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Barriers to Scientific Creativity of Physics Teacher in Practicing Creative Product Design

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Abstract. Barriers to scientific creativity often make it difficult for physics teachers to recognize their creative potential, let alone train their students to be creative. The research aims to identify the physics teachers' ability in practicing creative product design and their creative barriers. This research includes mix-methods using a survey approach and continued by Focus Group Discussion. It has involved 67 physics teachers in South Kalimantan divided into three groups (senior teachers, beginner teachers, pre-service teachers). The teacher's answers are analyzed by descriptive qualitative. The results showed that teachers' ability to design creative products limited to creative ideas and scientists; but it has non-integrated mathematical reasoning and technical design in designing an applicable product. The teacher's negative belief in scientific creativity and their learning are the main factors of creating barriers. Other factors are limited study time, laboratory equipment, teaching materials, and the amount of material structure.

1. Introduction

The global society of the industrial revolution era 4.0 requires an education system that can product designers, creators, and problem-solvers who are proactive in solving real-life problems [1-3]. The activity of designing creative products has become the most recent educational phenomenon that occurs in many formal and non-formal schools in various parts of the world [4]. If students want to be designed that way, then the creative teacher always tries to facilitate students' responsibility, creativity, and independence in constructing scientific knowledge and making useful creative products [5-7]. The most important target is that students are trained to integrate physical content, engineering design, technical design, and mathematical reasoning in designing the latest creative products [8-10]. Creative products are interpreted as the result of creative ideas that are seen as something new [11]. This product can be in the form of objects, technology, or creative ideas that are useful for solving real-life problems [7,12]. Thus, students are trained to improve the quality of life, solve problems, and succeed in life and career for the future. This learning becomes more interesting and meaningful for students.

The creative teacher certainly realizes that every student has creative potential [13]. This creative potential is seen in a variety of creative products and student achievements outside of school, but this potential is often not displayed when they study in class. Schools provide too much material and time

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limits for creative practice, whereas designing this creative product requires autonomy and independence [14]. Also, teacher beliefs about scientific creativity and creative teaching behavior play an important role in maximizing student creativity [1,15].

The results of previous studies indicate that teachers still lack understanding of scientific creativity and learning [7,12,16-18]. The main cause is the lack of scientific knowledge, resources, support and opportunities to collaborate. Also, teachers' negative beliefs in science, technology, engineering, and mathematics along with their learning are believed to be the main factors of barriers to scientific creativity [19,20]. As a result, teachers find it difficult to recognize their creative ideas and lack of confidence in practicing scientific creativity, especially designing creative products [12,21]. Teachers often recognize creativity as an intellectual ability but lack of recognizing scientific creativity as discovery, authenticity, curiosity, flexibility, autonomy, or the ability to make connections [22]. As a result, when teaching physics, teachers only transfer their knowledge to students. The teacher does not facilitate students to be more responsible, more creative and independent in constructing knowledge and designing creative products that are useful [18,23].

The teacher plays a key role in facilitating the development of students' scientific creativity, especially designing creative products. Therefore, the purpose of this study is to explore the ability of teachers to practice creative product design and the barriers to scientific creativity that accompanies it. Through this research, it is expected to obtain information on various barriers to scientific creativity felt by the teacher and to obtain alternative solutions to overcome these obstacles.

2. Method

This research is a mix-methods using a survey approach and continued Focus Group Discussion (FGD). The research was conducted from March to September 2019. The research subjects were 67 science-physics teachers in South Kalimantan, divided into three groups, namely 24 senior teachers (teachers who taught for more than 5 years), 12 beginner teachers (teachers who taught less than 5 years), and 31 physics teacher candidates (the final semester students in the physics education department ULM). Research data was collected using a Creative Product Design Test (CPDT) adapted from Scientific Creativity Assessment [24]. The CPDT used is presented in Figure 1.

Test 1: Designing a simple electric circuit
You are given 10 minutes. If provided 4 lamps, 3 batteries, and several power cables. Describe as many ways as you can to make the lights turn on!

Test 2: Designing nail sweeping tools on the road
You are given ten minutes. Make a design of a nail sweeper on the road that can be used to clean nails on the highway, show the name of each part and its function!

Figure 1. Creative product design test.

The two items above were previously validated by three physics learning experts and obtained validity values of 3.81 and 3.92 respectively; and the Cronbach's alpha coefficient of 0.93. Thus, both test items have met the validity and reliability criteria as CPDT instruments [24]. Next; Creative product design data collected was assessed using a holistic assessment [25], i.e. the teacher's answers were observed thoroughly and then adjusted to the assessment criteria in Table 1.

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Table 1. Criteria of creative product design assessment [24].

Criteria	Description
Very Good	Creative design, scientific, mathematical reasoning, and applicative.
Good	Creative design, scientific, and mathematical reasoning
Enough	Creative design and scientific
Poor	Creative design and less scientific
Not Good	Design is less creative and less scientific

From Table 1; creative product design is said to be creative when the teacher is able to produce at least 4 unique designs; design is said to be scientific, when it is in accordance with scientific content (concepts, theories, laws, principles); design is said to meet mathematical reasoning, when equipped with precise physical quantities; and design is said to be applicable when following a logical technical design so that it can be applied in real life. The qualitative data are then analyzed using percentage techniques, namely the number of teachers who meet the criteria divided by the total number of teachers multiplied by 100 %. Next; to explore the barriers to scientific creativity felt by teachers obtained through FGD. Barriers to scientific creativity are various obstacles that make it difficult for teachers to understand scientific creativity and their learning in class [7,12]. These obstacles can come from students, supporting resources, or from the teacher himself related to the level of scientific knowledge and teacher confidence in scientific creativity and learning [19,20]. This data was analyzed descriptively qualitatively, i.e that is carried out reduction, exposure, and then concluded.

3. Results and Discussion

Creative product design reflects the accumulation of complex thought processes that are actualized in the form of objects (technology) or creative ideas that are useful for solving problems. The ability of physics teachers in designing creative products is presented in Figures 2 and 3.

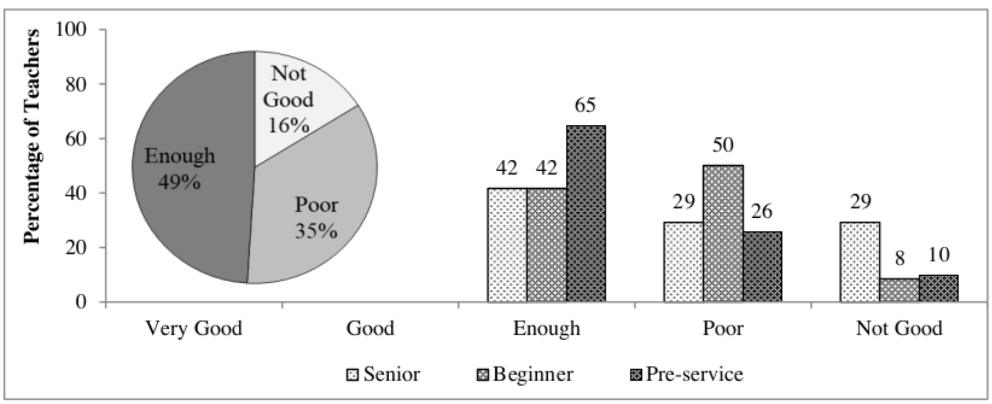

Figure 2. The teacher's ability to design simple electric circuits.

Figure 2 shows that the ability of teachers to design simple electric circuits varies from enough, poor, and not good; but there are no teachers in the good/very good criteria. Senior and novice teachers are 58% still within the criteria of poor/not good; while pre-service teachers are more in enough criteria. This also happens to the teacher's ability to design nail minesweeper as shown in Figure 3.

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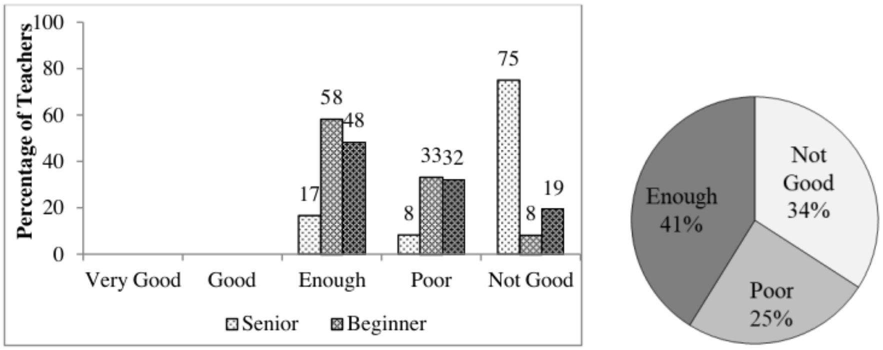

Figure 3. The teacher's ability to design nail sweeping tools on the road.

Figure 3 shows that the ability to design the best creative products is a beginner teacher, i.e 58 % of beginner teachers are in enough criteria; pre-service teacher in second place with 48% are in enough criteria, and the lowest is a senior teacher who is 75 % is not good criteria. Means; senior teachers, novice teachers, and pre-service teachers experience barriers to scientific creativity. The teachers have difficulty connecting science-physics content with its application in solving real-life problems, both in the form of creative ideas and technology. The teacher's inability to design this creative product can be seen from the example of the teacher's answer presented in Figure 4-5.

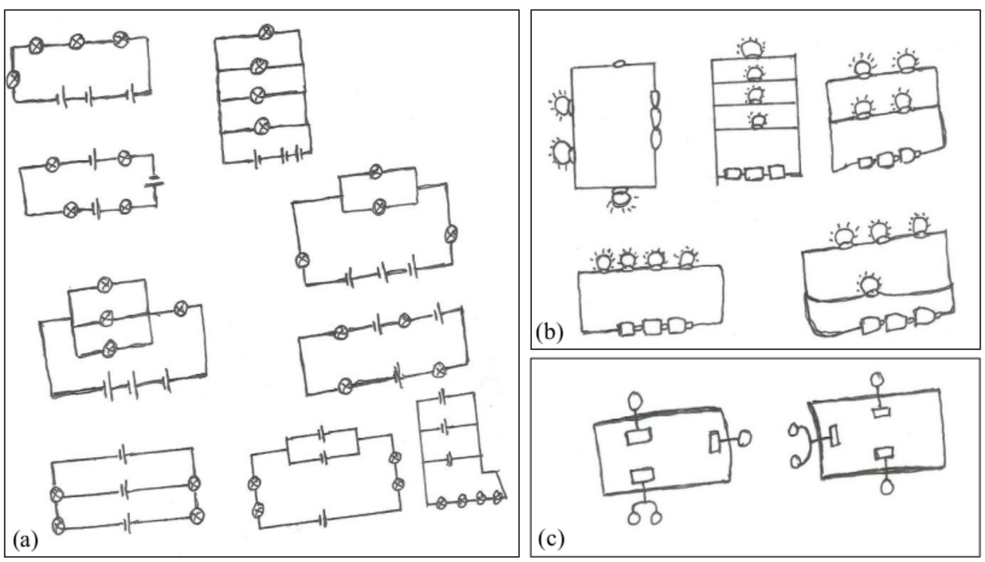

Figure 4. Designing of simple electrical circuit: (a) enough, (b) poor, (c) not good.

Figure 4a shows that the teacher's answers are enough criteria because they can produce five variations of a simple electrical circuit by utilizing the symbols of the lights and batteries. The picture has not been given a specification of the type of lamp or battery used, so it is still not logical and cannot be applied in real life. In Figure 4b; Teacher's answers are poor criteria, although the teacher can produce 4 variations of the series, the design of the lights and batteries is less clear. While in Figure 4c; the

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teacher's answers are not good because they only produce 2 variations of the series and the design of the series is unclear. The design of a series of nail mines sweepers can be presented in Figure 5.

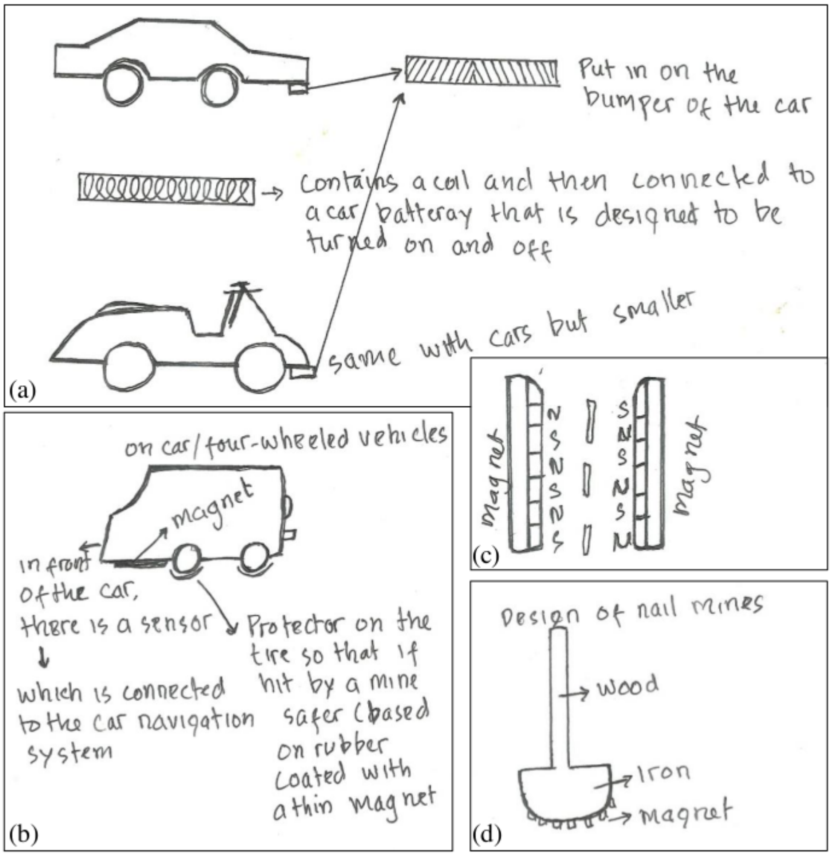

Figure 5. Nail sweeping tools on the road: (a-b) enough, (c) poor, (d) not good.

Figure 5a-b shows enough answer because the teacher can relate the concepts of physics and technology in designing nail minesweeper, but it is less logical and applicable because the equipment specifications used are not written down. In Figure 5c; the teacher's answers include poor criteria, even though the teacher can show uniqueness (example: making a magnetic design that is placed right and left the edge of the road), but it does not involve the exact physical quantities. Whereas in Figure 5d, the answer still very simple and less scientific. Means; the teacher's still experience obstacles of scientific creativity when designing nail sweeping tools on the road.

Senior teachers, beginner teachers, and pre-service teachers have not been able to design creative products properly (Figures 2 and 3). For teachers who are enough criteria; they can connect physics content with technology (for example cars, sensors) in designing creative products, but not yet accompanied by precise physical quantities. Especially for teachers who are poor and not good; they are still having trouble thinking outside the box. The teacher is only able to make a simple product design (for example: designing a nail minesweeper consisting of wood and magnets). Also, there are no teachers included in the good/very good criteria. Although there are already teachers who can create creative and scientific product designs; but it has not been specified in precise physical quantities (mathematical

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reasoning) and does not involve technical design, so the design cannot be applied in problem-solving. This indicates that the teacher is still experiencing obstacles to practice scientific creativity, this is known as the obstacle of scientific creativity. From FGD results, obtained information on barriers to scientific creativity as presented in Figure 6.

Barriers to teacher scientific creativity

Some barriers that make teachers find it difficult to develop creative product designs, including: (1) the teacher has been understanding creativity as limited to knowledge; not scientific creativity as a process of finding and solving problems, creative science experiments, and creative science activities; (2) limited learning time and the amount of material structure, making teachers prefer the transfer of knowledge rather than facilitating scientific creativity and independence in designing creative products; (3) limited laboratory equipment, making it difficult for teachers to apply laboratory-based learning; (4) lack of teacher understanding of innovative productive learning; making teachers rarely apply inquiry learning, problem-based learning, project-based learning, STEM learning, and creative learning; (5) the teacher's lack of understanding of scientific creativity and its learning, this makes it difficult for teachers to design creative and applicable products to solve real-life problems; (6) the use of LCD and photocopying machines in education, this makes students rarely write and design series/drawings on books/blackboards because they have been presented via LCD and can be photocopied. As a result, the quality of the product design produced does not match the actual conditions.

Figure 6. Summary of FGD results about the barrier to teacher scientific creativity.

Besides 1-6 (Figure 6); the main factor as a barrier to scientific creativity is the teacher's negative belief in scientific creativity and its learning. This is supported by previous research [19,20] that negative beliefs from teachers are the main obstacle to learning scientific creativity. For teachers with negative self-confidence; every problem is considered a threat and an obstacle in teaching the best. However, for teachers with positive self-confidence, each problem is considered as inspiration and imagination to create creative products that are useful for overcoming every problem [7,12].

The limitations of this study are the number of research subjects with only 24 senior teachers and 12 novice teachers; so, the results of this study cannot yet be generalized to the teacher population in South Kalimantan. However; this is consistent with the findings of previous researchers and the results of accreditation visitation experience in schools that the above barriers to scientific creativity are the main factors causing obstacles in designing creative products for science-physics teachers in South Kalimantan. Therefore, the fundamental implication of this study is that efforts are needed to increase positive teacher confidence in scientific creativity and learning. Also, teaching materials and teaching aids based on scientific creativity were developed; and training and assistance in learning scientific creativity in schools.

4. Conclusion

The physics teacher's ability to design creative products is limited to creative and scientific ideas; they have not been able to integrate mathematical reasoning and technical design in designing products that apply to solving problems. The teacher's negative self-confidence in scientific creativity and learning are believed to be the main factors inhibiting scientific creativity. Other barriers are limited study time, laboratory equipment, learning resources, and a large amount of material structure in schools. This finding is expected to be able to inspire teachers to increase positive self-confidence in scientific creativity and learning. Thus, each problem can be an inspiration and imagination for teachers to create creative products that are useful for solving problems.

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