW which train creative thinking skills is only used in experimental groups. Here is shown the increase in scientific creativity (average n-gain) of students in table 2:

| Creative Aspect | N-Gain Control | N-Gain Experimental |
|-----------------|----------------|---------------------|
| Fluency         | 0.39           | 0.48                |
| Flexibility     | 0.54           | 0.79                |
| Originality     | 0.46           | 0.58                |
| Average         | 0.43           | 0.53                |

The average gain of the two classes were categorized as showed in table above. The result is due to restrictions on the tools and materials used. Basically, creative thinking is to think freely but when the treatment has been done there are some obstacles one of them permission from the school. When the treatment has been done, researchers prepare tools and materials that can be used students. Although at previous meetings researchers have encouraged students to bring in used equipment or materials that would be useful for project creation. However, students experience confusion because no samples of the project at all will be made so that the tools and materials that are brought student really improvise. Based on table 2 above, the results obtained in line with previous research conducted by Wibowo which states that project-based learning that is integrated with SCL (Scientific Creative Learning) can improve the creative thinking skills of students of medium category. PjBL is more effective when integrated with something that will support the improvement of the skill being measured [20]. The result of n gain in Table 2 is in line with Luthvitasari study on Implementation of Project-Based Physics Learning on Critical Thinking Skills, Creative Thinking and Generic Science Proficiency which concludes that students’ creative thinking skills have improved moderate after project-based learning [23].

Same with cognitive ability, different test performed because the n-gain of the two classes is categorized into the same category of moderate. Then a different test has been done to see the significance of skill enhancement between the two groups [22]. After the Kolmogorov-Smirnov normality test and variance test (homogeneity test) the data are classified as normal and homogeneous distributed then t-test to see the difference between experimental class and control class, the result is shown at table 3:

| Group       | N     | Dk   | T_count | t_table (α=0,95) |
|-------------|-------|------|---------|------------------|
| Experimental| 35    | 63   | 2.996   | 1.669            |
| Control     | 30    |      |         |                  |

Based on results above, T_count > t_table which means the null hypothesis (no difference between the two groups) is rejected [22]. This means that there is a difference in the improvement of scientific creative thinking ability between the two classes. therefore, the use of SCCW on project-based learning is more effective than the use of SCW in project-based learning in improving students' thinking skills.

3.3. Improved Scientific Critical Thinking Ability

Students' critical thinking skills improvement from applying a project-based learning model integrated with LK3I treatment in the experimental group and SCW in the control group can be determined using the n-gain averaging test. There were three critical thinking skills tested: critical thinking ability 1 (CTA-1), critical thinking ability 2 (CTA 2) and critical thinking ability 3 (CTA-3). CTA-1 is tested on Problem
1e and 2e, CTA-2 is tested on Problem 1f and 2f while CTA-3 is tested at 1g and 2g [10]. Here is a graph that states the average pre-test and post-test scores of the experimental and control groups:

![Graph showing average pre-test and post-test scores](image)

**Figure 3.** Graph of scientific critical thinking ability improvement each aspect for control group and experimental group

Based on the graph of the data, the improvement of critical thinking skills of the experimental class is greater than the control class. From the graph above, seen a very significant increase in the both classes. The increase occurred in three aspects, namely CTA-1, CTA-2 and CTA-3. This is because at the time of pre-test the students are very confused with the problem aspects of creative thinking skills because it involves taking data and experiments, considering the experiment activity are very rarely happened in school. If reviewed based on the categorization of n-gain, the increase in scientific critical ability is still in the level medium [21]. The significant increase shown in the graph above is due to Pre-test score of students' very low critical thinking skills. Although the average post-tests score is 3.5 but it should be remembered that the maximum value for each of the three critical scientific thinking skills is 8. So, if we categorize the average score obtained, the critical thinking skills of students are still classified as low result [10]. Best answer post-test students’ critical scientific thinking skills only up to level 3. None of the students whose level of critical scientific thinking ability to level 4.

| Creative Aspect | N-Gain Control | N-Gain Experimental |
|-----------------|----------------|---------------------|
| CTA-1           | 0.33           | 0.44                |
| CTA-2           | 0.35           | 0.41                |
| CTA-3           | 0.39           | 0.48                |
| Average         | 0.35           | 0.44                |

**Table 5.** N-Gain scientific critical thinking ability recapitulation

According to Table 3, the average n-gain categorization of Pretest-posttest of scientific critical thinking skills for both classes is in the medium category [21]. The overall gain of scientific critical thinking skills for the control class is 0.35 while the experimental class is 0.44. The results are in line with research conducted by Nur Oktavianti on the application of project-based learning model to the skills of scientific creative thinking and critical thinking skills of high school students in Bandung [24]. Different test performed because the n-gain of the two classes is categorized into the same category of moderate. Then a different test was done to see the significance of skill enhancement between the two groups. After the Kolmogorov-Smirnov normality test and Levene’s Test (homogeneity test) the data are stated not normal and homogeneous distributed then Mann-Whitney test to see the difference between experimental class and control class [25], the result is shown at table 3:
Table 6. Mann-Whitney’s Test Recapitulation.

| Group       | The number of students | Rank (R) | U   | Z    | Large of Z | P-value (1-Large of Z) |
|-------------|------------------------|----------|-----|------|------------|------------------------|
| Control     | 30                     | 732      | 783 | 3,085 | 0.999      | 0.001                  |
| Experimental| 35                     | 1413     | 267 |       | 0.999      |                        |

Based on the above results, $\alpha > P$-value which means the null hypothesis (no difference between the two groups) is rejected. This means that there is a difference in the improvement of critical thinking ability between the two classes. therefore, the use of SCCW on project-based learning is more effective than the use of SCW in project-based learning in improving students’ critical thinking ability. There is strong connection between the result and SCCW. Every SCCW question is purposed to train students’ brain sharpness step by step from CTA-1 up to CTA 3 according to variables and data they have obtained.

4. Conclusion
Once applied to a project-based learning model that is integrated with SCCW and SCW, creative and critical thinking skills as well as students’ cognitive abilities increase. Improved creative thinking skills and critical scientific and student cognitive abilities of larger groups applied by SCCW than those applied by SCW can be seen from the average of n-gain pre-test-post-test of both groups and different T test to see the level of difference. SCCW is influential in improving the creative thinking skill and scientific critical as well as students' cognitive ability, it can be seen from different T-test and Mann-Whitney test result post-test of experiment and control groups.

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