TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 16, Sayı 1, Mart 2019

Journal of
TURKISH SCIENCE EDUCATION
Volume 16, Issue 1, March 2019

http://www.tused.org

Creative Thinking Skills Students in Physics on Solid Material Elasticity

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Received: 07.08.2017 **Revised:** 04.11.2018 **Accepted:** 05.12.2018

The original language of article is English (v.16, n.1, March 2019, pp.48-61, doi: 10.12973/tused.10265a)

Reference: Batlolona, J.R., Diantoro, M., Wartono, & Latifah, E. (2019). Creative thinking skills students in physics on solid material elasticity. *Journal of Turkish Science Education, 16*(1), 48-61.

ABSTRACT

The research mixed method aims to investigate students' creative thinking skills about elasticity in physics. The students' creative thinking skills were measured by diagnostic tests developed by researchers and validated by theoretical physics. The instrument included several indicators of critical thinking skills including fluency, flexibility, originality, and elaboration. This study involved 58 students of 11th grade of public senior high school 8, Malang. The research findings showed that students who were learning with the PBL and conventional approach had good scores in originality and fluency. Particularly in the PBL classes, the highest scores of critical thinking skills were achieved on parallel and parallel spring topics, while in conventional classrooms, the highest scores of critical thinking skills were achieved on the stress, tension, and topic of Young's modulus. Both the PBL and conventional classes got the lowest score on Hooke's law topic. The t-test results showed that there was no difference between the pretest score of PBL students and the conventional student's pretest score. However, the difference was found in post-test scores. In conclusion, the PBL was recommended to develop or enhance students' creative thinking. Future research was expected to fully examine the effect of the PBL on student motivation, and high-level thinking with or without moderator variables. In addition, it was also necessary to conduct other researches that aims to analyze the relationship between pretest and post-test students in creative thinking after engaging in the PBL classes.

Keywords: Creative thinking skills, PBL, solid material elasticity.

INTRODUCTION

Learning skills are important in the 21st century. These skills are required by students to cope with the rapid changes in people's life along with advances in science and technology

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© ISSN:1304-6020

(Chu et al., 2017). In this regard, educational institutions are required to prepare learners to face with global challenges. Interaction with the social community and technological advancement encourages teachers to use all their abilities to produce qualified graduates that make creation in the community environment (Navarrete, 2013). The qualified graduates are developed by someone who has good the skills (Newton & Newton, 2014). The skills are part of one's creative thinking or known as creative thinking skill (CTS) which are managed by memory in the form of planning or ideas and included in a quality product (Baum & Newbill, 2010; Ritter & Mostert, 2016). Thus, CTS is a life skill that plays an important role in developing the quality of human life or society (Yıldırım, 2007) and one's long-term success (Ford & Gioia, 2000).

The process of establishing CTS involves the ability to generate original ideas to build things that others have not thought of and produce something unique (Piaw, 2010; Dolgun & Erdogan, 2012; Robson, 2014). An effective way to improve the welfare and quality of life is to have creative thinking skills (Runco & Acar, 2012). CTS is a divergent thinking ability (Torrance, 1966), consisted of four basic components, named fluency, flexibility, originality, and elaboration (Guilford, 1950, 1968, 1971; Jackson et al., 2012). Creative people use imagination to produce unique solutions to solve a problem. The creative thinking considers problems from different perspectives, makes self-regulation, and finds many ways to see a situation (Sheu & Chen, 2014; Kim, 2011). Based on the description, it can be concluded that the CTS is the ability to produce new works in the form of products that combine data, information, and elements that can form a new work or idea.

In decades, there was a decline in creativity in the results of previous research report that for the first time in the United States. The creativity decreased in almost all age groups, characterized by the appearance of less imaginative student behavior, less verbal expressiveness, lack of enthusiasm, and minimal in synthesizing a variety of information, less motivated to describe the idea in detail, limited in capturing the essence of problems, intellectuals and less open to new experiences (Prentice, 2000).

The creativity is perceived as the capacity of human intelligence (Alzoubi et al., 2016). The biggest challenge faced by students in developing creativity is less confidence and ashamed then their friends who have better ability (Iram, 2007). In relation, the UN agency of UNESCO's education sector called for teachers to give students opportunity to express themselves in expressing good ideas. In the classroom, community learning can serve as a space for managing abilities of all students' in generating original ideas or ideas. It can be developed if the students get a good coaching. The trainer is the teacher itself, who provides space and movement for the students to learn and discover, and trigger the right one where students need intensive mentoring (Leggett, 2017). The results show that, if teachers facilitate students in developing creativity, it has a positive impact on learning outcomes and problem solving in everyday life (Akinoglu & Tandogan, 2007).

According to Ersoy and Baser (2014), oriented learning toward cognitive learning outcomes is no longer a standard in the learning process. The learning outcomes can be changed or adjusted to the interests of learning in the present era, for example by developing various skills and problem-solving skills, including creative thinking skills. Therefore, the education system recognizes the advantages of Problem Based Learning (PBL) in developing CTSs of students. PBL is one example of learning that empowers creative thinking skills (Ersoy & Base, 2014). However, there has been no information related to the study of PBL in empowering creative thinking skills, especially related to the learning content of the elasticity of a material. Many CTS research reports are on whether using PBL model and not using PBL learning model in various contents without applying elastic material. They are collaborative learning design with creative solving process (Wahyu et al., 2016) such as water purification (Etikasari et al., 2016), computer engineering and network (Lim et al., 2014), academic achievements (Malik et al., 2017), electrical circuits and steam distillation (Diawati et al., 2017), gender (Bart et al., 2015). scientific roles in The Qur'an (Smit & Maertz, 2017), CTSs and domain designing (Perry & Karpova, 2017), the effectiveness of creative thinking skills (Pringle & Sowden, 2017), associative and analytic thinking (Yeung et al., 2003).

PBL is a learning model that uses problems as a context for students to acquire problem-solving skills (Kumar & Refaei, 2017). The PBL is a way of learning that encourages to understand the material more deeply and problem-oriented. In the model, students gain not only basic knowledge while learning but also experience on use of their knowledge in solving problems (Bilgin et al., 2009). The PBL also aims to improve student ability to work in a team or group, demonstrating a coordinated ability to access information and turn it into proper knowledge (Khoiriyah et al, 2015; Siew et al, 2017). The PBL is a learning model that can enhance CTSs in each phase of learning. Students will be given problems according to the topic and given the opportunity to answer more than one question.

In a study using a sample of first grade students in Malaysia, it was found that the PBL had a significant impact on creative traits such as fluency, flexibility, originality and elaboration which increase scientific knowledge (Ulger & Imer, 2013). Munandar (2002) was also reported information related to the role of the PBL in improving student CTS in a sample of seventh grade students. In the study, the PBL was used as experimental class and conventional learning as control class. Results of research indicated that the PBL had significant effect to student CTS. The limited information that discloses the use of the PBL in practicing CTSs of high school students in physics learning encourages this research. Thus, this study aims to reveal the influence of the PBL learning model on the CTSs of high school students in physics learning especially elasticity of materials.

METHODS

a) Research Design

This research used an embedded experimental design model adapted from Cresswell & Clark (2007), which is presented in Figure 1.This research aims to reveal student CTSs in learning elasticity material by PBL and conventional. The PBL and conventional learning model is independent variable while CTS is dependent variable.

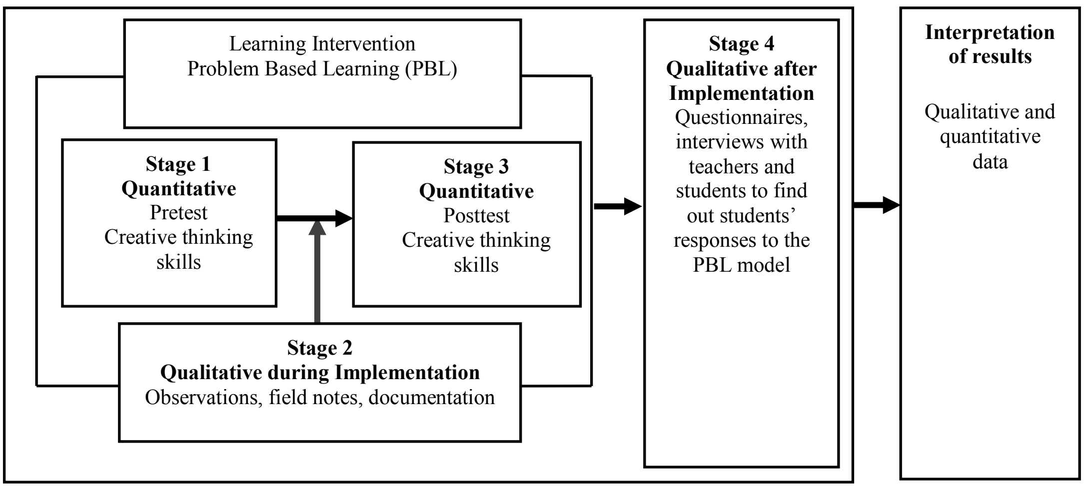


Figure 1. Research Design

The implementation of this research is explained as follows:

1. The first step, the pretest was conducted to find out creative thinking skills in the form of the description questions before the PBL model was implemented in the experimental group and the control group. The pretest results are used as quantitative data. Then, the intervention was carried out in the form of implementing PBL model learning.
2. The second step, the intervention with PBL was conducted by carrying out qualitative data collection in the form of observations on the implementation of PBL-based Learning Implementation Plans and changes in the development of students' creative thinking skills. Observation activities were assisted by observers and learning activities were documented by photos and videos.
3. The third step, the posttest of creative thinking skills was conducted in the form of the same questions as the pretest to obtain quantitative PBL data in the experimental group and the control group.
4. The fourth step, the qualitative data was collecting again by filling out the response questionnaire and interviewing students to find out the students' responses to PBL model learning. After all the stages were carried out, the interpretation of the results of qualitative data was collected to make conclusions in accordance with the formulation of the research problem.

b) Sample

In this research, population is student of 11th grade of science program. Sample consisted of 58 students that were chosen randomly. The research sample focuses on a high school in Malang with average school status. The study used two classes, namely experimental group class (n = 29) and control group class (n = 29). Students in the experimental group used the PBL, while students in the control group received the conventional learning. Data collection for CTS is done for two times in the form of pretest and posttest. The treatment of this research is the use of the PBL learning model in experimental class and conventional class in control class.

c) Instruments

The used research instrument is a test of CTSs in the form of a description of 15 items. The instrument was developed by the researchers after it was validated by the expert of learning and theoretical physicist from the State University of Malang. The instrument was developed with reference to four indicators of CTSs, i.e. indicators of fluency, flexibility, originality, and elaboration (Hart, 1994). CTS instruments have been tested empirically, so that information about the validity and reliability are 0.72 and 0.944, respectively. The scoring of CTSs refers to the scale 0-4 (Hake, 1999), based on the developed rubric of CTSs. On the scale, there are 5 categories, i.e. the score is 4 if the students answer more than 3 aspects of the answer or more. The score is 3 if the students answered 2 aspects of the answer. The score is 2 if students answer 1 aspect of the answer. The score is 1 when students try to answer but it is wrong. And, the score is 0 if there is no answer at all.

d) Data Analysis

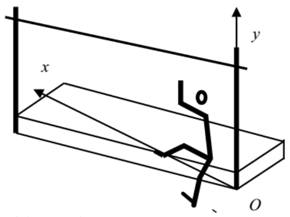
The qualitative data were analyzed descriptively, while the quantitative data were analyzed by independent t samples test to reveal differences of CTS of students' in the control and experimental group. Data analysis assisted with SPSS program version 23.00 for

Windows. Before the data analysis, normality and homogeneity tests were performed as the prerequisite test. The results of both prerequisite tests indicated that the distribution of data in the control and experimental groups were normal and homogeneous.

FINDINGS

The student responses to a given CTS problem are shown in Table 1.

Table 1. *Records of students' answers*

Questions	Students' answers	Category
1. Rudolf is a student of SMAN 2 Batu City. Sports subjects are usually scheduled on Monday at 07.15-09.15. This time, the material to be practiced is high jump (see picture). What things should Rudolf do to jump over the bar with a 1.5m jumping skid? Explain.  (Adashevskiy et al., 2013)	S_{23}: Speed in running, pedestal accuracy, flexibility when jumping, and the type of shoe used. S_{35}: Using poles, using elastic footwear base, jumping using a trampoline, and lowering the height of the ruler.	Very Creative
	S_{3}: On the shoes are given spring and flexibility when jumping. S_{38}: Running speeds should be maintained when jumped, on the pedestal floor given elastic material.	Creative
	S_{33}: Rely on stronger legs when going through the ruler. S_{1}: Use a strong stick to jump over the ruler.	Quite Creative
	S_{19}: Run at high speed. S_{3} : Use shoes with a strong base.	Less Creative
2. Look at the picture below, students struggling through a bridge made of rope. If the number of people passing through this rope is likely to happen that the rope will be tense and broken so they will fall on the water so fast. If you as a village head with a so minimal budget. Explain what things you can do so that the bridge strap does not tighten and break.  http://beritatrans.com	S_{17}: Built-in centerpiece, limiting the number of passers-by, replacing the rope with a strong steel wire, and replacing the rope at a low cost but strong. S_{21}: Replacing the new bridge with the flying fox system, along the rope edge is mounted a strong support, the position of the rope when installed should stretch and increase the number of ropes.	Very Creative
	S_{2}: At the ends of the strong fastening straps and the diameter of the rope is enlarged. S_{18}: More relaxed while passing the rope to keep the body position relaxed and reduce the amount of mass load below when passing through the rope.	Creative
	S_{8}: Replace the bridge rope with a strong material. S_{5}: Build a new bridge from village self-help.	Quite Creative
	S_{10}: Do not limit the number of people passing by. S_{20}: Put a longer strap	Less creative

Analysis of posttest results on students' CTS achievement on each topic studied shows that the highest achievement of CTS on PBL on spring and parallel arrangement, while with conventional learning on the topic of stress, strain, and Young's modulus. The lowest achievement of CTS in both PBL and control classes is the same on Hooke's legal topic. The information is shown in Figure 2.

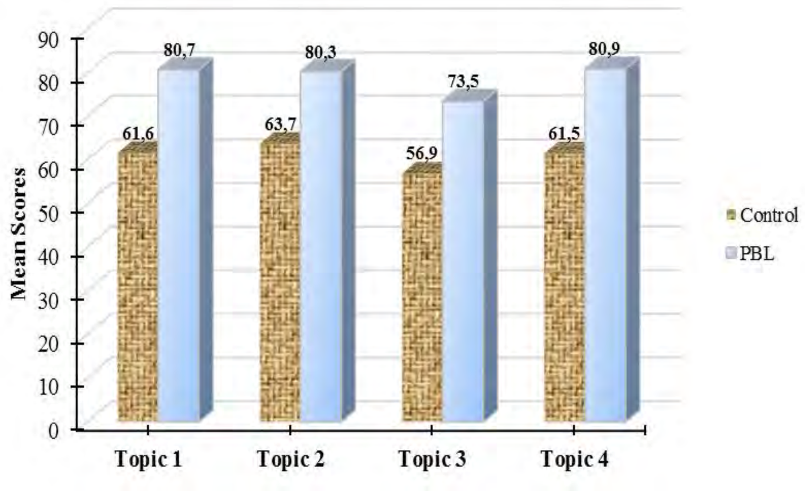


Figure 2. The mean score of student's creative thinking skills on each topic learned

Information:
Topic 1 = Elastic and non-elastic objects
Topic 2 = Voltage, strain, Young Modulus
Topic 3 = Hooke's Law
Topic 4 = Serial and parallel spring arrangement

Descriptions of pretest and posttest score of CTSs, as well as N-Gain obtained by students in the treatment and control group are shown in Table 2.

Table 2. *Description of pretest, posttest, and n-gain score of creative thinking skills*

Description	**PBL Group**		**Conventional Group**	
	Pretest	Posttest	Pretest	Posttest
Highest Score	40	95	40	71,7
Lowest Score	3,3	50	11,7	50
Average	26	78,9	26,8	61,4
N-Gain	0,71		0,47	

Table 2 shows that, the highest pretest score and the lowest posttest score in the treatment and control group were the same, while the lowest pretest score in the treatment group was smaller than in the control group. Nevertheless, the highest posttest score in the treatment group was greater than the control group. Similar with the average value and N-Gain, it appears that N-Gain in the treatment group was 0.24 point larger than the N-Gain control group.

In the treatment group, the highest N-Gain was in the originality indicator whereas the highest was on the fluency indicator in the N-Gain control group. The lowest N-Gains in both the control and the experiment group were found to be in the elaboration indicator. N-Gain of all CTS indicators i.e. fluency, flexibility, originality, and elaboration in the experimental group was greater than the control group.

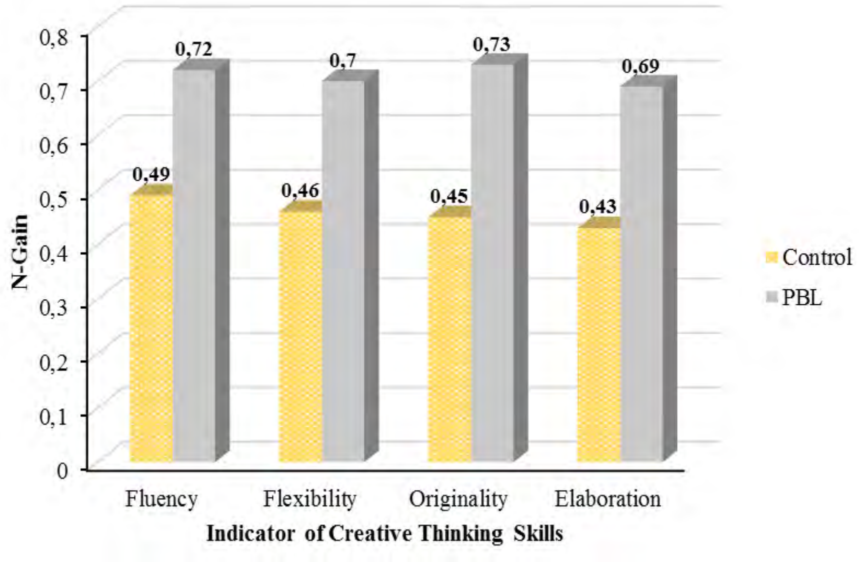


Figure 3. N-gain indicators of creative thinking skills

The t test result based on the student pretest data in both the control and experimental groups is shown in Table 3.

Table 3. *T Test results on the pretest score of creative thinking skills*

Group	N	X	Standard Deviation	Standard Error Mean	df	Sig.	Ket.
PBL	29	26,0	10,8142	2.0081	56	0,75	p > 0,05
Conventional	29	26,7	8,0854	1.5014			

Table 3 shows that the Sig value was greater than alpha (0.05) which means that there was no difference in the students' CTS pretest results in the experimental group and the control group.

The t test results based on the students' posttest data in both the control and experimental groups are shown in Table 4.

Table 4. *T Test results on posttest score of creative thinking skills*

Group	N	X	Standard Deviation	Standard Error Mean	df	Sig.	Ket.
PBL	29	78,9	11,4703	2,1299	56	0,000	p < 0,05
Conventional	29	61,4	5,9440	1,1037			

Table 4 shows that the Sig value was smaller than alpha (0.05) which means there were differences in the results of CTS posttest between the students in the experimental group and the control group.

DISCUSSION and CONCLUSION

Table 1 describes the posed different student responses to the questions. There were students who can answer up to a very creative level, even some students were still on the level of less creative. This indicated that humans or individuals have different abilities or creativity. Teachers have a big task and responsibility to address the creativity of students who are still less creative, it is necessary to again approach continuously in improving creativity. Creativity can be developed through several things such as teachers can provide problems in the surrounding environment and direct students to identify problems that exist, then students can solve problems based on their potential. Another thing that teachers can provide is more challenging questions to improve student CTS.

Figure 2 showed that CTS of students were at a better level when they were taught by the PBL model. The PBL is very potential to improve students' physics skills in the learning process. The PBL facilitates students to learn independently, formulate problems and solve problems individually or in groups. Students were still weak on Hooke's legal topic because teachers only familiarize students at the level of understanding and application so rarely apply patterns of analysis to students with high-level questions. It causes students still find it difficult in the process of learning when they are given a high-level problem so that it disturbs their mindset (Wartono et al., 2018).

Figure 3 showed that N-Gain score in the treatment group was greater than 0.24 points from the control group. Overall, it was revealed that the overall N-Gain of the CTS indicator in the treatment group was superior to the control group. The information indicates that the PBL learning model was more effective in improving CTSs of students. Further test results through t-test were used to reinforce the explanation that the PBL model was superior in improving student creative thinking. It is emphasized that the PBL learning model can help students to develop CTSs in group and individual learning in solving problems, besides the PBL also facilitates students to learn better independently or collaboratively when compared with conventional learning (Lou et al., 2000; Overton & Randles, 2015).

Table 3 shows that the Sig value was greater than alpha (0.05) which means that there was no difference in the students' CTS pretest results in the experimental group and the control group. The mean of pretest score in the experimental and the control group were respectively 26,7 and 26,0. There were several reasons that can be advanced along with the findings. The first factor which is information supporting the absence of difference of pretest score in the PBL group and conventional was student have equal academic ability. Academic ability was a measure of the intellectual capabilities peculiar to each student. The students in the experimental and control groups were each placed based on the results of the selection test for admission from junior to senior high school.

Table 4 showed there were differences in the results of CTS posttest between the students in the experimental group and the control group. Preliminary CTS pretest results data between the experimental and control groups indicated that the learning environment was able to maintain the academic ability of students that had been standardized from the beginning they were placed. It means that the learning environment including curriculum, learning facilities, teacher as a learner, and the pattern of learning that had been done so far was able to maintain the stability of academic ability of students recorded from the beginning. These conditions indicated that students in both experimental and control groups were not contaminated by anything that happens inside and outside the learning environment. Pretest data was a good benchmark to assess the effectiveness of the PBL in empowering the CTS.

The posttest data showed that there were differences in learning outcomes of students who experience learning with the PBL model with conventional model. Several studies had shown that good learning can improve student learning outcomes (Wilkinson & Townsend, 2000; Barrett, 2013). Good learning means learning that has involved the use of models or methods that can improve student learning outcomes or other learning outputs such as CTS. The advantages of the PBL in empowering student CTS can be known through based on teacher interview result with some students after having experience learning with the PBL as follows.

S23: *Learning with PBL makes me very excited and interested in physics lessons and training my cognitive skills.*

S1: *Learning with the PBL model made me excited and more challenged to physics lessons and the PBL made me not feel bored in learning.*

S2: *Studying physics with PBL models can train my creative thinking skills and understand physics concepts.*

S34: *Learning with the PBL model allows me to use the concept of physics in everyday life and I feel motivated in learning.*

The PBL consists of several syntaxes that have the potential to encourage students' creative thinking. In the student's orientation phase on the problem and create a hypothesis, students were confronted with various cases or phenomena of elasticity of a material. Through video and demonstration shows, students were directed to formulate a problem or to make a hypothesis based on the case/phenomenon. Problems used in the PBLs should be designed in such a way as to enhance students' knowledge, personality, academic performance and affective students (Siew et al., 2015). Besides, it must also increase a structured problem-solving process with a series of procedures and showing improvements to student creativity (Inel & Balim, 2010). Student orientation activities on problems and hypotheses were not done in conventional learning. This was consistent with research reports (Munandar, 2002) that PBL gives a good influence on students' CTS, it was seen that classes using conventional learning in the form of lectures and frequently asked questions had bad CTS.

The PBL is one of the learning models rooted in constructivist approach (Tarhan & Acar, 2007). Learning with the PBL model allows students to associate prior knowledge with new knowledge gained in the group discussion process so that it can be used to solve problems in learning (Tseng et al., 2008; Prosser & Sze, 2014). In learning with PBL, students must also learn to work on various tasks, adhere to class rules and responsibilities, and learn how to interact with the classroom environment in a classroom community or interact with other students (Harrison & Treagust, 2001).

Another phase in the PBL that encourages students' creative thinking was the phase of guiding individual and group investigations. In this phase students did experiments, as well as observing and analyzing experimental results.The students were encouraged to develop CTSs by analyzing experimental data and answering questions. The process for presenting data, interpreting data can empower students' elaboration abilities. While by answering questions, students were encouraged to think by expressing a flexible, versatile and original idea (Birgili, 2015; Zubaidah et al., 2018). Problem solving through the PBL was able to improve thinking ability by building interaction with the learning environment or scientific concept building. Previous research reports confirm that the PBL encourages students' conceptual constructions in learning (Rotgans et al., 2011; Mubuuke et al., 2016). The establishment of good student conceptual is an important asset in solving problems in everyday life.

The next phase in the PBL that encourages creative thinking was to analyze and evaluate the problem-solving process. In this phase, the teacher re-confirmed the problem-solving process providing an opportunity for students to reiterate the knowledge gained previously. If students still had questions, they can resubmit. As part of the evaluation process, students were encouraged to think creatively in answering questions posed either verbally or in writing. Although this process was a confirmation of the knowledge that had been formed on the students, it was expected that this process can strengthen the understanding and creativity of students to encourage increased learning outcomes. Ersoy and Baser (2014) reported the PBL contributions to student learning outcomes of 77.16%.

This report concluded that the effect of PBL on CTS is enormous. Kayali et al. (2002) also showed that the PBL as active learning was more effective than conventional methods.

Based on the results of research and discussion concluded that in the process of learning the level of creative thinking skills of students were still different. In the PBL class, the highest achievement of CTS was on spring and parallel arrangement topics, while by conventional learning on the topic of stress, strain, and Young's modulus. The lowest achievement of CTS both PBL and control classes is the same on Hooke's legal topic. Thus, the PBL learning model can improve the score of posttest result of students' CTS on elasticity material. Furthermore, the PBL can be recommended in developing or training students' creative thinking.

IMPLICATIONS

This research is important because it involves the PBL learning model which is currently a constructivist based learning model that has the potential to be implemented in physics learning. Physics learning content contains theories, principles, and concepts that are expected to be meaningful in solving problems encountered daily, so creative thinking is needed. In PBL, students are accustomed to identifying problems, developing creative ideas, doing problem solving processes, and creating real works as proof of student learning. Within that framework, PBL is able to facilitate the development of creative thinking skills.

Recently, some information about students' creative thinking skills has been found through PBL. Ersoy & Baser's research (2014) found that PBL improved students' creative thinking abilities. At the end of learning with PBL, students demonstrate their ability to identify and solve problems with their own ideas and abilities. This research proves the effectiveness of PBL in increasing the 3 elements of creative thinking, namely: fluency, flexibility, and originality by using the creative thinking instrument Torrence (Torrence Test of Creative Thinking). Wartono et al (2018) have revealed that PBL learning has a significant effect on creative thinking skills. This study used a quasi-experimental research design. In line, Ulger (2018) also concluded that PBL has a significant effect on creative thinking in visual arts education because it helps students in the process of solving non-routine problems. In the learning scenario with the PBL, the teacher develops group studies, motivation, assistance / facilitation, and an adequate learning environment. In the study, there were 6 indicators of creative thinking, namely: fluency, originality, titles, elaboration, closure, and strengths. Thus, PBL is able to make a positive contribution in developing students' creative thinking skills in various subject areas.

Based on the results of research and discussion, the authors recommend the following:

1. Learning by using PBL requires the ability and skills of teachers in designing teaching materials to bring up phenomena that can be solved by students. The teacher is expected to be able to use deep questions to provoke students' creative ideas. The main part is the teacher must align the learning steps with the PBL pattern.
2. Students are expected to be able to explore various references to strengthen their thinking skills, so they are able to express creative ideas or solutions. Students need to practice in solving problems in everyday life more scientifically and logically.
3. Further research is needed to explore the influence of PBL on students' creative thinking skills in physics learning with other concepts. It also includes information about the contribution of creative thinking skills to student learning outcomes.

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