JIPM: Jurnal Ilmu dan Pendidikan Matematika
Vol. 2 No. 1 April (2024)
e-ISSN: 2988-7763
DOI: 10.33830/hexagon.v2i1.6163

Increasing Mathematical Literacy and Numeracy Abilities with Problem-Based Learning Model Through Technological Pedagogical Content Knowledge

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ARTICLE INFO

Article history:
Received: January 10th, 2024
Revised: March 13th, 2024
Accepted: April 2nd, 2024
Available: online April 30th, 2024

Keywords:
Mathematical literacy ability, mathematical numeracy ability, PBL, TPACK

ABSTRACT

The background of this research was that nowadays, high school students are required to have a significant understanding and appreciation of mathematics. The fact was that students experience difficulties in learning mathematics, including their mathematical literacy and numeracy abilities. This study examined the increase in mathematical literacy and numeracy abilities with the problem-based learning (PBL) model using technological pedagogical content knowledge (TPAK). The method used in this research was quasi-experimental. The statistical analysis tool used was the MANOVA test, which analyzes two dependent variables (mathematical literacy and numeracy abilities) simultaneously—and then uses the t-test of two independent and dependent samples. The instrument test consists of 5 essay questions with the subject matter trigonometry. The research sample was class XI at one of the public high schools in Bandung, which consisted of 2 classes, each composed of 31 students. The results showed a significant difference in the achievement and improvement of mathematical literacy and numeracy abilities jointly owned by students in the two learning groups. The conclusions obtained in this study were that there were simultaneously increasing differences in achievement of mathematical literacy and numeracy abilities between students who received the PBL model using TPACK and a scientific approach.

INTRODUCTION

Learning mathematics is an essential aspect of the education system, and it aims to improve students' mathematical literacy and numeracy abilities (Kuswanti, 2023). Mathematical literacy abilities involve understanding, using, and interpreting mathematical information. In contrast, mathematical numeracy involves the ability to understand, use, and communicate mathematical concepts and processes in various contexts of everyday life. Mathematical solid literacy and numeracy abilities are prerequisites for success in education (Genc & Erbas, 2019). Mathematics is a subject that forms the basis for many disciplines, including science, technology, engineering, and economics. Literacy and numeracy abilities have broad applications in daily life, education, career, and social participation. For example, in Grocery shopping, understanding product labels, comparing prices, and calculating quantities require numeracy skills. Reading shopping lists and understanding written descriptions of products also involves literacy. Enhancing these two abilities is essential for individuals to function well in an increasingly complex society, increasingly technologically advanced, and evolving challenges in various fields (Graesser et al., 2021).

Literacy and numeracy are essential concepts needed to increase Indonesia's human resources. In the current context, literacy and numeracy not only cover the ability to read, write, and count but literacy and numeracy are interpreted as life abilities that cover many aspects of human life (Fauziyyah et al., 2020) (Inten, 2017). One of the indicators used in measuring developed countries is looking at the level of literacy and the lives of its people. Lavenia et al. (2023) State that literacy rates are essential in order to have sources of quality human resources so that they can improve their standard of living, which will reduce the number unemployment in a place and the importance of wage adjustments to the basic needs of that community can be fulfilled or not. In order to stand on an equal footing with developed countries, serious efforts are needed to improve the nation's literacy and numeracy in order to support the achievement of the collective intelligence of the Indonesian people (Idrus et al., 2020). Moreover, in a competitive global context, especially in education, literacy and numeracy must be mastered by all stakeholders, including internal stakeholders such as teachers, students, parents, and the school ecosystem (Ferianti & Irna, 2020).

Literacy and numeracy abilities are essential for students to master from the elementary school level so that it is easier to understand other fields of knowledge and as a provision for continuing education at a higher level (Ifrida et al., 2023). Mathematical literacy and numeracy abilities are essential in everyday life, education, and career, as well as in addressing complex issues. Mathematical abilities help us to think logically, develop analytical abilities, and make intelligently informed decisions. Therefore, it is essential to prioritize the development of mathematical literacy and numeracy abilities as part of a comprehensive education. For example, reading bus or train schedules, understanding route maps, and calculating fares require literacy and numeracy skills.

Research related to numeracy abilities has been carried out by (Maulidina & Hartatik, 2019), which states that high-ability elementary school students can use various types of numbers or symbols related to basic mathematics to solve problems in various contexts in everyday life, can analyze various information displayed in various form (graphs, tables, charts, diagrams, so on), as well as being able to interpret the results of the analysis to predict and make good decisions. The research results (Ayuningtyas & Sukriyah, 2020) show that students of the Mathematics Education study program have low numeracy knowledge but are quite capable of understanding the categories of numeracy questions. Research conducted by (Mahmud and Pratiwi, 2019) shows that students can solve unstructured problems in everyday life by using numeracy abilities; students can analyze information based on questions and then make interpretations to predict and draw conclusions. Furthermore, the study's results (Winata et al., 2021) show that the reading literacy and numeracy abilities of class XI students of MA DarulMa'wa Plandirejo are still low.

To improve literacy and mathematical abilities in this study, the PBL Model with the TPACK approach is used as a solution. The PBL Model is a student-centred learning method in which students are given real problems that encourage them to think critically, analyze, and solve problems collaboratively (Ali, 2019). PBL provides students with relevant context and helps them better understand mathematical concepts (Mustaffa et al., 2016). In mathematical literacy and numeracy, PBL can help students relate mathematical concepts to real life, thus increasing their understanding and ability to solve complex mathematical problems (Simamora et al., 2017).

The application of the TPACK approach combines three essential elements, namely technological knowledge (TPACK-T), pedagogical knowledge (TPACK-P), and knowledge of mathematical content (TPACK-C) (Janah, 2022). Technological knowledge refers to the teacher's understanding of the use of technology in the context of learning mathematics. Pedagogical knowledge relates to effective learning strategies and methods in teaching mathematics. At the same time, knowledge of mathematical content involves the teacher's understanding of mathematical concepts and structures.

In the PBL model using TPACK, the teacher acts as a facilitator who helps students solve math problems with the help of relevant technology. In the steps of PBL, teachers can use technology, such as math software or interactive aids, to help students explore math concepts visually and interactively. This allows students to build deeper understanding and acquire better mathematical literacy and numeracy abilities.

One example of applying PBL with TPACK in learning mathematics is by giving students projects or assignments related to the real world. For example, students are assigned to design a playground that requires an understanding of measurement, geometry, and data analysis. While completing the assignment, students use graphic design software or modelling applications to develop their playground plans. They also collect and analyze data about children's preferences regarding certain games. Through this project, students develop their mathematical abilities and improve their mathematical literacy and numeracy abilities by thinking critically, communicating their ideas, and collaborating with classmates.

In conclusion, PBL with the TPACK approach effectively improves students' mathematical literacy and numeracy abilities. By blending technology, pedagogy, and mathematics content knowledge, students can better understand mathematical concepts and apply them in real-life contexts. PBL with TPACK also assists students in developing critical thinking, collaboration, and communication abilities, which are very important in dealing with the challenges of mathematics in today's digital era. Therefore, this approach should be considered an innovative and compelling learning strategy for teaching mathematics.

METHOD

The method used in this research was quasi-experimental because the researcher did not randomize classes. The statistical analysis tool used was the MANOVA test to simultaneously analyze two dependent variables (mathematical literacy and numeracy abilities). The subject matter is Then used for the t-test of two independent and dependent samples. The research sample was class XI at one of the public high schools in Bandung, consisting of 2 classes. Each class consist of 31student. The instrument test consists of 5 essay questions with the subject matter trigonometry. At the beginning and end of learning, both classes were given a test so that the research design was as follows Ruseffendi (Hidayat & Yuliani, 2012):

O X O
____
O O

Information:
X : PBL model using TPACK
O : Pretest / Posttest (mathematical literacy and numeracy abilities test)
________ : Sampling is not random.

The pretest and post-test data were then analyzed by inference using appropriate statistical analysis tools, SPSS 24. The inferential statistical analysis tool used is the MANOVA (Multivariate Analysis of Variance) test, which analyses two dependent variables (mathematical literacy and numeracy abilities) simultaneously/together. Then, the t-test of two independent and dependent samples. These statistical analysis tools are used concerning the procedures written by (Dencik et al., 2019).

The following describes the use of statistical analysis tools in this study.

1) MANOVA Test (Multivariate Analysis of Variance), MANOVA is one of the multivariate analyses and is also an extension of the univariate, which can be used to examine simultaneously the relationship between several independent variables with a nominal or ordinal measurement scale and expressed as a treatment with two or more dependent variables that have an interval or ratio measurement scale and are described as independent variable. If the ANOVA tests whether there is a significant difference between one dependent variable and several independent variables, then MANOVA will test whether there is a significant difference between several dependent variables on more than one independent variable (Sarwono, 2014).

2) Two independent sample t-tests (Setiawan, 2019) were used to investigate and test differences in achievement and improvement in literacy and numeracy abilities in 2 learning groups, namely the group of students who received the PBL model through TPACK and the group of students who received a scientific approach (because these schools generally use scientific approach). Investigation and testing of differences in achievement and improvement of literacy and numeracy abilities are carried out separately (not simultaneously) between literacy and numeracy abilities. This was done to see which of the two independent variables had differences in the achievement and improvement of abilities in the two learning groups, namely the group of students who received the PBL model through TPACK and the group of students who received the scientific approach.

Achievement data were obtained from the posttest scores of mathematical literacy and numeracy abilities, while improvement data were obtained from the N-Gain of mathematical literacy and numeracy abilities. The N-Gain values and criteria are referred to by (Hake, 2002), as shown in Table 1.

$$N\_Gain = (\text{posttest score} - \text{pretest score})/(\text{maximum score} - \text{pretest score})$$

Table 1. N-Gain Index Criteria

Range	Criteria
< 0,3	Low
0,3 ≤ N_Gain < 0,7	Moderate
N_Gain ≥ 0,7	High

The analysis tool with the t-test is used to see which independent variables help answer the formulation of the problem about N-Gain.

RESULTS AND DISCUSSION

Results

Research questions 1

We are testing the hypothesis related to the achievement of students' mathematical literacy and numeracy abilities with the PBL model through TPACK and a scientific approach.
The results of inferential calculations for the mean difference test with the MANOVA test using SPSS 24.0 Statistics software are shown in Table 2.

Table 2. Multivariate Analysis Test Literacy and Numeracy Ability Posttest Scores

Effect		Value	F	Hypothesis df	Error df	Sig.
Kelas	Pillai's Trace	.204	7.567^{b}	2.000	59.000	.001
	Wilks' Lambda	.796	7.567^{b}	2.000	59.000	.001
	Hotelling's Trace	.256	7.567^{b}	2.000	59.000	.001
	Roy's Largest Root	.256	7.567^{b}	2.000	59.000	.001

a. Design: Intercept + Kelas
b. Exact statistic

From the calculations of the SPSS 24.0 Statistics software, the significance obtained for the four test statistics shows a value of sig (0.001) < 0.05, so it can be concluded that it is rejected, which means that there are differences in the achievement of mathematical literacy and numeracy abilities of high school students together between students who received the PBL model through TPACK with students who acquire a scientific approach.

Research question 2

Testing the hypothesis related to increasing students' mathematical literacy and numeracy abilities together with the PBL model through TPACK and a scientific approach.
The results of calculations with the MANOVA test using SPSS 24.0 Statistics software are shown in Table 3.

Table 3. Multivariate Analysis Test Literacy and Numeracy Ability N-Gain Scores

Effect		Value	F	Hypothesis df	Error df	Sig.
Class	Pillai's Trace	.224	8.495^{b}	2.000	59.000	.001
	Wilks' Lambda	.776	8.495^{b}	2.000	59.000	.001
	Hotelling's Trace	.288	8.495^{b}	2.000	59.000	.001
	Roy's Largest Root	.288	8.495^{b}	2.000	59.000	.001

a. Design: Intercept + Class
b. Exact statistic

From the calculations of the SPSS 24.0 Statistics software, the significance values for the four test statistics were obtained which showed a value of sig (0.001) < 0.05, so it can be concluded that they are rejected, which means that there is a significant difference between increasing students' mathematical literacy and numeracy abilities simultaneously between students who received the PBL model through TPACK with students who acquire a scientific approach.

Research questions 3

Testing the hypothesis related to the achievement of literacy abilities between classes that get the PBL model through TPACK and classes that get a scientific approach. Data from the difference test results of the two average values are presented in Table 4 below:

Table 4. Test Results for the Average Difference in Literacy Ability Posttest Scores

Literacy ability posttest	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	.245	.623	-1.351	60	.182	-1.161	.860
Equal variances not assumed			-1.351	58.766	.182	-1.161	.860

Based on Table 4, it can be seen that the Sig (2-tailed) value is 0.182. This value meets the test criteria, namely sig. (0,182) > 0.05, then H_0 is accepted. This shows that there is no difference in the achievement of students' mathematical literacy abilities between those who get the PBL model through TPACK and those who get the scientific approach.

Research questions 4

Testing the hypothesis related to increasing literacy abilities between classes that get the PBL model through TPACK and classes that get a scientific approach.
Data from the two average difference test results are presented in Table 5 below:

Table 5. Test Results for the Average Difference in Literacy Ability N_Gain Scores

Literacy ability N-Gain	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	0,344	0,560	-1.836	60	0,071	-0,071855	0,0391457
Equal variances not assumed			-1.836	56.25	0,072	-0,071855	0,0391457

Based on Table 5, it can be seen that the Sig (2-tailed) table is 0.071. This value meets the test criteria, namely sig. (0,071) > 0.05, then H0 is accepted. It was concluded that there was no difference in increasing the ability of mathematical literacy between students who received the PBL model through TPACK and classes that received a scientific approach.

Research questions 5

Testing the hypothesis related to the achievement of numeracy abilities between classes that receive the PBL model through TPACK and classes that receive a scientific approach.
The results of inferential calculations for the mean difference test with the t-test using SPSS 24.0 Statistics software are shown in Table 6.

Table 6. Test Results for the Average Difference in Numeracy Ability Posttest Scores

Numeracy ability posttest Scores	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	2.785	.100	-3.919	60	.000	-2.903	.741
Equal variances not assumed			-3.919	55.548	.000	-2.903	.741

Based on Table 6, it can be seen that the Sig (2-tailed) value is 0.000. This value does not meet the test criteria, namely sig. (0,00) < 0.05, then H_0 is rejected. This shows that there are differences in the achievement of mathematical numeration abilities between students who get the PBL model through TPACK and those who get a scientific approach.

The conclusion from the t-test is that it turns out that only numeracy abilities have different achievement abilities. This means that there is no difference in students' mathematical literacy abilities between students who received the PBL model through TPACK and students who received a scientific approach.

Research questions 6

Testing the hypothesis related to improving numeracy abilities between classes that receive the PBL model through TPACK with classes that receive a scientific approach.

The results of inferential calculations for the mean difference test with the t-test using SPSS 24.0 Statistics software are shown in Table 7.

Table 7. Test Results for the Average Difference in Numeracy Ability N-Gain Scores

Numeracy ability N-Gain Scores	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	1.478	0,229	-3.954	60	0,000	-0,247465	0,0625884
Equal variances not assumed			-3.954	56.811	0,000	-0,247465	0,0625884

Based on Table 7, it can be seen that the Sig (2-tailed) table is 0.000. This value does not meet the test criteria, namely sig. (0,00) < 0.05, then H0 is rejected. This shows that there is an increase in mathematical numeracy abilities between students who get the PBL model through TPACK and those who get a scientific approach.

Discussion

Based on the pre-test and post-test results on the mathematical literacy and numeracy abilities above, a test for the difference between the two averages was carried out using MANOVA. The test results show a significant difference between the mathematical literacy and numeracy abilities of students who receive mathematics learning through the PBL model through TPACK and scientific approaches simultaneously or together.

However, based on the average difference test for each ability, it turned out that only in numeracy abilities was there a significant difference in students who received mathematics learning through the PBL model through TPACK and the scientific approach. This is in line with (Rahma & Agustika, 2023), who state the PBL model with the TPACK approach can increase the numeracy abilities of students. Meanwhile, for literacy abilities, it can be concluded that there is no significant difference between students who receive mathematics learning through the PBL model through TPACK and those who receive it through the scientific approach.

This result is possible because in learning mathematics through the PBL model through TPACK, the teacher-centred learning paradigm has shifted to learning that emphasizes student activities to construct and reconstruct their knowledge. So that students are more challenged to create a field of strategy and their way of learning. This is to research conducted by (Sumarno et al., 2022), which revealed that learning using the PBL model can ease student activities, provide opportunities for students to learn independently and reduce the tendency of teacher-centred mathematics learning that should be student-centred. In line with (Nurcahyono, 2023), who says learning models, including the PBL model, can improve numeracy literacy abilities, this is because the PBL model involves problems that arise in everyday life. This will make students feel happier and more challenged to carry out learning activities.

The MANOVA test shows that there is a difference between increasing students' mathematical literacy and numeracy abilities simultaneously (together) in learning mathematics through the PBL model through TPACK and the scientific approach. However, individually, between literacy abilities and numeracy abilities, based on the average difference test for each ability, it turns out that only in increasing the ability of numeracy is there a significant difference in students who get mathematics learning through the PBL model through TPACK and the scientific approach. This is in line with (Rahma & Agustika, 2023), who state that the PBL model with the TPACK approach can be used in the learning process, especially numeracy learning, because this model can encourage students to learn independently so that students can discover and understand concepts through themselves. Meanwhile, to increase literacy abilities, it was concluded that there was no significant increase in students who received mathematics learning through the PBL model through TPACK and the scientific approach.

The high increase in mathematical literacy and numeracy abilities in students in the experimental group and the control group, apart from being caused by the PBL model through TPACK, is also caused by a supportive learning atmosphere in the classroom. In the experimental class, the domination of students in the teaching and learning process is optimal. They are involved in almost all stages of learning. So, the role of the teacher as a facilitator in providing learning stimulants is greatly alleviated. Slightly different from the control class, students in the control class were not very active in learning. They tend to be passive in ongoing learning. In the question-and-answer session, only 3-4 students gave positive responses. The teacher must continue to provide interventions so that the required prerequisite materials can be optimally used. Regarding this condition, the mathematics teacher in this case and the researcher teaching in the control class also stated the same thing. Students in the control class feel more comfortable when the teacher is giving lessons, and students are only listening.

Research by (Setiawan et al., 2014) states that literacy or mathematical literacy is the ability of an individual to formulate, use and interpret mathematics in various contexts. This includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to explain and predict phenomena. Someone with good mathematical literacy must be sensitive to mathematical concepts relevant to the problems they face (Asmara et al., 2017).

Research related to numeracy abilities to solve problems by PISA questions has been carried out by (Fakhriyana et al., 2018), which shows that students with high and moderate logical-mathematical intelligence can understand problems, identify and select information, make mathematical models and provide arguments, while students with low logical-mathematical intelligence are unable to do all of these things. Another study on numeracy abilities was carried out by (Saputro, 2018), which stated that 20.91% of students had not been able to evaluate the completion of the PISA-type questions given by researchers, and 29.55% of students had been able to formulate real problems contained in type questions. PISA. Also, research on numeracy abilities (Anderha & Maskar, 2021) found that the relationship between numeracy abilities and mathematics learning achievement was very close.

CONCLUSION

Based on the results of data analysis and the findings of quantitative and qualitative research that have been presented in the previous section, several conclusions can be drawn as follows:

1. There are differences in the achievement of mathematical literacy and numeracy abilities together (simultaneously) between students who receive the PBL model through TPACK and the scientific approach.
2. There is no difference in the achievement of mathematical analysis abilities between students who get the PBL model through TPACK and the scientific approach.
3. There are differences in the achievement of mathematical evaluation abilities between students who obtain the PBL model through TPACK and the scientific approach.
4. There are differences in increasing the ability of mathematical literacy and numeracy together (simultaneously) between students who get the PBL model through TPACK and the scientific approach.
5. There is no difference in increasing the ability of mathematical analysis between students who get the PBL model through TPACK and the scientific approach.
6. There is a difference in improving mathematical evaluation abilities between students who use the metacognitive abilities approach with advanced organizers and those who use a scientific approach.

However, this study also has limitations and deficiencies that prevent the results from being applicable in general. Some of the limitations and shortcomings of this research are:

1. The research sample has unique characteristics that can give different results from other samples with different characteristics.
2. Sample learning materials, in this case, the topic of trigonometry, can give results that are different from other material topics.

ACKNOWLEDGMENTS

We would like to thank to Mathematics Education Study Program, IKIP Siliwangi, for providing special time so that researchers were able to complete this research on time. Do not forget to thank the researchers to UPI doctoral class 2016 friends who always provide motivation and enthusiasm to continue working.

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