

Do Scientific Learning and Problem-solving Develop Mathematics Students' Creativity?

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Abstract—This paper aims to investigate the connection between scientific learning, problem-solving, and creative thinking theoretically. Building on the results of elaborating theories among scientific learning, creative thinking, and mathematics problem solving, it is then acquired connection among them, that is, in the activities of (1) observing and asking positively connect to the ability in problem-solving in the aspects like identifying problem, finding problem goal, and formulating the problem; (2) identifying problem, finding problem goal, and formulating the problem connect positively to the ability in creative thinking in both aspects fluency and flexibility; (3) reasoning and trying out connect positively to the ability in problem solving in the aspects of finding strategies for solving problem, choosing appropriate strategy, and implementing the strategy; (4) finding strategies for solving problem, choosing appropriate strategy, and implementing the strategy positively connect to the ability in creative thinking in the aspects such as fluency, flexibility, and elaborately; (5) concluding and communicating/intertwining positively connect to the ability in problem solving in the aspects like finding strategies for solving problem, choosing appropriate strategy, implementing the strategy, and looking back/verifying conclusion; (6) finding strategies for solving problem, choosing appropriate strategy, implementing the strategy, and looking back/verifying conclusion positively connect to the ability in creative thinking in the aspect such creation/novelty.

Keywords—creative thinking, scientific learning, mathematics problem solving

I. INTRODUCTION

A type of high-order-thinking level that is currently gaining wide attention among cognitive psychologists and being the goal of education in every country is creative thinking [1]. The importance of creative thinking abilities is expressed by Mumford & Gustafson [2]; Runco [3]; Goldenberg & Mazursky [4]; which states that individuals who have high creative thinking skills can create jobs for others, solve problems effectively, overcome any changes that occur, seize the available opportunities, excel in technology, adapt with change, success in their life, excel at work, or can change the face of the world.

Craft [5]; De Bono [6]; and Feldman & Benjamin [7] stated, all individuals have the potential to be creative, and the ability to think creatively can be developed through continuous practice. Based on this opinion, curriculum reform has been carried out, and creative thinking has been included in education policy in western countries such as the US, UK, France, Germany, Sweden and Australia [7][5][8].

Asian countries also respond to this trend. Phenomena in China show that high-achieving students in mathematics at international events are noted to have low rankings in imagination and creative thinking [9]. In Hong Kong, creative thinking is recognized as one of three generic skills to be developed in education, and some general principles for developing creative thinking have been included in the curriculum [10]. In other countries, such as Japan, South Korea, Taiwan, and Singapore have also implemented curriculum reforms with an emphasis on developing creative thinking [8][11]. This is done top-down [10].

Indonesia as a developing country realizes that to be a developed and parallel country with other developed nations, creative human resources are needed. Therefore, the ability to think creatively is included in the goals of national education. This is stated in Ministerial Regulation No. 22 of 2006:

National education based on Pancasila and the 1945 Constitution of the Republic of Indonesia serves to develop the ability and shape of dignified national character and civilization in order to educate the lives of the nation, aiming to develop the potential of students to become believers and fear of the Almighty God, noble, healthy, knowledgeable, capable, creative, independent, democratic citizen and responsible.

In the 2025 vision of the Ministry of National Education, it states that:

In order to realize the ideals of developing the intellectual life of the nation and in line with the vision of national education, the Ministry of National Education has a vision of 2025 to produce intelligent and competitive Indonesian people. Smart Indonesian people are comprehensive intelligent people, namely emotionally intelligent, socially intelligent, intellectual intelligent, and kinesthetic intelligent. Intellectual intelligence is the actualization of intellectual people who are critical, creative, innovative and imaginative.

The seriousness of the Indonesian government in addressing the importance of creative thinking is marked by the issue of the curriculum 2013 which leads to the formation of people who are creative, characterized, and never give up. Fryer [12], Esquivel [13], Cheng [14]; said that learning models, strategies, approaches, and methods used by teachers play a great role to develop students' creative thinking. Curriculum 2013 requires teachers to use a scientific

approach to learning in schools that are believed to be able to develop students' creative thinking. However, in the curriculum 2013, it is not implicitly explained why scientific learning can develop students' creative thinking, especially in terms of mathematics. Therefore, this paper will examine the theoretical relationship between scientific learning and students' creative thinking in solving mathematical problems.

II. THE CONNECTION OF SCIENTIFIC LEARNING, CREATIVE THINKING, AND MATHEMATICAL PROBLEM SOLVING

Larson [15] places problem-solving as the highest in the hierarchy of intellectual skills. According to him in solving problems, there occur more complex forms of teaching that require simpler rules that must be known in advance. In general, the goal of problem-solving learning is to improve high-level thinking skills. Higher-order thinking skills are characterized by the following characteristics: not algorithmic, tend to be more complex, produce a variety of solutions, involve a variety of criteria and thought processes, see structure in order, and involve deep mental effort.

The relationship between creative thinking and problem solving, among others, was stated by Launch Pad [16], that there are at least three important aspects of skill in thinking, namely critical thinking, creative thinking, and problem-solving. These three aspects complement each other, but on the other hand, need each other. Problem-solving requires finding problems and questions to investigate (creative thinking) and evaluating needed solutions (critical thinking). Open-ended problem solving can be used as a vehicle to uncover creative thinking, which is related to divergent thinking in solving problems. This shows that in building knowledge and skills to solve problems, both in mathematics and in everyday life requires the ability to think creatively.

Hwang et al. [17] and Nakin [18] define creative thinking as an association process and synthesis of various concepts that can be used to solve problems while Krutetskii [19] views creative thinking as an approach to finding problem solutions in an easy and flexible way. Nakin [18] views creative thinking as a problem-solving process. A clearer link between creative thinking and problem-solving is presented by Treffinger et al. [20], that the ability to think creatively is needed to solve problems, especially complex problems. This opinion is strengthened by Wheeler et al. [18] which states that without the ability to think creatively, individuals find it difficult to develop their imaginative abilities so that they are unable to see various alternative solutions to problems. The importance of the ability to think creatively in problem solving activities is shown by the results of research conducted by Hwang et al [17], which concluded that the ability of elaboration, which is one component of creative thinking, is a key factor that stimulates students to create their knowledge in problem-solving activities and creative thinking skills support individual performance in problem-solving activities. McIntosh [21], Isaksen [18], and Robinson [22] explain that a vehicle or context that supports the growth of creative thinking abilities is a problem-solving task.

The scientific approach, or more generally, is said to be a scientific approach in the curriculum 2013. Before discussing the scientific approach, it is necessary to understand the scientific method. In general, someone always wants to get knowledge. Knowledge can be scientific knowledge and

unscientific knowledge. Scientific knowledge can only be obtained from the scientific method. Scientific methods basically look at special (unique) phenomena with specific and detailed studies to then formulate in conclusions. Thus, the need for reasoning can occur in the framework of search (discovery). To be called scientific, the method of inquiry must be based on evidence from observable, empirical, and measurable objects with specific principles of reasoning. Therefore, the scientific method generally contains a series of data collection activities or facts through observation and experiment, then formulating and testing hypotheses. Furthermore, simply a scientific approach is a way or mechanism to gain knowledge with procedures based on a scientific method. There are also those who interpret the scientific approach as a mechanism to acquire knowledge based on logical structures. This scientific approach requires steps, namely: observing, asking, reasoning, trying, and forming networks. In fact, the scientific character of each subject matter is not the same. Therefore the scientific approach to certain lessons is not exactly the same as other specific lessons. For example in mathematics, the steps are in the scientific approach as follows.

A. *Observing and Asking*

Objects observed in mathematics are two things, namely: direct objects and indirect objects. Direct objects are very suitable for elementary school children, while indirect objects are very suitable for students who already accept logical truths. In observing indirect objects, students can find facts in the form of definitions, axioms, postulates, theorems, properties, graphs and so forth. The question cannot be separated from observing activities. Careful observation will produce various information in the form of facts, concepts, and principles. This has an impact on the quality and varied questions. To get perfect observations and quality and varied questions, accuracy, perseverance, ability to connect various facts and various concepts are needed. They are the ability to bring up knowledge stored in long-term memory. This can develop the ability to identify problems, formulate problems, find goals problems, find problem-solving strategies, and divergent thinking skills. If the students' abilities are hierarchical and continuously trained, it will have an impact on the growth and development of the ability to find various ways and solutions and to solve the problems faced. In other words, scientific learning is related to fluency and flexibility.

B. *Reasoning (Associating), Trying and Concluding*

Reasoning, in general, is a process of logical and systematic thinking of empirical facts that can be observed to obtain conclusions in the form of knowledge. Here, reasoning can have a meaning of associating and can also be the reasoning. There are two ways of reasoning, namely inductive reasoning and deductive reasoning. Inductive reasoning is a way of reasoning by drawing conclusions from specific phenomena for general matters. Inductive reasoning activities are more based on sensory observation or empirical experience. Deductive reasoning is a way of reasoning by drawing conclusions from statements or phenomena that are general in nature towards specific things. The mechanism of deductive reasoning is to apply things that are general in advance to be connected to their specific parts. Trying in mathematics cannot be separated from the ability to connect and elaborate concepts and facts. This elaboration result will generate various strategies. To produce the right strategy is

sometimes generated through multiple elaboration processes. In other words, to produce the right strategy, students must go through the process of trying many times. In the process of reasoning and trying requires the ability to elaborate and make the connection between analytical, systematic, and divergent thinking skills. If this ability is continuously trained in students, it will develop students' ability to elaborate and find different strategies and solutions (fluency and flexibility).

C. Communicating or Intertwining

Communicating or intertwining in mathematics is defined as the mental activity that students do to 1) generalize conclusions that have been discovered through the process of reasoning and trying 2) implementing or linking conclusions that have been found with the real problems or other subjects. Achievement of one of these goals allows students to find or create a new way or solution or principle. For example, students associate trigonometric functions with swing motion in physics.

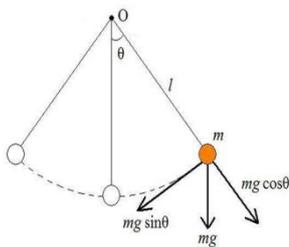


Fig. 1. Trigonometric functions with swing motion in physics

III. CONCLUSION

Building on the aforementioned outline, it can be concluded as the following.

A. The connection of Scientific Learning, Creative Thinking, and Mathematical Problem Solving

The connections are: (1) observing and questioning activities have a positive relationship with problem-solving abilities in the aspect of identifying problems, finding the purpose of the problem, and formulating problems, (2) identifying problems, finding the purpose of the problem, and formulate problems related to positive ability to think creatively in fluency and flexibility aspects, (3) reasoning and trying activities are positively related to problem solving abilities in terms of finding problem solving strategies, choosing the right strategy, implementing strategies, (4) finding solutions strategies problems, choosing the right strategy, implementing strategies related positively to the ability to think creatively in the aspects of fluency, flexibility, and elaboration, (5) activities to conclude and communicate or intertwine are positively related to problem solving abilities in terms of finding a solution strategy problems, choose the right strategy, implement strategies, and look back or verify conclusions, (6) find a problem solving strategy, choose the right strategy, implement strategies, and look back or verify conclusions related positively with the ability to think creatively in the aspect of creating or novelty.

B. The development of Mathematical Problem-Solving Ability and Students' Creative Thinking Ability

Mathematical problem-solving ability and students' creative thinking ability can be developed through the application of scientific learning appropriately and continuously.

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