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Problem Based Learning on Newton's Law: Can It Improve Student Creativity?

Nurlaili Wisda Agustin[1]*, Sarwanto[1], Agus Supriyanto[2]

[1]Physics Education Master Program, Faculty of Teacher Training and Education, Universitas Sebelas Maret, Surakarta, Indonesia

[2]Physics Department Master Program, Faculty of Mathematics and Science, Universitas Sebelas Maret, Surakarta, Indonesia

*Email: wisdagustin08@gmail.com

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Abstract. Creativity is important in facing a challenging future life. Therefore, current learning is focused on not only values but also soft skills such as student creativity. Few teachers provide opportunities for students to develop their creativity in the classroom. This creativity can be developed and trained through various learning strategies. Probem-based learning was chosen in this study as a means to increase students' creativity through two learning methods, experiment and demonstration. This study seeks to determine the effect of experimental and demonstration methods with problem-based learning model on student creativity on Newton's law material. The subjects included 72 tenth-grade science students in Surakarta, Central Java. They were selected using the purposed random sampling technique where out of 8 tenth-grade science students in SMA Al Islam, Surakarta, 2 classes that met the research category were selected. This experimental study collected the data using pretest and posttest for cognitive data and questionnaire using a Likert scale for student creativity data. Data were analyzed descriptively through independent sample t-test. The results showed that both methods through problem-based learning model had a significant effect on the level of student creativity. From the characteristics of the methods and the number of students in the high creativity category, experimental method is superior to be applied. It is implied that teachers can use the experimental method with problem-based learning model in Newton's law to develop student creativity soft skills.
Keywords: Problem based learning, experiment, demonstration, creativity

Introduction

The rapid change of technology, globalization, and the work environment causes an education system centered on reading, writing, and arithmetic no longer sufficient to prepare students to compete in the global society later. The biggest problem is the change in nature of work in the future so that education needs to be adjusted through a framework that focuses on developing student soft skills, known as the 4C's of soft skill education, which consists of critical thinking, communication, collaboration, and creativity, which are closely related to human agency in technological and mechanical terms. The importance of soft skills leads to the initialization of several educational systems that integrate 4C's of soft skill education into the educational curriculum (Pardede, 2020).

Teachers should focus on these areas because they are aware that their students need these soft skills in the future. However, many lessons in the classroom only prioritize values or cognitive knowledge. These soft skills have not yet been developed in the classroom. In the world of global competition, innovative capacity and creative spirit are prerequisites for personal and professional success. Creativity encourages critical thinking, attention and memory, social skills, and problem-solving (Brock, et al., 2014; Vygotsky, 1971). These skills are what most employers are looking for in applicants and should be developed at the earliest by education specialists in students.

Creativity is a pivotal soft skill to be developed in students but is rarely emphasized by teachers in learning due to many factors, the teacher not knowing the right way to improve student creativity in learning (Cheng, 2010; Laius & Rannikmäe, 2014; Pang, 2015), the learning process that emphasizes unproductive thinking (only focusing on memorizing and looking for correct answers), and creativity that is too difficult to develop for students with limited knowledge and thinking skills (Cheng, 2010).

It is time for teachers to be aware of increasing student creativity through appropriate learning strategies. Cheng (2010) revealed that creative thinking can be done through scientific processes, scientific content, and science learning scenarios. Constructive approaches and active learning methods such as problem-based learning (PBL) are very relevant to the development of students' creative thinking (Rusydi 2017; Taber 2011). Analyses reveal that PBL may support productive and even innovative efforts to infuse creativity elements into regular classrooms (Neber & Neuhaus, 2013). Its implementation has been proven to improve students' critical and creative thinking skills (Kardoyo, et al., 2020; Rudibyani, 2019; Ulger, 2018). Students can solve a given case by doing the right analysis and being able to provide alternative solutions. They consider the learning process to be more exciting and challenging. They can express their opinions well in the front of the class. The implication of this research is that lecturers can apply PBL with various combinations of learning strategies to improve students' critical and creative thinking skills (Kardoyo, et al., 2020).

Physics is a subject based on processes and products. Physics as a process is not necessarily effective if it is only focused on understanding the material but should emphasize the acquisition of skills such as critical, collaborative, and creative thinking (Sipayung, et al. 2018). The physics learning process should emphasize the provision of direct experience to develop students’ competence to better understand the various natural phenomena around scientifically (Pratiwi & Muslim, 2016). Problems encountered in the teaching of physics in the 21st century are generally not limited to the ability to master the concept of physics, but also require students to develop the ability to think creatively, allowing them to analyze innovative and efficient problem-solving.

Compared to other sciences, physics needs help in demonstrating its concepts through demonstration method or hands-on experiments (Milner-bolotin, 2015). In some cases, an experiment should be done either as a demonstration or as a class experiment as in Newton's law material which can be explained through several experiments. PBL methods such as experiment and demonstration can be used to enhance students' creativity and cognitive understanding. Demonstration can clarify the physical principle or some interesting applications of a principle. However, it must be ensured that when doing demonstrations, all students can hear and see all the processes. The experimental method can provide direct experience to students since they are allowed to practice being scientists, designing, developing hypotheses, designing experiments, predicting outcomes, and returning to fresh hypotheses and more experiments. In this experimental learning, students develop the ability to observe, think, and solve problems with ideas that can be out of the box.

Lesson planning holds important points about the success of learning. In addition to students' cognitive understanding, other soft skills, such as creativity, must be given with the right portion of learning objectives. Several solutions have emerged to improve student creativity. This study focuses on the application of PBL by comparing two learning methods (experiment and demonstration) to find out its effect on the level of student creativity. This study is expected to provide an overview of how PBL, experiment, and demonstration affect the development of student creativity on Newton's law material.

Method

This study explores the effect of the learning method on Newton's law material towards student creativity using experiment method with static group comparation design. The study was conducted on two groups, each of which was given a different learning method even though the learning model referred to problem-based learning. Group 1 was assigned treatment in the form of an experimental method, and group 2 was given a demonstration method. Student creativity data were taken in each group when learning Newton law material had been completed. A quantitative approach with the survey method was employed. The subjects included 72 tenth-grade science students in Surakarta, Central Java. They were selected using the purposed random sampling technique where out of 8 tenth-grade science students in SMA Al Islam, Surakarta, 2 classes that met the research category were selected.

The static-group comparation design is the research design used in this study. It is described as a study design that compares two groups where the dotted line indicates the two groups have been formed. The study subjects are not subject to randomization. The symbol X refers to the treatment in the experimental group. In contrast, the space under X indicates the "control" group, which did not receive special treatment but usually received treatment. Both groups are observed or measured simultaneously with an O symbol that is placed vertically to each other.

Student creativity data were collected through a questionnaire using a Likert scale with four answer choices (strongly agree, agree, disagree, strongly disagree). Student creativity instrument was designed based on the dimensions of creativity Guilford (1975). This questionnaire consists of 30 question items that map 8 indicators of student creativity that are developed can be seen in Table 1. Cronbach's Alpha score for the creativity questionnaire was 0.982.

Table 1. Indicators of student creativity

The dimensions of creativity	Indicators	Items
Fluency	Determining many solution ideas	1,2,3,4,5
	Providing appropriate problem-solving solutions	6,7
Flexibility	Answering questions by categories	8,9,10
	Seeing problems from different perspectives	11,12,13,14,15
Originality	Giving ideas for new solutions	16,27,18,19
	Thinking about an innovative way of solving	20,21,22,23
Elaboration	Giving the right reasons for choosing a solution	24,25,26
	Looking for a deep meaning for the answer to solving the problem	27,28,29,30

Results and Discussion

Student creativity level

Student creativity can be a crucial skill in the development of innovative ideas. Creativity is about applying and interpreting knowledge innovatively and uniquely, where students must understand the content in detail and have the confidence to provide their unique take on it (Fazelian & Azimi, 2013). The development of student creativity is essential to be considered by the teacher in achieving learning objectives. Gallagher (1980) reveals four crucial things in the development of creativity for students, namely:

1. Creative learning is crucial because it helps students be more effective when we aren't around
2. Creative learning is crucial because it creates possibilities for solving future problems that we can't even anticipate
3. Creative learning is crucial because it may lead to powerful consequences of our lives
4. Creative learning can produce great satisfaction and joy

The two classes given different treatments, experimental and demonstration methods, showed the groups of students with high and low creativity. The difference in the number of students in the high and low creativity categories in both classes is shown in Figure 2. Figure 2 shows that the number of students with high creativity is outperformed by the experimental class while the demonstration class is superior in the low creative category. Students with high creativity tend to provide new ideas in their learning methods and styles. Meanwhile, students in the lower category are more passive in participating in discussions. Student who has a creative personality can be seen from several indicators. According to Guilford (1975), indicators of a person having a creative personality can be seen from the characteristics of the cognitive dimensions (fluency, flexibility, originality, and elaboration) and non-cognitive dimensions (interests, attitudes, and temperamental qualities).

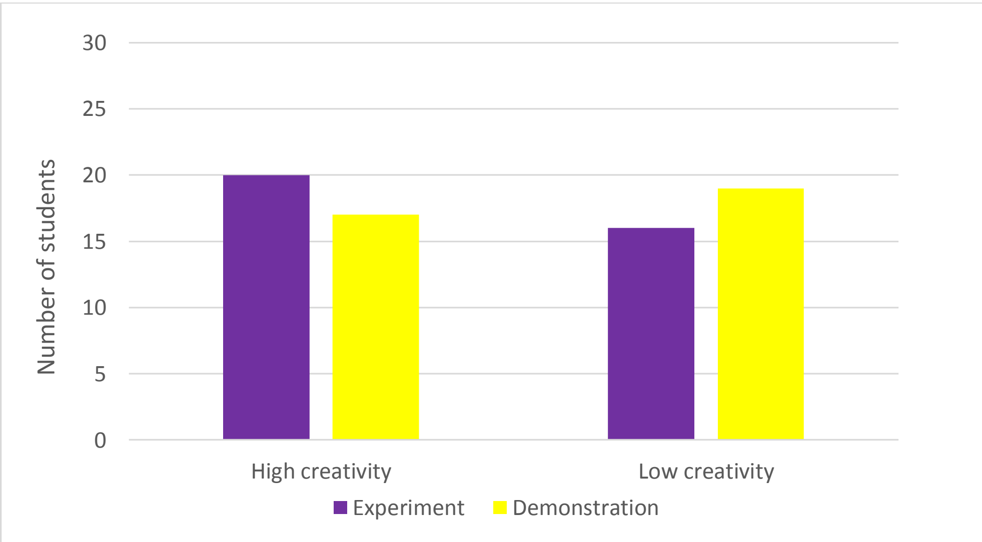

Figure 2. The number of students in both categories of creativity

The four cognitive dimensions in the form of internal intellectuality refer to innate abilities as potentials that still need to be developed and trained to be realized through providing the right environment (Munandar, 1995). First, regarding fluency related to the ability to provide answers or express similar opinions/ideas to solve a problem. Activities carried out by students are carrying out activities that generate various ideas in trying to overcome all obstacles and points (Torrance, 1965). Learning that is applied in both classes refers to providing cases/problems that require students to solve through experiments previously carried out or watched by students. The second aspect regarding flexibility is that students have various thinking patterns, are not rigid, and are not limited by certain situations. In this case, the students' thinking patterns are outside of regular habits, such as a certain leap or frame of mind that results in a new product (Torrance, 1965). The third and fourth aspects, namely originality and elaboration, involve producing clever or uncommon responses to specific situations and require the specification of detail that contributed to the development of a general idea.

In addition to these four aspects, student creativity is also influenced by typical personality traits such as talents, interests, attitudes, and temperaments (Amabile, 1983). In line with William (1979) opinion that the affective nature of each student in the form of curiosity, courage to take risks, being challenged by plurality and imaginativeness can affect the level of creativity of a person. There are two basic aspects in developing student creativity, namely mental security, in which no opinion or beliefs of students were criticized or even mocked, and mental freedom, in which students had freedom for conceptualization and the expression of ideas which emerged in their minds, and their ideas, opinions of beliefs were respected and taken into consideration (Trnova, 2015). These two basic aspects need to be instilled by teachers in students so that they are confident to come up with ideas that even sound "crazy".

Lin (2011) revealed that the creativity approach in education has a unique problem because it is directly related to creativity and knowledge, the right curriculum, and pedagogical strategy in developing creativity in the classroom. Importantly, creativity can be developed, and every student can potentially be creative. Especially at the identity stage, which is around the age of 13-18 years (formal operating period in intellectual development). Gowan (1972) call it the Golden Age stage. This is due to the child's creative process getting support from intellectual abilities, namely formal, conceptual, analytical, critical, and evaluative thinking. The party that plays a role in improving student creativity performance is the teacher in the classroom. The teacher can identify which students need to be "helped."Students with low creativity can be guided through appropriate learning strategies in the classroom by the teacher.

How experimental and demonstration methods contribute to the development of student creativity

The problem-based learning (PBL) learning model applied in both classes makes students plan designs, set goals, conduct independent research and apply newly built knowledge to complex problems. Gallagher (1997) formulating the objectives of PBL is developing students' capacity to see problems from multidisciplinary viewpoints, integrating information from many different sources, and improve flexible thought and the ability to adapt to the change. These objectives are in line with the indicators of creative personality so that PBL is considered an appropriate learning model in developing student creativity levels. In the implementation, teachers must be able to prepare well to teach science and creativity to students. Courses developing knowledge and skills for creative learning and teaching for creativity should be included in teacher education (Sadat & Dehshiri 2014). An integral part of these courses can be implemented in experimental processes in physical materials such as Newton's law. The learning methods used can be in the form of experiments and demonstrations. The contribution of the two methods to the development of student creativity is analyzed so that teachers can further use this information in their classrooms.

The effect of these methods was analyzed using the 2-sample t-test, where the results of the analysis can be seen in Table 2. Table 2 shows that the t-test results in sig. < 0.05, so the two methods provide significant differences. The experimental method can contribute better than demonstration to the development of student creativity. Lin (2011) presents three components of developing creativity through education: teaching, environment, and the teacher. The creative process helps to increase student learning and involvement, and it allows the teacher to present learning material in new and innovative ways. Creativity in the classroom builds a foundation for students' adaptability and skills in problem-solving. Based on this research, the experimental method seems to be the appropriate way for the development of student creativity because it involves all the above-mentioned components. In the experimental class, every student was allowed to try to assemble experiments from Newton's law so that their creativity could develop more through new ideas as outlined in the experiment. The provision of freedom by the teacher in conducting experiments has an impact on the students who can propose very interesting and original ideas applicable to the workplace (Escribá-esteve, 2012). All ideas/assumptions of students when looking for solutions to problems can arouse their excitement/interest in learning, which can be a "win-win" outcome for both the teacher and students (Ramdani & Artayasa, 2020).

Table 2. The results of analysis of the effect of the two learning methods on the level of student creativity.

Learning Method	Average Student Creativity	Normality Test	Homogeneity Test	Independent Sample T-test
Experimental	81.67	Sig. > 0.05	Sig. > 0.05	Sig. < 0.05
Demonstration	75.78	(0.648)	(0.884)	(0.003)

In the implementation of the experimental method in physics learning, the teacher provided a virtual laboratory about Newton's law material. The virtual laboratory is a computer-based media that contains simulations of activities in the physics laboratory. Virtual laboratories are created to describe reactions that may not be visible in real life (Goodwin, et al., 2011). This virtual laboratory was fully provided to each student to design and resolve cases in it. The teacher did not interfere in every step taken by students so that they were given the freedom to get ideas out of their thinking about Newton's law problems. The design of activities and learning media used and even created by the teacher greatly affects students' development of creativity. Utilizing virtual lab in learning may encourage students to involve actively in generating profound question towards given problems (Ye, Wong, & Ho, 2016). During the laboratories in physics, learning could improve the learning process in the current study; students were required to share opinions and conclusions at the end of a session. Students were asked to explore and discuss various problems encountered during the experiment. These results are in line with several studies which reveal that modern physics virtual laboratories can improve students' mastery of concepts and creativity (Hermansyah, et al., 2015), generic science skills (Gunawan, et al., 2018; Osman & Judge, 2014).

In other hand, students in the demonstration class just only see and hear the experimental process taking place through Newton's law material experiment video. Students are not allowed to independently explore the experimental sequence. Children's natural creativity is stifled when children start to differ from standard procedures in their activities (Trnova, 2015). They are "forced" unconsciously to follow the existing rules. Barriers that may be hindering one's creativity can come from behaviors and patterns of educational, social, and cultural points of view (Fazelian & Azimi, 2013). Student creativity will find it difficult to develop if these barriers are not immediately removed and replaced with a supportive environment. Teachers must be prepared for creative teaching and teaching for creativity. We can state that only creative teachers can develop student creativity. That is why the creation of methods for the development of teacher creativity, as a part of teacher education, is a necessity (Laius & Rannikmäe, 2014; Trnova, 2015).

Class activity with the demonstration method focuses on introducing experiments in Newton's law material through videos made by the teacher. All students can observe the experiment through the video. This demonstration method is one of the solutions of the teacher in replacing experimental activities online, given that current learning is carried out online. Besides having a positive impact that is more efficient, this method has a negative impact as well. The negative impact is that demonstration methods require direct clarification, for which teachers should be present in the classroom to clarify directly to students if students find difficulty (Nordin & Alias, 2013). With the development of student creativity, demonstration method has not been able to improve student creativity when compared to experimental method. In the application of the demonstration method in class, students were not encouraged to create and express their creative ideas related to Newton’s law, but they only carried out observational activities.

Creativity relates to the process of discovery; in this case, experimental activities are considered as one way to develop the process of discovery that develops creativity as well. Teaching creatively means that teachers use their creative skills to make ideas and content more interesting and comprehensible (Kasmaienezhadfard, et al., 2015). Teaching for creativity is defined as forms of teaching that are aimed to develop students’ creativity. It involves instructional strategies designed to encourage students to think and act creatively. It is desirable to encourage students to experiment, to innovate, not giving them all the answers but giving them the tools, they need to find out what the answers might be or to explore new avenues. The development of creativity in students is dependent, at least in part, on the environment in which they participate. In addition to the contribution of the learning methods used, physics learning, especially in this Newton’s law material, has the aim of developing other skills, one of which is creativity. Several researchers consider the goal of science education as not only learning specific scientific knowledge but also developing skills of scientific thinking and skills of argumentation that play an important role in high-level brain-storming, such as critical reasoning, creative thinking, and problem-solving (Laius & Rannikmäe, 2014).

How are student learning outcomes in both learning methods

The application of the two learning methods, experiment and demonstration, affects not only the level of student creativity but also their learning outcomes. The results of the analysis of the difference test in Table 3 state that both methods have a significantly different effect on student learning outcomes (sig. < 0.05). Student learning outcomes on Newton's law material in both classes showed the same tendency as the distribution of student creativity categories. Figure 3 shows that most experimental class students have high cognitive. The data on the mean posttest score of the two classes shows that the experimental class gets higher scores than the demonstration class. Experimental class students better understand the concept of Newton's law because they experience and try to solve cases from hands-on experiments using virtual laboratories. Previous research also stated the same results, students who were given the experimental method had better learning outcomes and had an easier time understanding the concept of the material

(Firdaus, et al., 2017; Hakİm, et al., 2016; Hilera, et al., 2010; Shishigu, et al., 2018). The experimental method can direct students to apply concepts from studied theory, make hypotheses, observe an object, analyze, and draw conclusions (Fransiska, et al., 2019).

Table 3. The results of analysis of the effect of the two learning methods on student achievement.

Learning Method	Average Learning Achievement	Normality Test	Independent Sample T-test
Experimental	75.56	Sig. > 0.05	Sig. < 0.05
Demonstration	68.75	(0.737)	(0.014)

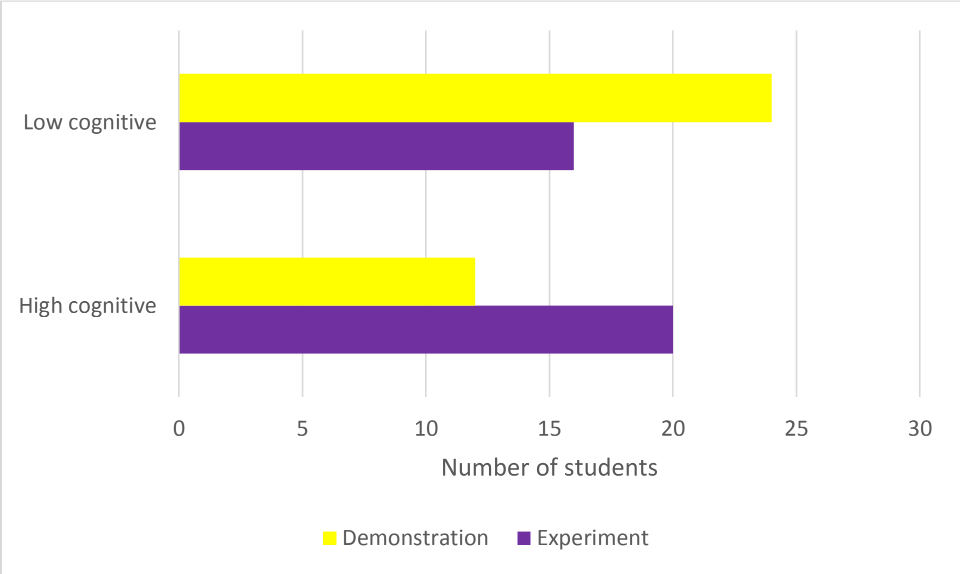

Figure 3. The number of students in both categories of cognitive comprehension

On the other hand, the implementation of the demonstration method only focuses on observing the experimental video made by the teacher. This can make students not interested in exploring deeper material related to Newton's law due to boredom and no challenges. One of disadvantage of demonstration method is that this method is limited only to certain types of teaching situations. Some teachers try to use it where other methods will produce better results (Criollo-c, et al., 2018). Demonstration method with experiment video as a medium should be created more creatively and varied to add students' attraction during learning (Ichsan, et al., 2018). Various learning media can be used to improve student learning outcomes, especially during distance learning as it is today. One example is the use of cartoon animation and collaboration with songs that are interesting to students. Multimedia with elements of audio, visuals, and even animation/simulation has a role in students' long-term memory in understanding the material (Linda et al. 2021; Novisya and Desnita 2020; Qusthalani and Muharti 2019).

Although the teacher is more focused on the development of student creativity, the cognitive learning outcomes of students are still the goal of learning so that the teacher should not rule this out. Learning still focuses on the process of understanding and meaningful learning in each material for students. Based on the physics curriculum, teachers need to provide practical activities as a meaningful learning method because they can link the theory with practice that can be sensed by students (Kostiainen, et al., 2018).

The complexity of physics material, especially Newton's law, makes teachers work harder in teaching students through distance learning. As in practical activities, teachers must provide alternatives such as virtual laboratories (Handayani & Jumadi, 2021; Keshavarz, 2018; Situmorang, et al., 2015) so that students continue to understand practical materials and skills. Teachers are expected to be more innovative and understand the use of technology to provide interesting learning activities for their students. Based on the results of the analysis of the application of these two PBL methods, the experimental method is more suitable for use in Newton's law material in online learning.

Conclusion

Creativity is a pivotal component in education as literature; thus, it should be included in education as a fundamental life skill that will enable future generations to survive and thrive in the 21st century. Science, especially physics, teachers should obtain professional competence for teaching for creativity and creative teaching. These teachers' activities should aim for the effective creative learning of students. PBL model with experimental and demonstration methods can have a positive effect on students' creativity skills if supported by good planning. The experimental method provides better results at the level of development of students' creativity and their learning outcomes compared to the demonstration method. Teachers must be aware of the soft skills development of students and not only focus on their learning outcomes. This can be started through creative teaching by considering all factors to create a learning environment that supports student development, one of which is the selection of appropriate models and methods.

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