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# Problem-based learning and case-based learning: Which is more effective for fostering mathematical connection?

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**ABSTRACT**

Problem-Based Learning (PBL) and Case-Based Learning (CBL) are two learning approaches that involve problem-solving activities, that can be used to encourage students' mathematical connection abilities. This study aimed to describe the differences in mathematical connection ability between students who studied with the PBL and those who used the CBL approach. A quasi-experiment with a pretest-post-test non-equivalent group design was conducted for the purpose. The data collection method in this study was non-routine problems about mathematical connections. The data was analyzed using inferential statistics. Paired sample t-tests to examine the difference between pretest and post-test data in each experimental class, and independent sample t-tests to verify the difference in the effectiveness of the two learning approaches. The results showed that both the PBL and CBL approaches were effective in enhancing mathematical connection ability. However, there was no significant difference in the mathematical connection ability between students who studied with the PBL and CBL approaches. The results of this research may suggest teachers construct appropriate learning to foster mathematical connection ability.



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## INTRODUCTION

The OECD (Organisation for Economic Co-operation and Development) world organization establish the Programme for International Student Assessment (PISA) in more than 70 countries to assess the ability of 15-year-old students in reading, science, and mathematics. In mathematics, the 2018 PISA results show that only 2.4% of students across OECD countries achieved the highest level (OECD, 2019a). Most students can only afford to answer questions with low categorization (Stacey, 2011), such as interpreting and recognizing mathematical representations of simple situations (OECD, 2019a;b). Indeed, in 24 countries, more than 50% of students score below that proficiency level.

The 2018 PISA survey indicates that most students still have difficulty working on questions related to other concepts or things. They could not integrate disparate sources of information or representations and flexibly translate this information (OECD, 2019a;b). The study by Kenedi et al. (2019) also shows that students still lack in utilizing and identifying relationships between ideas in mathematics learning. Meanwhile, mathematics is a discipline that connects ideas (Nurhasanah et al., 2017). Mathematics is the science of logic that studies quantities, structures, forms, and interrelated concepts. Prior knowledge of other concepts is required while studying a topic in mathematics. To know some concepts, students are expected to be able to interpret data and apply concepts within their cognitive structures (Istihapsari, 2017). Moreover, mathematics is closely related to many branches of science and many real-life ideas. When students connect one material to another, mathematical connection abilities emerge.

Mathematical connection ability is one of the mathematical abilities that students must master. NCTM (2014) defines mathematical connection ability as the capacity of students to connect one concept to other(s). The ability to relate mathematical knowledge to real-life situations and other mathematical concepts is also called mathematical connection (Bahr & Garcia, 2010). Networks of interconnected concepts (knowledge) are called mathematical connections. Learning mathematics will undoubtedly be more meaningful to students if they can relate the material studied to the previous material or connect it with other subjects (Linto et al., 2012). According to the several statements, mathematical connections consist of the ability to relate a mathematical concept to other mathematical concepts, a mathematical concept to other fields, and a mathematical concept to real life.

Mathematical connection ability has properties such as structured and systematic science and contains interrelated concepts, so mathematical connection skills become pivotal (Hendriana et al., 2014). The ability to connect mathematics helps students see the connections between mathematical ideas, the relationship between mathematics and everyday life, and the relationship between concepts, data, and situations (Agustini et al., 2017). Students' understanding becomes more profound and durable when students can relate mathematical ideas (Rismawati et al., 2016). Students will understand mathematics better and have greater mathematical power if they have mathematical connection skills (Romli, 2016). The ability of mathematical connections is also positively correlated to students' cognition, without mathematical relationships, students will have difficulty learning mathematical concepts (Siregar & Surya, 2017). Therefore, students' mathematical connection skills need to be strengthened. However, some teachers are not aware of the benefits of mathematical connections yet, and some teachers also lack strategies for improving mathematical relations (Kenedi et al., 2019). The process of learning mathematics that leverages mathematical connections in addressing issues has yet to be developed, some teachers have not connected mathematics material with student life (Kenedi et al., 2019).

Learning mathematics should be carried out constructively where students build their knowledge actively. Students in the active learning strategy converse with one another rather than relying solely on the teacher. Students initiate and organize their activities while the teacher acts as a facilitator to increase students' independence in learning and build their creativity. Thus, classes that use active learning become more flexible. Educators can use a variety of constructivism-based learning approaches in their classrooms. Each approach has its characteristics and advantages.

Problem-Based Learning (PBL) is a constructivist-based learning approach that experiences problem-solving collaboratively (Napitupulu et al., 2016). Problems are initial trigger for learning that stimulates students to use their experiences and reasoning to find solutions. Surya & Syahputra's (2017) study proved that PBL effectively improves problem-solving abilities. A meta-analysis by Suparman et al. (2021) indicated that PBL positively affects critical thinking skills. Another study found that high school students in PBL classrooms had higher thinking abilities than students in conventional classes (Napitupulu et al., 2016). Padmavathy & Mareesh's (2013) research shows that PBL improves students' knowledge and understanding of using concepts in real life. PBL has an interdisciplinary perspective, allowing students to explore and conclude several disciplines (Arends & Kilcher, 2010). These facts indicate that PBL affects students' mathematical connection abilities. This assertion is in line with Wihaskoro's (2015) findings, which revealed that PBL significantly impacts students' mathematical connection ability.

Another learning approach that based on problem-solving is Case-Based Learning (CBL). In CBL, realistic case scenarios are given to students who study the case retrospectively (trying to solve the case interactively or finding out how the case was solved) (Mayer, 2002). CBL allows students to analyze the content relevant to a given case (content with the core knowledge domain or other knowledge domains). Bagdasarov et al. (2012) discovered that students learned more effectively when using well-structured cases. Another study by Yadav et al. (2014) demonstrates that CBL is a practical learning approach; students feel more involved and see more connections between the material being studied and the real world when learning from cases. Meanwhile, the link of subject matter with the real


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world is one aspect of mathematical connection. According to this argument, CBL appears to be closely related to students' mathematical connection abilities.

Williams (2005) argues that the CBL paradigm is closely related to the PBL paradigm. However, both have differences; they have different foci (Wang, et al., 2021). CBL is result-driven, while PBL is problem-oriented (Zhao et al., 2020). In addition, PBL does not require previous experience related to the material being studied, while CBL requires prior knowledge that can support case resolution (Syarafina et al., 2017). In line with the statement, CBL and PBL have unique characteristics, even though they both have the same goal. The attributes of PBL are problem-directed learning, while the traits of CBL are that in solving cases, students need prior knowledge (Garvey et al., 2000).

After analyzing various theories and research results above, it is clear that the PBL and CBL approaches have many advantages theoretically, especially concerning mathematical connection abilities. As in previous research, PBL was effective on mathematical connection abilities (Dewi & Marsigit, 2019). However, there are insufficient PBL and CBL research references on students' mathematical connecting abilities, especially when comparing the two. The previous study on CBL in mathematics focused on students' mathematical attitudes (Dewi & Marsigit, 2018). The other previous study compared the effectiveness of the two approaches for medical school (Srinivasan et al., 2007). Other studies on CBL are also more common in medical schools, such as the research of Macpherson et al. (2022), Qian et al. (2021), Burgess et al. (2021), Raza et al. (2020), Thistlethwaite et al. (2012), McLean (2016), and Harman et al. (2015).

Therefore, research to determine whether PBL and CBL approaches are effective in terms of students' mathematical connection abilities needs to be performed. The comparison of the effectiveness of the two learning approaches also needs to be known. This research was conducted to compare the effectiveness of the two learning approaches and determine which one is more effective in supporting students' mathematical connection abilities. Thus, the teacher can consider the appropriate learning approach in designing learning activities. Students will get a convenient learning experience to improve their mathematical connection abilities.

## METHOD

This study used a quantitative research approach with quasi-experimental methods. The independent variable in this study was the learning approach, including the PBL and CBL approaches. Students' mathematical connection ability is the dependent variable in this study. Pretest-post-test non-equivalent group design was used as the design of this study.

The research was carried out in a public junior high school in the Special Region of Yogyakarta, Indonesia. The study was carried out in the eighth grade. Samples were taken randomly, and two classes were selected from among the four classes in the school. The two chosen classes were then randomized again to determine which received treatment with the PBL approach (experiment class 1) and which class received learning treatment with the CBL approach (experiment class 2). The study consisted of pretest activities, learning activities undertaken in eight meetings, and post-test activities.

Before being given treatment, both experimental classes were given a pretest of mathematical connection ability first. Then the two classes were given the treatment, namely learning with the PBL approach in experiment class 1 and the CBL approach in experiment class 2. Both classes were taught by the same teacher and used the same material, i.e., circle material. The learning schedule followed the school schedule set by the school. Learning activities for experiment class 1 were held every Monday and Wednesday, while those for experiment class 2 were held every Wednesday and Thursday. To ensure that learning in the two experiment classes ran smoothly, lesson plans and student worksheets were also prepared according to the learning approach used in each class. Students in both classes were given a post-test with non-routine questions regarding their mathematical connection ability at the end of the meeting.

The pretest and post-test questions used in the study were equivalent. The questions were developed by the researchers. The pretest was used to measure the ability of mathematical connections before treatment, and the posttest is used to measure the ability of mathematical connections after treatment. The test instrument was presented in the form of three essay questions. The preparation of the test instrument begins with making a grid of questions, asking experts to validate the research instrument, and testing the instrument. To review the instrument's validity, content validity was


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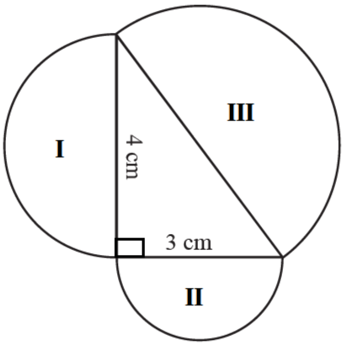
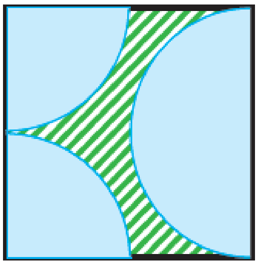
accomplished by expert judgment from two experts. The results show that the instrument has met the valid criteria. In addition, a reliability test was also performed on the instrument. An instrument was said to be reliable if the Cronbach's Alpha value was greater than 0.70. The reliability coefficient with Cronbach Alpha was 0.801 for the pretest and 0.857 for the post-test. This shows that the pretest and posttest instruments were reliable. The minimum completeness criteria for the mathematical connection test were at least in the excellent category, the minimum total score is 7.2. The grid of mathematical connection pretest questions is presented in Table 1.

Table 1. The grid of the mathematical connection pretest

| Aspect | Indicator | Problem |
|---|---|---|
| The relationships between mathematical concepts | Students can use the relationship between the circle concept and the Pythagorean concept. | Look at the following plane figure. The three sides of a right triangle are attached to a semicircle. a) What is the area of the semicircle III? b) What is the circumference of the plane figure?   |
| The relationship between mathematical concepts and real life | Students can use the concept of a circle sector to solve problems in everyday life | Mr. Santoso has a rectangular plot of land behind his house with a side length of 14 m x 14 m. According to the drawing, the garden will be made into a pond (not shaded) and partly planted with ornamental grass (shaded).<br>a) How much land will be planted with grass?<br>b) If the cost of purchasing grass seeds and fertilizer is Rp50.000,00/$m^2$. The lawn installer costs Rp250.000,00. Determine the budget that must be prepared by Mr. Santoso to plant ornamental grass in the garden.  |
| The relationship of other subject concepts with mathematical concepts | Students can use the relationship between mathematical concepts (circumference of a circle) and Physics. | A satellite orbits the earth at an altitude of 2000 km above the earth's surface. The approximate diameter of the earth is 12,800 km.<br>a) What is the best estimate of the path length traveled by the satellite for one orbit around the earth?<br>b) If the satellite takes 30 days to orbit the earth once, what is the approximate speed of the moving satellite in km/h? |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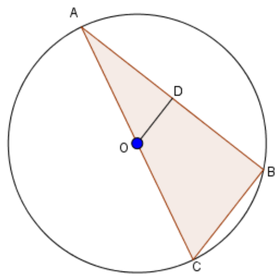
The grid of mathematical connection posttest questions is presented in Table 2.

Table 2. The grid of the mathematical connection posttest

| Aspect | Indicator | Problem |
|---|---|---|
| The relationships of mathematical concepts | Students can use the relationship between the concept of line and angle, and the concept of circle | Consider the following circle, OD is perpendicular to line AB. AC is the diameter of a circle centered at O. Is OD parallel to BC? Explain your answer.   |
| The relationship between mathematical concepts and real life | Students can use the concept of a circle sector to solve problems in everyday life | A contractor will build a hammer throw with grass. The price of grass per $m^2$ is Rp. 20,000.00. The size of the field is shown in the following figure. Determine the minimum cost of buying the grass. (Hint: $34{,}92° \approx 35°$)   |
| The relationship of other subject concepts with mathematical concepts | Students can use the relationship between mathematical concepts (circumference of a circle) and translation in Physics. | A car has wheels with a diameter of 63 cm. The car moves in a straight line in 36 seconds, the wheels rotate 200 times.<br>a) How far did the car travel?<br>b) Assuming the car's speed is constant, what is the car's speed? |

An instrument of learning implementation observation sheets was also prepared for experiment classes 1 and 2. This observation sheet was used to observe the learning process in the two experimental classes, and whether the learning was carried out according to the lesson plan. Thus, this instrument is arranged according to the learning steps planned in the lesson plan, accompanied by the "Yes" and "No" columns to record the implementation of the learning. The validity of this instrument has also been proven by using content validity conducted by two experts.

The pretest and post-test data in both experiment classes were analyzed using descriptive and inferential statistical tests with a significance level of 5%. An assumption test was also performed as an analysis condition, which included normality and homogeneity tests. All statistical calculations were performed using SPSS. The data from the observation of the implementation of learning was analyzed by calculating the percentage of the performance of learning by the results of the observations.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## RESULT AND DISCUSSION

PBL was implemented in five learning steps, namely (1) problem presentation; (2) problem-solving planning; (3) problem-solving implementation; (4) presentation of results; and (5) evaluation of learning outcomes. The problems presented were related to the material delivered at the beginning of learning. Then students understood the problems. After understanding the problems, students developed problem-solving plans with direction from the teacher. Students carried out problem-solving plans, followed by presenting the results of their problem-solving. The final step of PBL was to conclude the material resulting from problem-solving, re-checking student work, and reflecting on learning.

The first lesson in experiment class 1 with the PBL approach has been carried out according to the lesson plan. However, there were obstacles in this meeting. Some students are less involved in group discussions. To get around the obstacles, the researcher tries to maximize the learning process by appointing students who are less active in talks to represent their group presentations at the next meeting. It aimed to make students who were not playful dare express the results of group discussions. Students have started to get used to the PBL system at the second through eighth meetings. Students discussed in groups and found learning concepts through problem-solving activities provided in the worksheet. Figure 1 shows an example of a PBL worksheet.

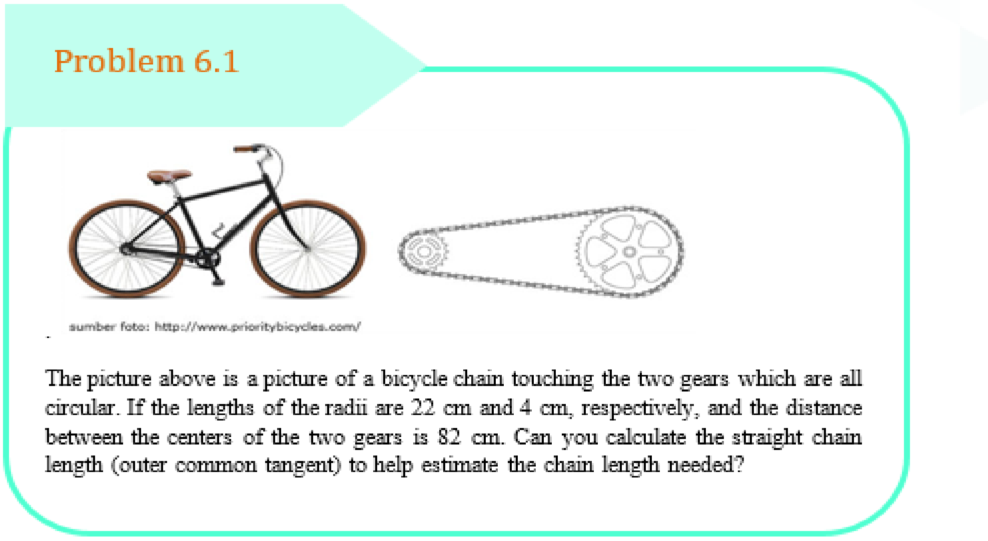


Figure 1. Examples of a problem presented in problem-based learning student worksheets

The average implementation of learning with PBL from the first to the last meeting was almost 100%, namely 96.5% according to the lesson plan. Learning was not carried out 100% because, at the first meeting, the researcher did not do an apperception, did not convey the material to be studied at the next meeting, and did not give questions to students independently. At the next meeting, after eight meetings were conducted, a post-test of the students' mathematical connection abilities was conducted. Thus, the number of meetings in experimental class 1 was ten, consisting of one meeting for the pretest, eight meetings for learning with the PBL approach, and one last meeting for the post-test.

Learning in experimental class 2 was carried out with steps from the lesson plan. Experimental class 2 used CBL. CBL is implemented in four learning phases, namely: (1) case presentation; (2) presentation of study questions; (3) group discussion for case resolution; and (4) evaluation of learning outcomes. The cases presented were related to the material delivered at the lesson's beginning. After understanding the case, students developed study questions related to the case. Furthermore, students discussed developing a case settlement plan with the direction of the teacher and carried out case resolution in groups. The last step of CBL was to conclude the material resulting from the completion of the case, re-check student work, and engage in learning reflection. In the core activity, students used the student worksheet that has been adapted to the characteristics of CBL. Figure 2 is an example of a case presented in the CBL worksheet.


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Case 6.1

A bicycle (or wind wagon) is a two- or three-wheeled vehicle that has handlebars, a seat, and a pair of pedals that are driven by the legs to run it. The bicycle is thought to have originated in France. According to historical reports, the country has known since the early 18th century a two-wheeled means of transportation called the velocipede. Single-speed bicycles are the most basic type of bicycle. A single speed bicycle is a type of bicycle with one gear ratio. There are many types of modern single speed bicycles; BMX bicycles, some bicycles designed for children (younger), cruiser type bicycles, classic commuter bicycles, light bicycles, bicycles designed for track racing, fixed-gear geared bicycles, and fixed-gear mountain bikes.

sumber foto: http://www.prioritybicycles.com/

In simple terms, what moves a bicycle or other vehicle is a part called the drivetrain. The drive system itself is actually a combination of various components that are interconnected and consist of pedals, crank arms (crankarm), front gear (chainring), rear gear (cog), and of course the chain (chain). The combination of the pedal components is known as the crankset, namely the pedals, crank arms and front gears. Then the chain will circle the front gear and connect it to the rear gear which is connected to the rear wheels. When the pedal is pressed, the crank arm will follow it, turning the attached front gear, which then pulls the chain which also automatically pulls the rear gear to turn, and because it is attached to the rear wheel, the wheel spins and off we go. A simple mechanism that has more or less never changed since the creation of this system.

A bicycle chain is a roller chain that transfers power from the pedals to the bicycle's steering wheel, thereby propelling it. Most bicycle chains are made of plain carbon or alloy steel, but some are nickel plated to prevent rust, or just for aesthetics. Bicycle gear is the aspect of a bicycle's propulsion system that determines the relationship between cadence, the rate at which the rider pedals, and the rate at which the drive wheels turn. If the radius of the front and rear gears is 22 cm and 4 cm, respectively, and the distance between the two gear centers is 82 cm. Can you calculate the length of a straight chain (outer common tangent) to help estimate the chain length needed?

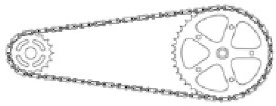

Figure 2. Examples of cases presented in case-based learning student worksheets

The students in experiment class 2 were grouped, consisting of four students. Researchers still had difficulties managing time at the first meeting according to the lesson plans. This was because students were not familiar with CBL. Students took a long time to understand the given case. As a result, only one group was present at the first meeting. After that, the students and the teacher concluded what they had learned, namely about the elements of a circle. Students were getting used to the CBL from the next meeting until the eighth meeting. Students began to get used to reading cases and then taking notes on the critical information. This situation can be seen from the average implementation of learning with CBL from the first to the last meeting, almost 100%, which is 96.25%. The learning was only carried out 96.25% because, in the first meeting, the researcher did not ask some questions as reflection material, did not convey the material to be studied at the next meeting, did not give questions independently, and did not close the lesson with prayers. This happened because the researcher ran out of time. A post-test of the students' mathematical connections was carried out after learning the circle material with CBL was completed. The number of meetings in experimental class 2 was ten, consisting of one meeting for the pretest, eight meetings for learning with the CBL approach, and one last meeting for the post-test.

The results from the mathematical connection test are summarized in Table 3, along with the results of the pretest and post-test. The pretest and post-test data described for mathematical connections


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came from experiment class 1, which used the Problem-Based Learning approach, and experiment class 2, which used the CBL approach.

Table 3. Mathematical connection test results

| Description | PBL Class | | CBL Class | |
|---|---|---|---|---|
| | *Pretest* | *Post-test* | *Pretest* | *Post-test* |
| Mean | 6.59 | 8.47 | 6.38 | 8.59 |
| Standard Deviation | 2.00 | 2.03 | 2.25 | 1.68 |
| Maximum Value | 10 | 12 | 10 | 12 |
| Minimum Value | 2 | 5 | 1 | 5 |
| Maximum Value Theoretical | 12 | 12 | 12 | 12 |
| Minimum Value Theoretical | 0 | 0 | 0 | 0 |

Based on Table 2, it can be concluded that the average results of the mathematical connection pretest in the two experimental classes have not reached the minimum completeness criteria. The average pretest in experiment class 1 with the CBL approach was 6.38, below the minimum completeness criteria. Likewise, in experiment class 2 with the PBL approach, the pretest results were below the minimum completeness criteria with an average of 6.59. The average post-test result for the mathematical connection in experiment class 2 with the PBL approach was 8.47. The average post-test result for experiment class 1 with the CBL approach is 8.59.

The pretest data on mathematical connections in both classes were analyzed. Data analysis before treatment aims to determine the characteristics of the data before treatment and the statistical test to be used after treatment. Assumption tests (normality and homogeneity) were carried out first on the data of the two classes. The normality test used the Shapiro-Wilk test, and the homogeneity test used the Lavene test. The results of the assumption test before treatment are presented in Table 4.

Table 4. Assumption test results

| | | Shapiro Wilk Test Significance | | Lavene Test Significance |
|---|---|---|---|---|
| | | CBL | PBL | |
| Before Treatment | Significance Value | 0.139 | 0.108 | 0.683 |
| | Information | Normal | Homogenous | Homogenous |
| After Treatment | Significance Value | 0.102 | 0.061 | 0.381 |
| | Information | Normal | Homogenous | Homogenous |

Furthermore, the post-test data on the students' mathematical connections were analyzed. The results of the assumption test after treatment have been presented in Table 4. Based on Table 4, each significant value of the mathematical connection in the two experimental classes after treatment was greater than 0.05. This indicates that the assumption of normality is met for the data after treatment with the CBL and PBL approaches. The significance value of Lavene's test was 0.381, greater than 0.05. This indicates that the data after treatment with the CBL approach and the PBL approach were homogeneous.

After the normality and homogeneity tests were met, a paired sample t-test was performed to determine whether there was a difference between the pretest and post-test data in each experimental class. The results from the paired sample t-test are presented in Table 5.

Table 5. Paired sample *t*-test results

| | *T* | *df* | Sig. (2-tailed) |
|---|---|---|---|
| Pretest-Post-test PBL | -3.828 | 31 | 0.001 |
| Pretest-Post-test CBL | -4.306 | 31 | 0.000 |

Based on the paired sample *t*-test, experimental class 1 (PBL) has a significance value of 0.001, less than 0.05, which means that there was a significant difference between the average pretest and post-test mathematical connections in experimental class 1 using PBL. This data is consistent with the results of the descriptive analysis in Table 3. There was an increase in the mathematical connections in experiment class 1. The average mathematical connection ability of the experimental class 1 students with the PBL approach increased by 1.88, from 6.59 to 8.47. This means that the PBL approach was effective in terms of mathematical connection abilities. The results of the experiment class 2, which has


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a significant value of 0.000, mean a significant difference between the average post-test and pretest mathematical connections in the experimental class 2 using CBL. The average mathematical connection ability in experimental class 2 with the CBL approach increased by 2.21, from 6.38 to 8.59. Thus, the CBL approach has an effective effect on mathematical connection abilities.

Furthermore, the difference in the effectiveness of the learning approach was tested on the ability of mathematical connections. The independent sample *t*-test was 0.790, more than 0.05, meaning that there was no difference in the post-test scores of students' mathematical connections in the learning group using the PBL approach and the CBL approach. It can be concluded that there is no difference in effectiveness between the CBL and PBL approaches in terms of the mathematical connection abilities. Therefore, the researcher did not conduct further tests to determine which approach was more effective in mathematical connection abilities.

Learning starts with problems, making students gain new knowledge related to the problem (Padmavathy & Mareesh, 2013). In the ideal PBL, students begin to identify the characteristics of the problem; then, their knowledge is expanded to find practical solutions to solve problems (Nurlaily et al., 2019). This shows that PBL affects students' mathematical connection abilities (Dewi & Marsigit, 2019). This statement is supported by the research results of Siregar & Surya (2017), who found that the process of solving mathematical problems is a student activity that can build students' mathematical connections. In the PBL, students should be able to find the relevance of the theorems or concepts used to solve a problem (Siregar & Surya, 2017). As stated by Wulandari & Shofiyah (2018), PBL is a learning approach that provides students with real-world problems that they are encouraged to use their scientific reasoning skills to solve. The ability to make mathematical connections is related to solving mathematical problems in everyday life (Hendriana et al., 2018). The first step of the PBL model gives students training in an important indicator of problem solving, namely, understanding the problem (Sari, Sumarmi, Dwiyono, Utomo, & Astina, 2021). PBL allows students to integrate theory and practice; conduct research in developing solutions to problems; and apply their skills and knowledge (Savery, 2015). Moreover, PBL is an ideal teaching strategy to fill the skill gaps regarding critical thinking and accentuate Generation Z’s strengths (Siebert, 2021).

In line with PBL, CBL makes students analyze content, looking for core knowledge domains and other knowledge relevant to the given case. This conforms with Ching's (2014) opinion that the case scenario used in presenting the questions is a case with a complex instructional design that involves many interests. The use of complex cases shows that students need various knowledge related to real life and other subjects across math topics. CBL has a significant effect on students' mathematical attitudes (Dewi & Marsigit, 2018). The advantage of using cases in learning is that students can apply theory to real contexts (Williams, 2005; McLean, 2016) and encourage deeper learning (McLean, 2016). CBL become an alternate method of teaching and learning for better learning and understanding (Kaur, et al., 2020). Through CBL, students can solve cases and build knowledge related to the context and understanding of the relationship between the elements presented in this case. This is consistent with Savery (2015) that CBL significantly affects the mathematical connections ability.

PBL and CBL are equally suitable for improving mathematical connection abilities. The two learning approaches are both constructivist learning approaches. Both approaches put forward the active involvement of students in learning so that students can find learning concepts independently. In PBL, the problem given by the teacher is in the form of a math problem. In learning with the CBL approach, students are given cases. The problem or case scenarios provided are realistic and pertinent to the topics being discussed. Students are allowed to include various sources of information into the original context of the case.

The results of this study provide suggestions for educators to choose both learning approaches in an effort to improve students' mathematical connection abilities. This is an essential ability to be developed. This ability is also implicitly included in the highest level of mathematics proficiency in PISA. At the highest level of PISA assessment, students can use their knowledge in unfamiliar contexts (OECD, 2019b). Students can also relate various information and representations and translate them flexibly (OECD, 2019b).

Due to the importance of mathematical connection skills, other research is still needed to investigate this ability more deeply. Future studies may focus on this ability by examining other aspects such as psychological, affective, or psychomotor. In addition, this research framework can be used as a reference for further research to compare the two experimental classes. However, this study has


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limitations. The study was only conducted for 8th graders (13–14 years). These results may not be the same if applied at different ages. Hopefully, there will be further research on mathematical connections for students of different ages or levels. This research was also only carried out on specific topics. Other topics may show different results. Likewise, with the problems and cases that present in learning. Thus, its effectiveness on other topics and problems/cases must be investigated. The data in this study was only test and observation results. Perhaps future research could be equipped with other techniques to gain a deeper understanding of the results. Such as interviews that will provide other important information, such as how students respond to the learning being carried out and how they experience the learning.

## CONCLUSION

The mathematical connection ability is one of the essential skills to be developed in learning mathematics. With this capacity, students can learn math material more meaningfully and can gain skills to deal with problems in everyday life. PBL and CBL are constructivist learning approaches that have the opportunity to enhance mathematical connection ability. Based on the research data analysis results, it can be concluded that PBL is effective in terms of students' mastery of mathematical connections. CBL is also effective in terms of the ability of mathematical connections. However, there is no difference in effectiveness between the CBL and PBL approaches on the mathematical connection ability. As a result, teachers can apply both the PBL and CBL approaches to enhance the students' ability to mathematical connections.

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