Prosiding 1 Exploration of student's creativity

by Tantri Mayasari

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Exploration Of Student's Creativity by Integrating STEM Knowledge Into Creative Products

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Abstract. Creativity is an important capability that should be held to competitive standards in the 21st century in entering the era of information and knowledge. It requires a creative generation that is able to innovate to meet the challenges of an increasingly complex future. This study examines the student's creativity level by integrating STEM (Science, Technology, Engineering, and Mathematics) knowledge to make creative products in renewable energy (solar energy). Total respondents in this study were 29 students who take applied science course. This research used qualitative and quantitative method (mixed methods), and used "4P" dimension of creativity to assess student's creativity level. The result showed a creative product is influenced by STEM knowledge that can support student's creativity while collaborating an application of knowledge, skills, and ability to solve daily problems associated with STEM.

INTRODUCTION

In the 21st century, science and technology were developing rapidly so it was also affecting the lives and the kind of work the public had at this time. Result of research [1] mentions that there has been a shift in the kind of job and the skills required in the 21st century, the needs of human resources to routine jobs declined from year to year because they were replaced by machines. On the contrary needs of expert thinking and complex communication increased. Figure 1 shows pyramid of future work where the highest form is creative work which requires intelligence and creativity to produce creative and innovative products [2]. Independence, flexibility, communication, and creativity are keywords describing their future job expectations [3, 4].

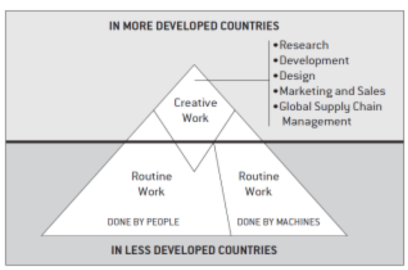

FIGURE 1. The Future of 21st Century Work.

Aware of this, Indonesia's education system seeks to prepare the next generation to have skills needed in the 21st century and developing creative education toward "Indonesian Creative 2045". However, examination of the system in Indonesia still emphasized problems related to memorizing knowledge [5] and most of the teachers utilize traditional lecturing as the major teaching strategy. Hence, the stimulation of students' creativity still could not be reached.

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The integration of science, technology, engineering, and mathematics (STEM) courses became new educational issues [6, 7]. Lecturers designed the STEM courses to enhance students' problem-solving, evaluation of the plans, and decision-making [8]. In addition, STEM learning encourages learners to practice in real world situations. In this way, learners can review and incorporate the comprehension and application of STEM in a way that was more meaningful.

The aims of this study were to explore the creativity of students through learning that integrated STEM knowledge. This research used project based learning to be aware of creative products that could be generated by learners. This study will answer three research questions, namely: 1) whether by integrating STEM knowledge in the project, the students became more creative?; 2) how was students' level of creativity effected based on four dimensions of creativity (4P)?; 3) what were the advantages and weaknesses of the learning activity that made creative products by integrating STEM knowledge?.

METHOD

Creativity does not happen by chance. Learning which aim to develop creativity must be designed carefully to maximize students' potential creativity [9]. This research involved 29 pre-service physics teachers whom were enrolled in an applied science course at one of the campuses in Madiun, Indonesia. The research was conducted over 15 lessons, each lasting 100 minutes with a design learning that consists of eight stages as outlined in figure 2.

FIGURE 2. Eight Stages of Learning

No	Stages
1	Identify problem and constraints
2	Exploration
3	Ideate
4	Analyze Ideas
5	Project design
6	Build
7	Test and refine
8	Present and reflect

Students were guided to recognize an energy crisis condition and opportunities to develop renewable energy in Indonesia, especially in Madiun city. Through this activity, learners played the role as a citizen who were responsible for contributing renewable energy (especially solar energy) and made creative products that work by using solar energy and integrated STEM knowledge. There were seven groups with different projects. The projects were chosen by learners based on the analysis of the daily problems which surround the neighborhood of learners. The seventh projects undertaken by learners include: solar rice dryer, solar water purification, solar air condition machines, energy efficient home, solar oven, solar clothes dryer cupboard, and solar light trap.

This research used both qualitative and quantitative method or usually called mixed methods [10]. Quantitative data were collected using a creativity test, concept test of renewable energy were obtained from a pre-test and a post-test, and assessment of creative products. While qualitative data were obtained through interviews, questionnaires about creative personality, students' response of learning questionnaires, and students' journals project work. All the instruments used in this research were reviewed by five experts, then calculated validity using Content Validity Ratio (CVR) [11]. The reliability of the instruments was first tested in a pilot study with 30 students.Various data collected subsequent triangulation of data to ascertain whether the data are mutually supportive or conflicting each other. The researchers conducted a quantitative analysis of a paired-sample t-test by SPSS 18 to examine the effectiveness of the integration STEM knowledge in the project against students' creativity.

RESULT AND DISCUSSION

The result of the research was divided into three parts. The first part to answer the research question "whether by integrating STEM knowledge in projects, students became more creative?". The second part presents the students' creativity level based on four dimensions of creativity (4P). The third part described the advantages and weaknesses of learning.

1. The impact of integration STEM knowledge in the project against students' creativity

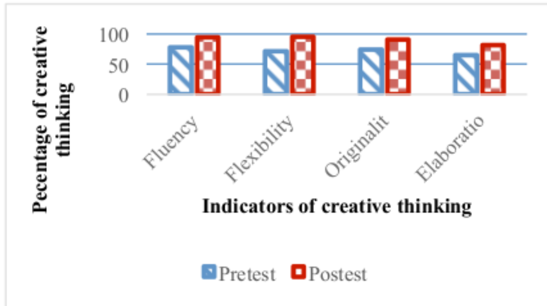
Creative thinking tests were done before and after learning (pre-test and post-test) to know whether by integrating STEM knowledge in the project will affect students' creativity. Students' creative thinking covering four indicators namely fluency, flexibility, originality, and elaboration [12, 13]. The results of students' creativity for each indicator were presented in table 1.

TABLE 1. The difference between the student pre-test and post-test creative thinking (n = 28, df = 27)

Subject	Pre-test/Pos-test	Paired Differences M (SD)	t
Fluency	Pair 1 Flu-pFlu	4.036 (2.874)	7.431***
Flexibility	Pair 2 Fle-pFle	4.500 (2.152)	11.067***
Originality	Pair 3 Ori-pOri	3.179 (2.525)	6.662***
Elaboration	Pair 4 Ela-pEla	2.714 (2.551)	5.630***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

(a)

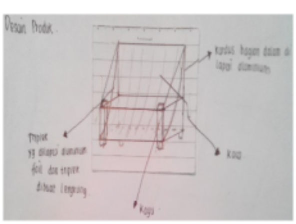


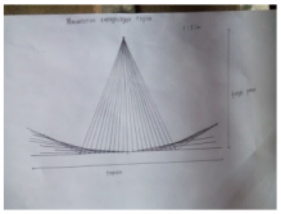
(b)

In table 1, the data of students' creative thinking skills generally showed an increase in creative thinking skills. The ability to think fluently (fluency) experienced an increase of 16,8%, the flexibility showed the largest increase of 22,9%, the originality increased by 16,7%, and elaboration increased by 15, 2%. From the above data, it can be noted that learning processes that integrate STEM knowledge can enhance students' creativity effectively. Students' creativity develops well at any stage of the study (figure 1). At the stage of identifying problems, exploration, and ideate, students' creativity at flexibility (t = 11.067, $p < 0.001$), and fluency (t = 7.431, $p < 0.001$) indicators were well developed. Students were able to identify energy problems and provide many and unique solutions. Furthermore, the learners made product designs to solve these problems.

Students learn to identify problems, provide alternative solutions, design products using STEM knowledge and creativity, and complete the project. At the beginning of the project, solar oven group revised their initial project after they analysed the design using their STEM knowledge. Furthermore, they worked in accordance with a design that has been made, and during the implementation of any project, they experienced a variety of problems that they had to solve using their creativity. They had been experiencing problems in choosing the materials and shaping materials as a substitute for a concave mirror in an oven to focus the rays in order to maximize heat on the pan. By utilizing the knowledge of science and mathematics, they then made a concave mirror which was made of cardboard and aluminium foil with a price that was much cheaper than buying a concave mirror in the market. The success of the oven solar group in completing the project was the result of a series of efforts and experiences based upon failure (table 2).

TABLE 2. Solar oven project process

Photo of Project Process		Description
 1. First design	 2. Design after integrated STEM knowledge	The students' initial design project changed after integrated STEM knowledge. **Science:** The design of solar oven was based on the principle of heat conversion from solar energy to thermal energy as well as the principles behind conduction of heat through materials. The students use plywood as material at first design, after they analyzed conductor and isolator, they realize that plywood was not able to prevent the escaping heat through the wall of the box. So, they change plywood to styrofoam.

 3. Mathematics and engineering analyzing to focused the rays	 4. Try to cook	**Technology:** Students used technology to calculate the design and gather important information from various sources. **Mathematics:** Students focuses light at a height of 9 cm (adjust the midpoint of the pan) and calculate the angle of curvature, in order to obtain the curve (table 2.3). With formula: $\boldsymbol{x^2 = 4Yf}$
 5. Finishing solar oven	 6. Presentation	**Engineering:** Students replace the function of a concave mirror (to focus the beam in the oven) with cardboard that has been cut in accordance with the curve $\boldsymbol{x^2 = 4Yf}$ then coated with aluminium foil so the light can be reflected.

Findings from this research indicated that students' creativity increased through the implementation of learning that integrated STEM knowledge in making creative products. Increased students' creativity was the result of open-ended activities to solve the problems related to energy, and the lesson included four pillars of educations, namely learning to know, learning to do, learning to be, and learning to live together [14].

2. Level of students' creativity

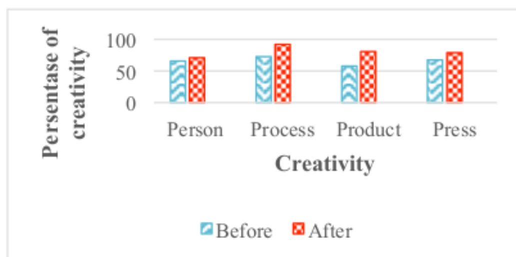
The creativity of the students viewed from the four elements that were commonly known as the "4P" i.e. Person, Process, Product, and Press [15, 16, 13]. The creative Person focus on individual characteristics as creator. Involving personality, motivation, intelligence, thinking styles, emotional intelligence, or knowledge [17]. The creative Process was assessed from the creative thinking process. The creative Product was an embodiment of the results of students' creative thinking. Environment (Press) greatly influenced the students' creativity.

TABLE 3. The difference of creativity between the student before and after integrated STEM knowledge (n = 28, df = 27)

Subject	Pre/Post	Paired Differences M (SD)	t
Person	Pair 1 Per – pPer	8.14 (7.25)	5.94***
Process	Pair 2 Pro – pPro	14.43 (7.60)	10.04***
Product	Pair 3 Prd – pPrd	18.11 (4.09)	23.40***
Press	Pair 4 Pres–pPres	11.14 (8.42)	7.00***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

(a)



(b)

This collected data measured the level of students' creativity data based on the four elements creativity (4P), and used a Paired-Samples t-test to measure the change of students' creativity before and after integrated STEM knowledge. In general, the result showed that student had the significant change in all elements of creativity (table 3). Element of the product (t = 23.40, $p < 0.001$) experienced the biggest change of other elements, then the process (t = 10.04, $p < 0.001$), press (t = 7, $p < 0.001$), and the smallest change in the person (t = 5.94, $p < 0.001$).

Based on the above results, it can be interpreted that the learning processes which integrated STEM knowledge were able to enhance the students' creative process effectively that will affect the students' creative product. In addition, the processes of learning which integrated STEM knowledge were able to create an environment (press) which supports learners to explore their hidden creativity.

3. The Advantages and weaknesses of learning

Results of the students' response of learning questionnaires showed positive response, students like the activity to make creative products by integrated STEM knowledge, they argue that these activities were able to develop students' creativity, build ability to work together, learn to be more responsible and provide new experience in project based learning that they had never experienced before.

The weaknesses of this learning were a lot of time and cost to complete the creative products. In addition, students usually used teacher-centered learning. Therefore, the students think it difficult to find alternative solutions when they are faced with difficulties at the time of working on a project, so the lecturer must often provide assistance and motivation to the students in order for them not to despair and finish the project

CONCLUSION

The activities to Creativity are an important capability that should be held to competitive standards in the 21st century in entering the era of information and knowledge. The aims of this study were to explore the creativity of students through learning that integrated STEM knowledge. Based on the results and discussions above, it can be concluded as follows:

1. Students'' creativity enhanced through creative products manufacturing activities by integrating STEM knowledge.
2. Made creative products by integrating STEM knowledge were able to influence the level of students' creativity in terms of the four elements of creativity (person, process, product, and press).
   The sequence of elements of creativity that detracted from this study: the process, press, product, and person.
3. Students show positive responses of the activities to made creative products by integrating STEM knowledge.

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