Al Khawarizmi: Jurnal Pendidikan dan Pembelajaran Matematika | **ISSN 2549-3906**
E-ISSN 2549-3914

THE EFFECTS OF PROBLEM-BASED LEARNING ON CREATIVE THINKING SKILLS AND MATHEMATICAL COMMUNICATION ABILITIES OF SENIOR HIGH SCHOOL STUDENTS

Khairul Umam[1], Suryawati[2], Suhartati[3], M. Hasbi[4]
[1,2,3,4]Department of mathematic Education, Syiah Kuala University
khumam77@unsyiah.ac.id

Abstrak

Pembelajaran matematika tidak hanya sekedar pembelajaran untuk mengembangkan kemampuan berhitung tetapi pembelajaran yang mengembangkan kemampuan berfikir matematika secara logis, sesuai dengan konsep matematika yang sistematis dengan melibatkan lingkungan siswa. Keterampilan berpikir kreatif dan kemampuan komunikasi merupakan dua aspek kemampuan yang harus dimiliki oleh peserta didik disamping keterampilan afektif.Penelitian ini bertujuan untuk mengetahui pengaruh pembelajaran berbasis masalah (*problem-based learning*) terhadap keterampilan berpikir kreatif dan kemampuan komunikasi matematis siswa. Penelitian ini menggunakan kuasi eksperimen dengan desain pre-test dan post-test. Subjek penelitian terdiri dari 50 siswa SMA. Pengumpulan data dilakukan dengan mengadakan pre-test dan post-test serta pemberian angket. Data dianalisis dengan menggunakan rubrik berpikir kreatif dan komunikasi matematis, kemudian diolah lebih lanjut dengan uji statistik. Hasil penelitian mengungkapkan bahwa pembelajaran berbasis masalah dapat meningkatkan kemampuan berpikir kreatif dan komunikasi matematis siswa lebih baik daripada pendekatan pembelajaran konvensional. Oleh karena itu, penelitian ini menunjukkanbahwa strategi pembelajaran memiliki peran penting dalam pengembangan kreativitas dan komunikasi matematis siswa.

Kata kunci: *Problem-based learning*, kemampuan komunikasi matematis, kemampuan berpikir kreatif

Abstract

Mathematics learning is not just learning to develop numeracy skills but learning that develop the ability to think matematics logically, according to a systematic mathematical concepts by involving students' environment. Creative thinking skills and communication abilities are two aspects of capabilities that must be owned by the students besides affective skills. This study aims to investigate the effects of problem-based learning on students' creative thinking skills and mathematical communication ability. The study used a quasi-experimental with pre-test and post-test design. The participants were 50 senior high school students. Data were collected by conducting pre-test and post-test and administering questionnaire. The data were analyzed using rubrics of creative thinking and mathematical communication, then processed further with statistical tests. The findings revealed that problem-based learning could improve students' creative thinking skills and mathematical communication abilities of students better than conventional learning approach. Therefore, this study suggests that instructional strategies have important roles for development of creativity and mathematical communication of students.

Keywords*: Problem-based learning, mathematical communication ability, creative thinking skills.*

INTRODUCTION

In mathematics learning, teacher is expected to create the learning that gives students more time to learn because the students' ability will not grow by itself. The best mathematics learning emphasizes the connection between students' mathematical concepts and their experiences since students need to apply the concept of mathematics to their life or in other fields. Mathematics learning also aims not only to develop numeracy skills but also to develop the ability to think mathematics logically, according to a systematic mathematical concepts by involving students' experiences. Creative thinking skills and communication abilities are two aspects of capabilities that must be owned by the students, in addition to affective skills, that support their interest in education.

Creative thinking is the ability to create new ideas or solutions in a problem-solving process (Hadar & Tirosh, 2019). Hadar and Tirosh classified creative thinking processes into three general dimensions: divergent, convergent-integrative, and lateral. Divergent thinking is defined as thinking of various ways of problem solving by providing different alternative solutions (Sun, Wang, & Wegerif, 2020). Convergent-integrative thinking means connecting mathematical ideas with other areas as the basis for new mathematical understandings, and connecting mathematical ideas with other contexts (Aizikovitsh-Udi & Star, 2011). Lateral thinking refers to generating and exploring innovative ways to deal with problems and recommending new mathematical understandings instead of following preexisting patterns (Hadar & Tirosh, 2019).

Moreover, researchers have defined criteria for creative thinking. Beghetto and Kaufman (2013) state that creative thinking involves originality and task appropriateness, while according to Runco and Jaeger (2012), creativity needs the criteria of originality and effectiveness. Levenson (2011) mentions that components of mathematical creativity includes originality, fluency, and flexibility. According Awang and Ramly (2008, p.63), "originality relates to the ability to produce uncommon or unique responses; fluency is the ability to produce a large number of ideas from which to choose; and flexibility is the ability to consider a wide variety of rather dissimilar approaches to a solution."These three components of creative thinking are the most widely used by researchers to assess creative thinking.

Another important ability needed by students in mathematics learning is mathematical communication. Communication ability is a tool to be effective leaders.

Through communication ability, leaders can interpret and process the information that he received and delivered back in a better language.In mathematics learning, mathematical communication is the ability to express, understand, interpret, assess and respond mathematical ideas and use terms, notations, and symbols to present mathematical ideas (Rohid, Suryaman, & Rusmawati, 2019). The National Council of Teachers of Mathematics(NCTM)(2000) suggests that learning mathematics in schools must provide the opportunity for students to: (1) arrange and associate their mathematical thinking through communication; (2) communicate their mathematical thinking logically and clearly to his friends, teachers, and others; (3) analyze and evaluate the mathematical thinking and strategies employed by others; and (4) use the language of mathematics to express mathematical ideas correctly.

Moreover, the assessment of mathematical communication should be integrated with mathematics assessment. In the assessment of mathematical communication, students are expected to be able to: "(1) express mathematical ideas by speaking, writing, demonstrating, and depicting them visually; (2) understand, interpret, and evaluate mathematical ideas presented in written, oral, or visual forms; (3) use mathematical vocabulary, notation, and structure to represent ideas, describe relationships, and model situations" (NCTM, 1989, p. 214).

Considering the importance of creative thinking and mathematical communication in mathematics learning, the need for implementing instructions that help develop those skills should be addressed by the teachers. According to Schoevers et al. (2019), several recommendations to improve creativity include creating an open classroom atmosphere and providing open lessons.Open classroom atmosphere refers to providing students opportunity to develop new mathematical concepts through interactions with classmates. This such classroom supports reflecting on mathematical ideas, multiple responses, sharing ideas, collaboration, and discovery (Schoevers et al., 2019).Meanwhile, open lessons mean inviting students to various solutions. That is, the lesson should allow students to search, explore, adapt strategies, advise plans, justify, conclude, and reflect (Nadjafikhah, Yaftian, & Bakhshalizadeh, 2012). In addition to that, a classroom that allows multiple interactions is key to foster mathematical communication, meaning that the learning should facilitates students to communicate their thinking and utilizes the mathematical language to express their mathematical ideas (Rohid et al., 2019).

One of learning models that have the potential to improve students' creative thinking and mathematical communication is Problem-Based Learning (PBL). PBL is an instructional approach that refers to constructivist theory, which students become a center of learning. PBL is known as a learning model where problems direct the learning (Hung, Jonassen & Liu, 2008; Roh, 2003). Savery (2015) defined PBL as a "learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (p.5).PBL has several characteristics: (1) problem focused—students begin learning by dealing with an authentic problem; (2) student centered; (3) self-directed—students individually and collaboratively generate learning problems and processes as well as find their own learning sources; (4) self-reflective—students reflect on their learning and learn to find alternative strategies for learning; and (5) teachers serve as facilitators who support and facilitate students' learning (Hung et al. 2008). Hung et al. also outline four phases of PBL, including: (1) students in groups attempt to define, understand and reason through the problem; (2) during self-directed study, individual students search for resources and report to the group; (3) students share their learning with the group and revisit the problem; and (4) students summarize and integrate their learning (Hung et al. 2008).Given those characteristics and phases of PBL, PBL embeds the characteristics of classroom environment recommended by Nadjafikhah, et al. (2012) and Rohid et al. (2019).

Furthermore, several researchers have studied the effect of PBL to improve creative thinking and mathematical communication. Awang and Ramly (2008) have impemented PBL model to improve students' creative thinking abilities. The method used in their study was a quasi-experimental (pretest–posttest) with 60 diploma students in Civil Engineering of Malaysian Polytechnics as a population. The samples were taken randomly and divided into two groups: an experimental group and a control group. Other researchers (Anjarwati, Sajidan, & Prayitno, 2018) have investigated the effect of PBL on students' creative thinking at senior high school levels. They found that the score of creative thinking skills of experimental group was higher than that of the control group.Ersoy and Baser (2014) and Birgili (2015) also revelead the improvement on students' creative thinking score after PBL implementation.

In regard to mathematical communication, Abdullah, Tarmizi, and Abu (2010) investigated the effects of PBL on mathematics performance and instructional efficiency. It also compared the affective products of learning between PBL and the conventional teaching. It was found that both PBL and conventionalgroups showed positive perception towards group work and endorsed the importance of helping and working with their classmates. However, many students find it hard to explain themselves while working in a group. On the aspect of interest in mathematics, although overall both groups showed positive interesting the subject, students in the conventional group showed a higher interest for mathematics.On student's perception towards the learning experience they went through, the experimental group agreed that the PBL was more effective in explaining difficult mathematical concepts and let them to understand the content better. This group also recommended the PBL approach for the next lessons and be implemented for other subjects.Other researchers have also confirmed that PBL has a significant influence on students' mathematical communication (Surya, Syahputra, & Juniati, 2018; Nufus& Mursalin, 2020).

Based on the explanation above, this research aims toinvestigate the effects of problem-based learning on creative thinking skills and mathematical communication ability of senior high school students in Banda Aceh.The objectives of the research are:

1. To examine the achievement of students' mathematical creative thinking skillswith problem-based learning and conventional learning.
2. To examine the achievement of students' mathematical communication abilities with problem-based learning and conventional learning.
3. To examine the increase of students' mathematical creative thinking skillswith problem-based learning and conventional learning.
4. To examine the increase ofstudents' mathematical communication abilities with problem-based learning and conventional learning.
5. To investigate the students' responsetoward problem-based learning model, mathematical creative thinking skills, and mathematical communication abilities.

METHOD

Design of Study

This study is a quasi-experimental research with pre-test and post-test design. Experimental and control groups were made to investigate the effect of problem-based learning on creative thinking and mathematical communication ability of both groups.

Settings

This study was conducted in one of senior high schools in Banda Aceh for two months.

Participants

The population includes all students (five classes) in a senior high school in Banda Aceh, with the total of 125 students. From five classes, the researchers randombly chose two classes which were later labeled as experimental and control groups.Each group consisted of 25 students. Thus, in total, participants of this study were 50 senior high school students. The experimental group was taught using PBL, and the control group was taught conventionally, where each group received eight lessons (meetings) in total.

Procedure

This study was conducted by following several procedures. In the first phase, the researchers gave pre-test for students both in experimental and control classes. In the next phase, both classes were given treatments. Problem-based learning model was applied in the experimental class while a conventional learning was implemented for the control class.The lessons were conducted for eight meetings. Subsequently, students in both classes were taken a post-test. Moreover, questionnaire was distributed to both groups of students to investigate their responses toward problem-based learning model and their mathematical creative thinking skills and mathematical communication abilities.

Data, Intrument, and Data Collection

Data were collected by administering pre-test and post-test to assess studens' mathematical creative thinking skills and mathematical communication abilities. Data were also gathered from questionnaire to learn students' responses to problem-based learning model and their mathematical creative thinking skills and mathematical communication abilities.Therefore, there were three instruments used in this study: tests, questionnaire, and rubrics. All those instruments were adopted and adapted from the previous research.

Data Analysis

Data collected from pre-test and post-test were analyzed based on the rubrics of mathematical creative thinking skills and mathematical communication abilities.The rubric of creative thinking skills comprised three components: originality, fluency, and flexibility (Levenson, 2011; Awang & Ramly, 2008). Whilst, the rubric for mathematical communication contained the components of mathematical language, representation, and explanation. The data were processed further with statistical tests.

RESULTSAND DISCUSSION

Results

The results of creative thinking skills referring to originality, fluency and flexibility components for students with different learning approaches in both experimental and control classes are showed in Table 1.

Tabel 1
Mean Scores for Creative Thinking

Method	**Originality**		**Fluency**		**Flexibility**	
	Pre	Post	Pre	Post	Pre	Post
PBL	38.27	46.77	48.45	58.91	35.18	39.19
Conventional	34.58	40.22	41.56	49.88	29.51	30.51

The findings indicate that overall creativity of students is characterized mainly by two component abilities, namely originality and fluency. Students who achieve a high score on originality have the ability to produce unexpected ideas. The highest score on fluency shows that students are capable of producing a large number of ideas in response to problem-solving situations. The flexibility scores reveal that most of students are not flexible in their approach to learning and acquisition of concepts. The results of the study suggest that problem-based learning approach could improve the creative thinking skills of students compared to conventional learning approach.

In addition, the results of mathematical communication abilities for problem-based learning (PBL) group and conventional learning (CL) group are presented in Table 2.

Tabel 2
Means and Standard Deviations on Mathematical Communication and Teamwork Based on Rubric

	Means		Standard Deviations	
Mathematical Communication	**PBL**	**CL**	**PBL**	**CL**
1. Mathematical language	2.90	2.58	0.41	0.83
2. Representation (tables and graphs)	2.62	2.46	0.56	0.83
3. Explanation	2.48	2.17	0.57	0.76
Total	**8.00**	**7.21**	**1.55**	**2.42**
Teamwork				
1. Working with others	2.66	2.50	0.55	0.83
2. Attitude in group	2.62	2.50	0.56	0.83
3. Focus on the task	2.62	2.50	0.56	0.83
4. Quality of work	2.59	2.67	0.73	1.01
5. Pride in work	2.76	2.29	0.91	1.00
Total	**13.24**	**12.46**	**3.32**	**4.51**

Total mean score for mathematical communication for the PBL group (8.00) seems higher than the CL group (7.21). The PBL group also has higher mean scores for mathematical language, representation and explanation ascompared to the CL group. The PBL group also displays a higher total mean score for teamwork (13.24) ascompared to the CL group (12.46). They were also awarded higher scores for working with others, attitude in group, and focus on the task and taking pride in their work. However, for quality of work, the CL group's mean score washigher (2.67) compared to the PBL group (2.59). The PBL group used the Polya's problem solving heuristic more effectively, displayed better mathematical communication skills and showed stronger teamwork compared to the CL group.However, minimal differential effect on mathematics performance and instructional efficiency was obtainedbetween the PBL and CL group. Hence, this indicates that the efficacy of PBL has yet to be explored in enhancing these aspects in the teaching and learning of mathematics.

Discussion

This study aims to examine the effects of problem-based learning on students' creative thinking skills and mathematical communication ability.The results showed that problem-based learning could improve students' creative thinking skills compared to conventional learning approach.This finding is aligned withprevious research revealing that problem-based learning effectively fosters creativity more than the traditional learning (Batdı, 2014). Ülger and Imer (2013) also found the significant effect of problem-based learning on students' creative thinking skills. Besides, Birgili (2015) suggests problem-based learning environments are helpful to develop creativity since creative thinking is related to problem solving.

Moreover, the findings indicated thatproblem-based learning could foster students' mathematical communication abilities. This result was confirmed by previous research (Abdullah, Tarmizi, & Abu, 2010; Nufus& Mursalin, 2020) that students who learned with problem-based learning demonstrated better mathematical communication than those who were taught traditionally. Another study (Surya, Syahputra, & Juniati, 2018) confirmed that there was a significant effect of learning model on students' mathematical communication, which in this case, problem-based learning significantly influenced communication ability compared with conventional learning. Finally, the findings of the present study suggest that instructional strategies have important roles for development of creativity and mathematical communication. This implies that teachers should be able to facilitate students with appropriate strategies that allow them to develop their capabilities.

CONCLUSION

The current study aims to discover the effects of problem-based learning on students' creative thinking skills and mathematical communication ability. The findings revealed that problem-based learning could improve students' creative thinking skills and mathematical communication abilities of students better than conventional learning approach. However,the phenomena would be very different when viewed from the side of each of the regions social and cultural as well as a shift study period. Effect of a model of perceived student learning in the previous period would be very different from today. Therefore, it is necessary to review the learning process to become effective continuously.

REFERENCES

Abdullah, N. I., Tarmizi, R. A., & Abu, R. (2010). The effects of problem based learning on mathematics performance and affective attributes in learning statistics at form four secondary level. *Procedia-Social and Behavioral Sciences*, *8*, 370-376.

Abdullah, N. I., Tarmizi, R. A., & Abu, R. (2010). The effects of problem based learning on mathematics performance and affective attributes in learning statistics at form four secondary level. *Procedia-Social and Behavioral Sciences*, *8*, 370-376. https://doi.org/10.1016/j.sbspro.2010.12.052

Aizikovitsh-Udi, E., & Star, J. (2011). The skill of asking good questions in mathematics teaching. *Procedia-Social and Behavioral Sciences*, *15*, 1354-1358.

Anjarwati, P. G. P., Sajidan, S., & Prayitno, B. A. (2018). Problem-based learning module of environmental changes to enhance students' creative thinking skill. *Biosaintifika: Journal of Biology & Biology Education*, *10*(2), 313-319.

Awang, H., & Ramly, I. (2008). Through Problem- Based Learning : Pedagogy and Practice in the Engineering Classroom. *International Journal of Human and Social Sciences*, *2*(4), 18–23.

Batdı, V. (2014). The effects of a problem-based learning approach on students' attitude levels: A meta-analysis. Educational Research and Reviews, 9(9), 272-276.

Beghetto, R. A., & Kaufman, J. C. (2013). Fundamentals of creativity. *Educational leadership*, *70*(5), 10-15.

Birgili, B . (2015). Creative and Critical Thinking Skills in Problem-based Learning Environments . *Journal of Gifted Education and Creativity*, 2 (2) , 71-80 . Retrieved from https://dergipark.org.tr/en/pub/jgedc/issue/38680/449365

Ersoy, E. & Baser, N. (2014). The effects of problem-based learning method in higher education on creative thinking. *Procedia-Social and Behavioral Sciences*, *116*, 3494-3498.

Hadar, L. L., & Tirosh, M. (2019). Creative thinking in mathematics curriculum: An analytic framework. *Thinking Skills and Creativity*, *33*, 100585. https://doi.org/10.1016/j.tsc.2019.100585

Hung, W., Jonassen, D. H., & Liu, R. (2008). Problem-based learning. *Handbook of research on educational communications and technology*, *3*(1), 485-506.

Levenson, E. (2011). Exploring Collective Mathematical Creativity in Elementary School. *The Journal of Creative Behavior*, *45*(3), 215-234.

Nadjafikhah, M., Yaftian, N., & Bakhshalizadeh, S. (2012). Mathematical creativity: some definitions and characteristics. *Procedia-Social and Behavioral Sciences*, *31*, 285-291.

National Council of Teachers of Mathematics (1989). Curriculum and evaluation standards for school mathematics. Reston, VA.

National Council of Teachers of Mathematics. (2000). *Principles and Standards for School Mathematics*. Reston VA : NCTM

Nufus, H., & Mursalin, M. (2020). Improving Students' Problem Solving Ability and Mathematical Communication through the Application of Problem Based Learning. *Electronic Journal of Education, Social Economics and Technology*, *1*(1), 43-48.

Roh, K. H. (2003). *Problem-based learning in mathematics*. ERIC Clearinghouse.

Rohid, N, Suryaman, & Rusmawati, R. D. (2019). Students' Mathematical Communication Skills (MCS) in Solving Mathematics Problems: A Case in Indonesian Context. *Anatolian Journal of Education*, *4*(2), 19-30.

Runco, M. A, & Jaeger, G. J. (2012). The Standard Definition of Creativity. *Creativity Research Journal*, *24*(1), 92-96.

Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. *Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows*, *9*, 5-15.

Schoevers, E. M, Leseman, P. P.M., Slot, E. M., Bakker, A., Keijzer, R., & Kroesbergen, E. H. (2019). Promoting pupils' creative thinking in primary school mathematics: A case study. *Thinking Skills and Creativity, 31*, 323-334.

Sun, M., Wang, M., & Wegerif, R. (2020). Effects of divergent thinking training on students' scientific creativity: The impact of individual creative potential and domain knowledge. *Thinking Skills and Creativity*, *37*, 100682.

Surya, E., Syahputra, E., & Juniati, N. (2018). Effect of problem based learning toward mathematical communication ability and self-regulated learning. *Journal of Education and Practice*, *9*(6), 14-23.

Ülger, K. A. N. İ., & Imer, Z. (2013). The effect of problem based learning (pbl) approach on students' creative thinking ability. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *28*(1), 382-392.