
Research articles

Higher-order thinking skills among male and female students: An experimental study of the problem-based calculus learning model in secondary schools

Hasan Djidu¹, Jailani², Heri Retnawati²

Abstrak Penelitian ini bertujuan untuk menguji keefektifan *problem-based calculus learning model* (PB-CLM) terhadap *higher-order thinking skills* (HOTS) siswa. PB-CLM merupakan modifikasi dari sintaks model *problem-based learning* (PBL). Penelitian ini menggunakan rancangan quasi eksperimen dengan desain *one group pretest-posttest* yang melibatkan 351 siswa kelas XI sebagai populasi penelitian. Tujuh puluh satu siswa dari 2 kelas dipilih secara acak sebagai sampel. Data penelitian dikumpulkan dengan menggunakan *pretest* dan *posttest* yang dikembangkan dari 3 aspek HOTS; analisis, evaluasi, dan sintesis. Untuk mengetahui keefektifan PB-CLM digunakan *paired sample t-test* dan *independent sample t-test* dengan taraf signifikansi 5% ($\alpha = 0,05$). Hasil analisis menunjukkan aktivitas siswa selama pembelajaran dengan PB-CLM efektif dalam meningkatkan HOTS (*mean difference* = 30,141; *sig.one-tailed* = 0,000). Lebih lanjut, tidak ditemukan perbedaan yang signifikan antara HOTS siswa laki-laki dan perempuan, baik pada *pretest* maupun *posttest* (*mean difference* = 0,81731; *sig.* = 0,295). Begitu pula peningkatan skor HOTS (*posttest-pretest*) juga tidak berbeda signifikan antara siswa laki-laki dan perempuan (*mean difference* = 0,88141; *sig. one-tailed* = 0,740).

Kata kunci Pembelajaran kalkulus berbasis masalah, Kemampuan berpikir tingkat tinggi, Gender

Abstract This study aims to examine the effectiveness of the problem-based calculus learning model (PB-CLM) towards students' higher-order thinking skills (HOTS). PB-CLM is a modification of problem-based learning's (PBL) syntax. It was a quasi-experimental with a group pretest-posttest design involving 351 11th-grade students as the population. Seventy-one students of two classes were randomly selected as a sample. Data was collected through pretest and posttest developed from three aspects of HOTS; analysis, evaluation, and synthesis. To determine the effectiveness of PB-CLM, paired sample t-test and independent sample t-test with a significance level of 5% ($\alpha = 0.05$) were used. The results show that students' activities during the learning process in PB-CLM has a positive effect on increasing their HOTS (mean difference = 30.141; sig one-tailed = 0.000). Furthermore, there was no significant difference in HOTS among male and female students, both at the pretest and posttest (mean difference = 0.81731; sig. = 0.295). Likewise, the increase in HOTS scores (posttest-pretest) did not differ significantly between gender (mean difference = 0.88141; sig. one-tailed = 0.740).

Keywords Problem-based calculus learning model, Higher-order thinking skills, Gender

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Introduction

Higher-order thinking skills (HOTS) is one of the competencies, which become an essential part of *Kurikulum* 2013 (K-13) implemented in Indonesia as well as the 21st-century education framework. Learning models recommended in implementing the curriculum are those that can facilitate students' HOTS. HOTS cannot be taught, because it is an indirect impact on learning. This is because HOTS is not just an understanding of mathematical concepts, but is obtained from the process of constructing mathematical concepts, and how these concepts are used. Instead of teaching it, HOTS can only be developed through learning activities (Hu et al., 2013; Sun, Wang, & Wegerif, 2020). Several studies uncover learning models that can develop students' HOTS, especially in mathematics learning (Akyol & Garrison, 2011; Chinedu, Olabiya, & Kamin, 2015; Maharaj & Wagh, 2016; Roets & Maritz, 2017). From these studies, it is revealed that learning activities that provide opportunities for students to be active in learning are the key to develop HOTS (Akyol & Garrison, 2011; Djidu & Jailani, 2017a; Limbach & Waugh, 2010; Miri, David, & Uri, 2007). In addition, developing students' HOTS can be facilitated by actively involving them in discussion activities related to a problem or phenomenon (Miri et al., 2007) and providing opportunities for them to collaborate in problem-solving (Akyol & Garrison, 2011; Miri et al., 2007). These activities can be pursued by conditioning students in group learning (Collins, 2014; Goethals, 2013) and providing real-world problems (Miri et al., 2007) that are unstructured and close to students' life.

It is true that the learning principles mentioned above have been empirically proven to develop students' HOTS. A number of studies have shown that learning models that apply these principles, such as Problem Based Learning (PBL), Project-Based Learning (PjBL), Discovery Learning (DL), can develop students' thinking skills (Barak & Yuan, 2021; Chen & Yang, 2019; Clements & Joswick, 2018; Mashuri, Djidu, & Ningrum, 2019; Zhou, Li, Wu, & Zhou, 2020). However, whether its effectiveness is applicable to all topics of mathematics, there is not enough empirical evidence. The different characteristics of each topic in mathematics affect the effectiveness of a learning model.

Experimentation on the PBL model in mathematics learning has been carried out by many previous studies. A meta-analysis conducted by Yunita et al. (2020) on 19 studies related to PBL in Indonesia found that it was effective in improving students' creative thinking. The results of this study also show that there is a tendency that the level of effectiveness decreases when given more than 4 lessons. In addition, the number of studies analyzed in relation to the duration of treatment was not sufficiently balance between those that were less than 4 lessons (only 3 studies) and those with more than 4 studies (16 studies). The variability in the effect size of the 19 studies analyzed was one of the reasons for this conclusion. Chinedu et al. (2015) conducted a literature review related to the strategies used in improving HOTS. One of their recommendations is to use the PBL model. However, they did not provide an explanation of whether this learning model could be applied to all learning topics or not. Mokhtar, Tarmizi, Tarmizi, and Ayub (2010) revealed the positive effect of PBL on students' HOTS. However, the study was conducted on 44 college students, not high school students. Therefore, the conclusions obtained in this study cannot be generalized in calculus learning in high school.

In this study, the learning model used is the problem-based calculus learning model (PB-CLM), which is a modification of PBL and designed for learning mathematics on secondary school calculus material (Djidu & Jailani, 2018). In its development, PB-CLM has met the criteria of practicality and effectiveness (Djidu & Jailani, 2018) according to the criteria

proposed by Plomp (2013). However, the effectiveness only measured by the percentage of the number of students who achieve the cut score. An experimental approach is needed to find out how effective it is on a broader scale. Therefore, this study is a continuation of the model development research, which aims to examine the effectiveness of the PB-CLM on students' HOTS. This study attempts to provide empirical evidence to answer the question of whether the learning of calculus in secondary schools can be facilitated by using a problem-based learning model or not. Besides, this study also aims to evaluate the comparison of students' HOTS to determine the differences between male and female HOTS, before and after learning with PB-CLM. There are two main differences between this study and previous studies (e.g., Chinedu et al., 2015; Mokhtar et al., 2010; Yunita et al., 2020). *First*, the learning model experimented on in this study is the modification of the problem-based learning's (PBL) syntax PBL. *Second*, in addition to revealing the effectiveness of PB-CLM, this study also reveals how the comparison of students' HOTS in terms of gender differences (male and female) before and after participating in learning using PB-CLM.

Theoretical Review

In accordance with the problems described above, this study will discuss the effectiveness of a learning model, namely PB-CLM, on students' HOTS. Therefore, the following section accounts for the results of the review of theories related to the learning model, PB-CLM, and HOTS.

Learning model

A learning model is a conceptual and operational framework that contains all components of learning activities (from beginning to end) and describes the procedures for implementing learning activities. The learning model is also known as Instructional Design or ID (Alonso, López, Manrique, & Viñes, 2005; Lee & Jang, 2014), Design Instruction or DI (Lo & Hew, 2017), and learning blueprints (Eggen & Kauchak, 2012), which are related to the learning environment and teacher activities in the learning process (Joyce, Weil, & Calhoun, 2009). The learning model also displays operational procedures for implementing the learning process (Gunter, Estes, & Schwab, 1990) to achieve the formulated goals (outputs and outcomes) that have been planned through the model (Gunter et al., 1990; Joyce et al., 2009). Therefore, a learning model serves to guide learning to be effective, efficient, and systematic (Eggen & Kauchak, 2012) so that learning goals can be achieved (Gunter et al., 1990). In other words, before teachers enter the classroom to start lessons, the teachers plan what goals to achieve, and in what ways those goals will be achieved.

We have reviewed the components of the learning model in previous studies (2017-2018) with the theme of developing HOTS and character-oriented learning models (Apino & Retnawati, 2017; Djidu & Jailani, 2017a, 2018; Djidu & Retnawati, 2018). From these studies, it was found that the learning model consists of seven components, namely (1) objectives, (2) theoretical basis, (3) learning syntax, (4) social systems, (5) principles of reaction, (6) support systems, and (7) learning outputs and outcomes. Descriptions of each of these components can be seen in (Djidu & Jailani, 2017b) and (Djidu & Jailani, 2018). In this study, we no longer focus on discussing the components of the model but only discussing how the effectiveness of the model on students' HOTS.

PBL and PB-CLM

PBL is a student-centred learning model (Arends, 2012), which makes contextual problems (real-world problems), complex and unstructured as a starting point for learning (Deep et al., 2020), and not oriented only to finding problem solutions, but also to the problem-solving process itself (Nurtanto, Fawaid, & Sofyan, 2020). PBL is expected to help students understand concepts through discovery and problem-solving activities (Mashuri et al., 2019). To achieve this, student involvement in the learning process is one of the keys to the success of PBL (Arends & Kilcher, 2010).

PBL is a learning driven by problems (Ajai & Imoko, 2014; Moust, Bouhuijs, & Schmidt, 2021). One of its characteristics is that learning begins with the presentation of the problem. Problems posed to students must be able to provide new information (knowledge) before they can solve the problems. The learning is more than just finding solutions to a given problem, but students must be able to interpret a given problem, gather important information, identify possible solutions, evaluate solution options or ways, and draw conclusions. PBL also shapes students into flexible and successful thinkers as problem solvers (Ertmer & Simons, 2006), strengthen their soft skills (Deep et al., 2020), and trains them to improve their thinking skills (Sastrawati, Rusdi, & Syamsurizal, 2011; Sumarmo & Nishitani, 2010).

PBL can be modified and adjusted to the learning outcomes to be achieved, both in the form of knowledge and skills. Several studies provide recommendations for the modification of PBL. Luks (2013) suggests that PBL modification with various active learning components can increase student activeness in the learning process. Modifications made include facilitating and providing initial knowledge for students to understand and solve problems (Liceaga, Ballard, & Skura, 2011). Salin (2011) also made modifications with the aim of giving students a real picture of the environment, the conditions they will face.

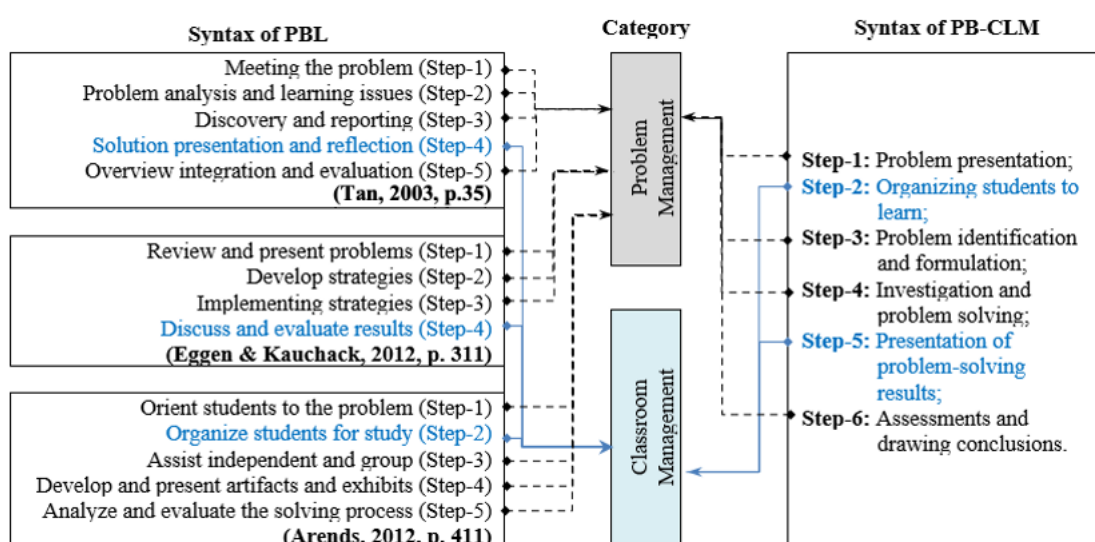


Figure 1. Comparison of PBL and PB-CLM Syntax

In this study, we developed the PBL-CLM syntax by restructuring the PBL syntax (Figure 1), starting by categorizing PBL activities into two categories (problem management and classroom management). This categorization aims to obtain a sequence of HOTS-oriented

learning activities. In addition, considering that PB-CLM was developed to develop students' HOTS in calculus learning in secondary schools (Djidu & Jailani, 2018), contextual problems related to secondary school calculus were also developed to be used in the learning process.

HOTS

Some experts argue that HOTS is the ability to solve problems or new tasks that are not the same (different) with tasks that are never solved before (Brookhart, 2010, p. 5; Mainali, 2012; Thompson, 2008), by involving several criteria that are not known at the beginning (Rubin & Rajakaruna, 2015), so that it will lead a person to a deep understanding of something that is being studied (Moseley et al., 2005). HOTS does not just understand concepts or facts, but makes connections, categorizes, manipulates, or applies existing facts and concepts to new situations (Thomas & Thorne, 2009).

HOTS will support students' achievement (Brookhart, 2010). A well-developed HOTS will also support students to prepare themselves for the rapid development of science, technology, and economics (Yen & Halili, 2015). In addition, students who have HOTS will be able to solve problems effectively (Snyder & Snyder, 2008.) In other words, HOTS will support the improvement of the quality of students' life (Limbach & Waugh, 2010) because they are ready with the knowledge and skills to solve problems in everyday life.

In the cognitive domain, HOTS refer to the last three levels in Bloom's taxonomy revision, namely analysis, evaluation, and synthesis (Anderson & Krathwohl, 2015; Ramirez & Ganaden, 2008; Saïdo, Siraj, Nordin, & Al-Amedy, 2015). A person who has the ability to think at a high level is measured by using standards in accordance with these characteristics. In this case, the ability to analyze, evaluate, and synthesize (create) can be seen as aspects of HOTS.

In this study, HOTS refers to the top three levels of the cognitive domain of Bloom's taxonomy, namely analysis, evaluation, and creation. Anderson and Krathwohl (2015) explain that analysis involves the ability to sort a given material or component into several small parts and determine how the relationship between parts and between each part and its overall structure. This aspect can be seen from the ability to distinguish relevant and irrelevant information related to problems, and the ability to describe appropriate procedures for solving problems. Evaluation is defined as making decisions based on criteria. The criteria used are usually related to quality, effectiveness, efficiency and consistency (Anderson & Krathwohl, 2015). This aspect can be measured by the ability to judge the truth of a statement, assumption, or mathematical process and the ability to interpret the solution to a problem. The last aspect, namely creation, involves the process of arranging the elements into a coherent or functional unit (Anderson & Krathwohl, 2015). This aspect can be measured by the ability to develop conjectures or patterns, draw conclusions based on data, and modify data to fit criteria.

Methods

This research is a quasi-experimental study using a one-group pretest-posttest design. The population in this study were 351 students from 10 classes. Of the 10 learning classes, there is one class (A) with higher ability than the others, while the remaining (B to J) has almost the same characteristics (medium ability). Therefore, the sample used is two classes originating from class A and class D as a representation of the high and medium ability classes. Sampling in this way was carried out because researchers could not randomize students (Creswell, 2012; Kirk, 1995). The two selected classes were then given the same treatment, namely following the

learning on derivative functions using PB-CLM. Before and after learning, students were given a test to measure students' HOTS before and after learning using PB-CLM.

The data collected in this study was quantitative data from the HOTS test before participating in learning (pretest) and after learning using PB-CLM (posttest). Students' HOTS data was collected using multiple-choice test instruments in the form of pretest HOTS and posttest HOTS. The multiple choices format was chosen as it can measure both knowledge and higher-level learning outcomes (Orlich et al., 2010; Nitko & Brookhart, 2011). The pretest and posttest were developed from three aspects, namely: (1) analysis, (2) evaluation, and (3) synthesis/creation. Each of the test consisted of 10 questions. Figure 2 shows samples of items to measure students' HOTS in each aspect.

The instrument to measure students' HOTS was validated and declared feasible by 3 measurement experts. Furthermore, the instrument was tested on 154 students who had studied the topic. Their responses were analyzed using the classical test theory approach (CTT). Data analysis was performed using Iteman 3.00 software. From the analysis of the data obtained: (1) difficulty level (p) = 0.564 which means the instrument is at a moderate level of difficulty (Allen & Yen, 1979), (2) discrimination (biserial) = 0.733 which means the instrument has a very good discrimination power (Allen & Yen, 1979; Ebel & Frisbie, 1991), (3) All distractors were selected by a minimum of 5% of participants, which means that they are good distractors (Allen & Yen, 1979), (4) the estimated reliability (α) was 0.600, and (5) the Standard Error Measurement (SEM) = 1.306. The estimation results of the instrument reliability that produce a value of 0.6 have met and been accepted and are suitable for use in conducting classroom assessments (Ary, Jacobs, Sorensen, & Razavieh, 2010; Ebel & Frisbie, 1991).

The data was analyzed to determine the students' HOTS before and after participating in learning using PB-CLM. Firstly, a descriptive analysis was conducted to determine the maximum, minimum, mean and standard deviation values of HOTS data at the pretest and posttest. Descriptive analysis was also conducted to determine the abilities of male and female students in each aspect of HOTS. Secondly, the effectiveness of PB-CLM was analyzed by performing a paired sample t-test. The paired sample t-test was used because the scores compared came from the same sample (Nolan & Heinzen, 2012). Before the effectiveness test is carried out, an assumption test is first carried out to prove that the change (Δ) in the pretest and posttest scores is normally distributed (Nolan & Heinzen, 2012). To prove it, a one-sample Kolmogorov-Smirnov test was conducted with the following hypothesis. The null hypothesis is that the Δ score comes from a population that is normally distributed. The null hypothesis is accepted if the significance value is greater than or equal to α (0.05). If the assumptions have been met, then the PB-CLM effectiveness test is carried out using the paired sample t-test using the following hypothesis. $H_0: \mu_{preHOTS} = \mu_{postHOTS}$ or the average HOTS of students before and after learning was not significantly different. The criteria for rejection of H_0 is if the sig. (1-tailed) $< \alpha$ (0.05). That is, PB-CLM is said to be effective if the analysis results show sig. (1-tailed) $< \alpha$ (0.05) and the average HOTS score of students on the posttest is greater than the score at pretest.

Thirdly, the comparison of HOTS scores between male and female students was analyzed using an independent sample t-test because the data comes from two different sample groups (male vs female) (Nolan & Heinzen, 2012). At this stage, the mean difference test was carried out twice. First of all, the mean difference test on the HOTS scores of male and female students

as a whole (pretest and posttest), with the null hypothesis $H_0: \mu_{HOT_F} = \mu_{HOT_M}$ (the mean scores of male and female students' HOTS is not significantly different).


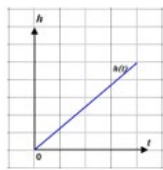
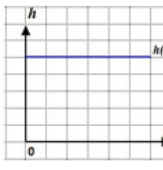
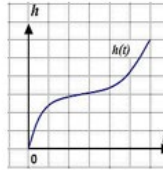
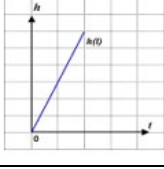
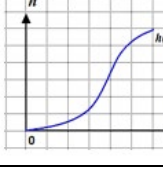
Analyze	<p>A function $h(x)$ has the derivative, which is $h'(x) = x^{-1}$. If $f(x) = h(x^2)$, which is the correct procedure to solve $f'(x)$?</p> <p>A. Solve $h'(x^2) \rightarrow$ Solve $\frac{d}{dx}(x^{-1}) \rightarrow$ solve the product of $h'(x^2) \times \frac{d}{dx}(x^{-1}) \rightarrow f'(x) = -x^{-4}$.</p> <p>B. Solve $h'(x^2) \rightarrow$ solve $\frac{d}{dx}(x^2) \rightarrow$ solve the product of $h'(x^2) \times \frac{d}{dx}(x^2) \rightarrow f'(x) = 2x^{-1}$.</p> <p>C. Solve $\frac{d}{dx}(x^{-1}) \rightarrow$ solve $\frac{d}{dx}(x^2) \rightarrow$ solve the product of $\frac{d}{dx}(x^{-1}) \times \frac{d}{dx}(x^2) \rightarrow f'(x) = -2x^{-1}$.</p> <p>D. Solve $\frac{d}{dx}(x^2) \rightarrow$ solve the product of $h'(x) \times \frac{d}{dx}(x^2) = 2x \rightarrow f'(x) = 2$.</p> <p>E. Solve $h'(x^2) \rightarrow$ solve the product of $h'(x^2) \times x^2 \rightarrow f'(x) = 1$.</p>																						
Evaluate	<p>Andi and Yuni are discussing their math assignment. They use different steps to complete the task. Following are Andi and Yuni's work.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2" style="text-align: center;">Problem: Determine $g'(x)$ if $g(x) = (2x + 1)^2(x - 1)$.</td> </tr> <tr> <td style="text-align: center; width: 50%;">Andi</td> <td style="text-align: center; width: 50%;">Yuni</td> </tr> <tr> <td>Given: $g(x) = (2x + 1)^2(x - 1)$</td> <td>Given: $g(x) = (2x + 1)^2(x - 1)$</td> </tr> <tr> <td>$g'(x) = ?$</td> <td>$g'(x) = ?$</td> </tr> <tr> <td>Solution:</td> <td>Solution:</td> </tr> <tr> <td>$g(x) = (2x + 1)^2(x - 1)$</td> <td>using the product and chain rule, obtained:</td> </tr> <tr> <td>$= (4x^2 + 4x + 1)(x - 1)$</td> <td>$g'(x) = 2 \cdot 2(2x + 1)(x - 1) + (2x + 1)^2 \rightarrow$ step 1</td> </tr> <tr> <td>$= 4x^3 - 4x^2 + 4x^2 - 4x + x - 1$</td> <td>$= 4(2x^2 - 2x + x - 1) + (2x + 1)^2 \rightarrow$ step 2</td> </tr> <tr> <td>$= 4x^3 - 3x - 1$</td> <td>$= 4(2x^2 + x - 1) + (2x + 1)^2 \rightarrow$ step 3</td> </tr> <tr> <td>then</td> <td>$= (8x^2 + 4x - 4) + (4x^2 + 4x + 1) \rightarrow$ step 4</td> </tr> <tr> <td>$g'(x) = 12x^2 - 3$</td> <td>$= 12x^2 + 8x - 3 \rightarrow$ step 5</td> </tr> </table> <p>Andi and Yuni obtained different results. After observing it, the teacher said that Yuni's solution was incorrect. Where did it go wrong?</p> <p>A. Step 1 B. Step 2 C. Step 3 D. Step 4 E. Step 5</p>	Problem: Determine $g'(x)$ if $g(x) = (2x + 1)^2(x - 1)$.		Andi	Yuni	Given: $g(x) = (2x + 1)^2(x - 1)$	Given: $g(x) = (2x + 1)^2(x - 1)$	$g'(x) = ?$	$g'(x) = ?$	Solution:	Solution:	$g(x) = (2x + 1)^2(x - 1)$	using the product and chain rule, obtained:	$= (4x^2 + 4x + 1)(x - 1)$	$g'(x) = 2 \cdot 2(2x + 1)(x - 1) + (2x + 1)^2 \rightarrow$ step 1	$= 4x^3 - 4x^2 + 4x^2 - 4x + x - 1$	$= 4(2x^2 - 2x + x - 1) + (2x + 1)^2 \rightarrow$ step 2	$= 4x^3 - 3x - 1$	$= 4(2x^2 + x - 1) + (2x + 1)^2 \rightarrow$ step 3	then	$= (8x^2 + 4x - 4) + (4x^2 + 4x + 1) \rightarrow$ step 4	$g'(x) = 12x^2 - 3$	$= 12x^2 + 8x - 3 \rightarrow$ step 5
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Synthesize (create)	<p>Look at the picture!</p> <div style="display: flex; align-items: center;">  <p>If water is poured into the glass at a constant rate until it is fully filled, the water level in the glass will increase over time. Suppose the level of water in a glass is determined by the function $h(t)$, where h is the height of the water (cm) and t is the time in seconds. Which is the correct graph to describe the level of water in the glass?</p> </div> <div style="display: flex; flex-wrap: wrap; justify-content: space-around;"> <div style="text-align: center; margin: 10px;"> <p>A</p>  </div> <div style="text-align: center; margin: 10px;"> <p>C</p>  </div> <div style="text-align: center; margin: 10px;"> <p>E</p>  </div> <div style="text-align: center; margin: 10px;"> <p>B</p>  </div> <div style="text-align: center; margin: 10px;"> <p>D</p>  </div> </div>																						

Figure 2. The excerpt items of the test

Then, the mean difference test of the delta scores of male and female students' HOTS, with the null hypothesis $H_0: \mu_{HOT_DF} = \mu_{HOT_DM}$ (the mean of the delta scores of male and female

students' HOTS scores were not significantly different). The criteria for rejection of H_0 is if the $\text{sig} < \alpha$ (0.05). After the data analysis was completed, interpretation was carried out to answer the research questions.

Findings and Discussion

Descriptive statistics of students' HOTS scores

The results of the descriptive analysis of the pretest data (Table 1) showed that the students' HOTS was very low (the categorization criteria can be seen in Ichsan et al., 2019; Purwanto et al., 2020). This is indicated by the average HOTS score of the students was only 27.75 with a maximum score of 60. There were even 5 students with the lowest score (score = 0). In Figure 1, it is shown that most student scored less than 60. Of the 71 students, 65 or 91.55% of students scored less than 60, and only 5 students (8.45%) achieved a score of 60.

Table 1. The descriptive statistics of students' HOTS

	Pretest	Posttest
Maximum	60	80
Minimum	0	10
Average	27.75	57.61
St. Dev.	17.254	12.924

Meanwhile, the posttest results (Table 1) show that the average HOTS score of students has increased to 57.61, with a maximum score of 80. Although this average has not reached the high category, students with low scores have shown progress in their learning outcomes. This is evident from the results of the analysis of the distribution of student scores (Figure 3), which show that the distribution of student scores less than 60 has decreased. A total of 49 students (69.01%) had achieved a minimum score of 60, while 15 students (21.13%) reached a score of 50 and only 7 students (9.86%) with a score below 40.

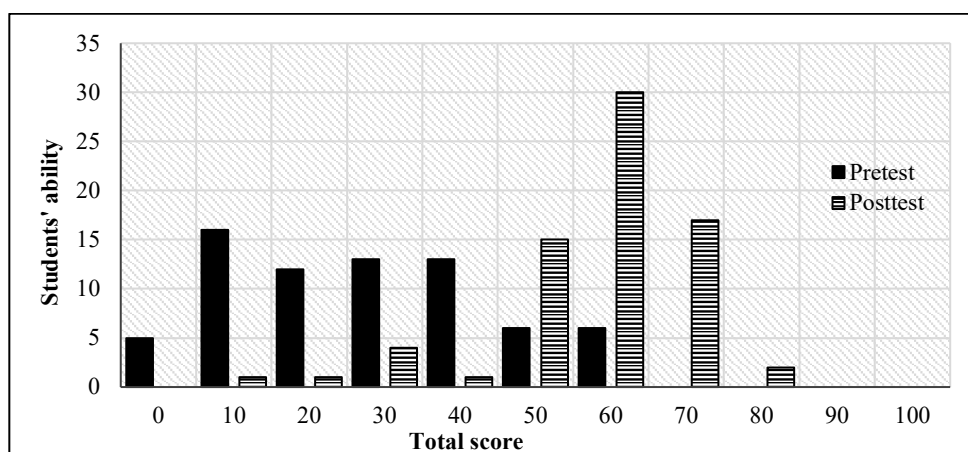


Figure 3. Distribution of students' HOTS scores

The increase in student scores is in line with the increase in students' abilities in every aspect of HOTS (ability to analyze, evaluate and synthesize). Even though the students' HOTS at the pretest was still in a very low category, the posttest results showed that the students' abilities in all aspects of HOTS had increased. The results of the analysis of students' abilities (Figure 4)

shows that the HOTS aspect that has the most improvement is the ability to evaluate, following by the ability to analyze and the ability to synthesize. The ability to analyze has increased from 0.275 to 0.585 (on a scale of 0-1). The ability to evaluate increased from 0.268 to 0.810, while the ability to synthesize increased from 0.282 to 0.495.

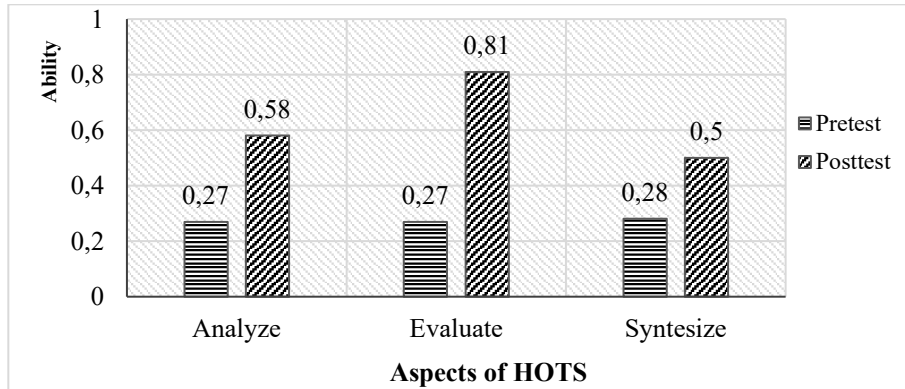


Figure 4. The improvement of students' ability to analyze, evaluate, and synthesize

Apart from that, we analyzed students' HOTS by gender (Figure 5). The results showed that the increase in students' abilities in analyzing, synthesizing, and evaluating occurred in male and female students. Students' ability to analyze has increased from 0.31 to 0.61 (male), and from 0.24 to 0.56 (female). Students' ability in evaluating increased from 0.27 to 0.83 (male), and 0.27 to 0.79 (female). Meanwhile, the students' ability to synthesize increased from 0.28 to 0.49 (male) and from 0.29 to 0.50 (female). These results reaffirm that the ability that has increased the most for male and female students is the ability to evaluate. Meanwhile, the ability to synthesize is the ability to have the lowest increase.

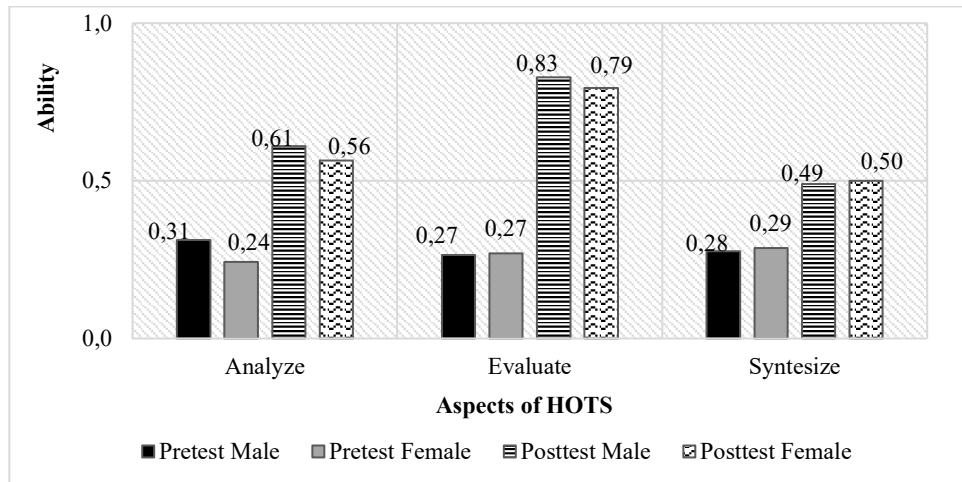


Figure 5. A comparison of male and female students' HOTS

Effectiveness of PB-CLM on students' HOTS

As described in the above section of the research method, before the effectiveness test was carried out, a pretest and posttest delta score data normality test was carried out. The results of the data normality test for the difference between the pretest and posttest scores using the one-sample Kolmogorov-Smirnov test is presented in Table 2. The results of the analysis show that

the Kolmogorov-Smirnov Z value is 1.16 with a sig (1-tailed) of $0.131 / 2 = 0.066$. This means that the null hypothesis of the data normality test is accepted, which means that the pretest and posttest delta scores come from a normally distributed population.

Table 2. Normality test result

	pretest-posttest
Kolmogorov-Smirnov Z	1.168
Asymp. Sig. (2-tailed)	0.131

Referring to [Table 2](#), then the PB-CLM effectiveness analysis was carried out using the paired sample t-test ([Table 3](#) and [Table 4](#)). [Table 3](#) shows the correlation between the pretest and posttest, while [Table 4](#) shows the results of the mean difference between the pretest and posttest. Conclusions about the effectiveness of PB-CLM are drawn based on the value of the data analyzed in [Table 4](#).

Table 2. Paired samples correlations

	N	Correlation	Sig.
Pair 1 <i>Pretest & Posttest</i>	71	0.462	0.000

The results of data analysis ([Table 3](#)) shows that the pretest and posttest scores have a significant correlation, namely 0.462. Meanwhile, [Table 4](#) shows the *t* value of -15.883 with sig. (1-tailed) of $0.00 / 2 = 0.00$, which means that the null hypothesis is rejected, or in this case the average HOTS score of students and after learning is significantly different. Furthermore, based on the results of the analysis regarding the difference in the mean pretest and posttest, it was found that the difference between the posttest and pretest was 30.141 (positive), which means that the posttest score is greater than the pretest. Thus, it can be concluded that PB-CLM is effective in increasing students' HOTS.

Table 4. Paired samples t-test (pretest vs posttest scores)

	Paired Differences			t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean			
<i>Posttest - Pretest</i>	30.141	15.990	1.898	-15.883	70	0.000

Comparison of HOTS among male and female students

The results of data analysis ([Table 5](#) and [Table 6](#)) show that the mean HOTS score of male students is not different enough from that of a female with a mean difference of only 0.81731 (scale 0-100). From the results of this descriptive analysis, there is an indication that the mean scores of these two groups are not significantly different.

Table 5. Descriptive statistics of students' HOTS (Male vs Female)

Gender	N	Mean	Std. Deviation	Std. Error Mean
Male	64	43.1250	20.69238	2.58655
Female	78	42.3077	21.97537	2.48822

The results of the data analysis in Table 6 show that the mean difference between the two groups (male vs. female) is not significantly different. The significance value (sig.) = 0.295 (sig.> 0.05) means that the null hypothesis is accepted, so it is concluded that the mean scores HOTS of male and female students do not differ significantly.

Table 6. Mean difference of male and female students' HOTS

Male vs Female	Levene's Test for Equality of variances		t-test for Equality of Mean		
	F	Sig.	t	df	Mean Difference
Overall score	1.103	0.295	0.226	140	0.81731
Delta score (posttest - pretest)	1.111	0.740	0.228	69	0.88141

Furthermore, the results of the analysis on the mean difference of the delta scores of the HOTS of male and female students were also not different. The significance value (sig.) = 0.740 (sig.>0.05) means that the null hypothesis is also accepted. That is, the increase in their HOTS (male vs female) after taking PB-CLM was no different.

Discussions

Effectiveness of PB-CLM on students' HOTS

The results of this study show that PB-CLM is effective in increasing students' HOTS. This result is inseparable from the learning design used in PB-CLM which enable students to participate and be active in every learning process. The activities carried out by students in the learning process have trained students to analyze, evaluate and synthesize (create). The activities designed in PB-CLM are contained in operational steps carried out during the learning process which consists of six operational steps (see Table 7).

Table 7. Aspects of HOTS developed through the learning activities in PB-CLM

PB-CLM Syntax	Students' Activities	Aspects of HOTS
Step-1 Problem presentation	<ul style="list-style-type: none"> ▪ observing ▪ asking 	Analyze
Step-2 Organizing students to learn	<ul style="list-style-type: none"> ▪ observing ▪ asking ▪ taking individual roles in the group 	Analyze
Step-3 Problem identification and formulation	<ul style="list-style-type: none"> ▪ identifying important information from the problem ▪ distinguishing relevant and irrelevant information 	Analyze
Step-4 Investigation and problem solving	<ul style="list-style-type: none"> ▪ planning solving procedures; ▪ choosing a solution strategy ▪ creating ideas ▪ making patterns ▪ making conjectures ▪ choosing relevant concepts according to context, ▪ evaluating problem-solving processes and solutions 	Evaluate & synthesize
Step-5	<ul style="list-style-type: none"> ▪ communicating mathematical ideas in various ways 	Evaluate

PB-CLM Syntax	Students' Activities	Aspects of HOTS
Presentation of problem-solving results	<ul style="list-style-type: none"> evaluating ideas from other groups 	
Step-6 Assessment and drawing conclusion	<ul style="list-style-type: none"> assessing mathematical statements/predictions/procedures made by their own group or other groups interpreting the obtained solution according to the context making conclusions drawing logical conclusions from the results of problem-solving 	Evaluate & Synthesize

The activities in PB-CLM are indeed no different from activities in PBL, but PB-CLM focuses on activities that practice HOTS aspects, as mentioned by Maharaj and Wagh (2016) about eight learning activities that can develop students' HOTS. The problems in PB-CLM are presented in various ways, either in writing (using worksheets), conveyed verbally, or by direct visualization or using media such as video recordings. The problems given are problems that have relevance to the daily life of students. One example of a problem used (Figure 6) is as follows.

Diketahui:

a. panen tahun I = 30 ton

b. panen tahun II = 22,5 ton (berkurang)

c. Prediksi hasil panen tahun berikutnya:

$$h(t) = 15 + \frac{15}{t}$$

h = hasil panen (ton)

t = waktu (tahun)

d. supaya untung sekarang - kurangnya harus panen 15 ton

Berdasarkan informasi diatas berarti

$h(t) > 15 \rightarrow$ untung

$h(t) < 15 \rightarrow$ rugi

- Kapan petani akan rugi ?
- Pake cara apa menyelesaikannya ?
- Kalau dihitung satu-satu hasil panennya bagaimana ?
- Apakah harus digambar grafiknya ?

Important information related to the problem

Questions related to the problem

Figure 6. Students identified important information and asking questions

The problem is presented so that students are motivated, and a sense of curiosity arises to solve the problem. Furthermore, in the second phase (problem identification and formulation) students are given the opportunity to analyze the problem by writing down the information contained in the problem. Students are asked to sort important information from various

information on the problem and make questions related to the problems (see Figure 6). This phase also aims to train students' ability to analyze.

The results of the analysis of the information in the problem are used by students in conducting investigations and solving problems. Activities undertaken by students include planning problem-solving procedures, choosing strategies, creating ideas, making assumptions, making patterns, modifying existing concepts to fit the context of the problem, and evaluating the processes and results obtained before drawing conclusions logically based on the information and results obtained. These activities train students' ability to synthesize (create) and evaluate.

The results of the investigation and problem solving are then presented in front of the class. The activities carried out by students were communicating mathematical ideas using various methods and providing arguments for their friends' responses, while the other groups evaluated the ideas and ideas of students who made presentations. At this stage, the ability of students to evaluate or provide reassessment is trained. After obtaining solutions to existing problems, students assessed several solutions that had been presented by several groups (Figure 7). At this stage, students interpret the solutions obtained in accordance with the context being studied, determine the most effective and efficient solution steps, and draw conclusions. Therefore, this stage trains students' ability to evaluate and be creative.

Substitution on function

Untuk mengetahui kapan hasil panen akan kurang dari 16 ton dengan cara hitung hasil panen tiap tahun:
tahun 3 = $15 + \frac{15}{3} = 15 + 5 = 20$ ton
tahun 4 = $15 + \frac{15}{4} = 15 + 3,75 = 18,75$ ton
tahun 5 = $15 + \frac{15}{5} = 15 + 3 = 18$ ton
tahun 6 = $15 + \frac{15}{6} = 15 + 2,5 = 17,5$ ton
tahun 7 = $15 + \frac{15}{7} = 15 + 2,14 = 17,14$ ton
tahun 8 = $15 + \frac{15}{8} = 15 + 1,875 = 16,875$ ton
tahun 9 = $15 + \frac{15}{9} = 15 + 1,67 = 16,67$ ton
tahun 10 = $15 + \frac{15}{10} = 15 + 1,5 = 16,5$ ton
tahun 11 = $15 + \frac{15}{11} = 15 + 1,36 = 16,36$ ton
tahun 12 = $15 + \frac{15}{12} = 15 + 1,25 = 16,25$ ton
tahun 13 = $15 + \frac{15}{13} = 15 + 1,15 = 16,15$ ton
tahun 14 = $15 + \frac{15}{14} = 15 + 1,07 = 16,07$ ton
tahun 15 = $15 + \frac{15}{15} = 15 + 1 = 16$ ton (rugi)
tahun 16 = $15 + \frac{15}{16} = 15 + 0,94 = 15,94$ ton (rugi)

Using inequality

$$\begin{aligned} \text{Untung : } & 15 + \frac{15}{t} > 16 \\ \Leftrightarrow & 15 + \frac{15}{t} - 15 > 16 - 15 \\ \Leftrightarrow & \frac{15}{t} > 1 \\ \Leftrightarrow & \frac{15}{t} \cdot t > 1 \cdot t \\ = & 15 > t \\ \text{petani untung dari tahun } & 1-14 \end{aligned}$$

Figure 7. Students tried to solve the problem using a different mathematical concept

Although the activities described above support the development of students' HOTS, the teacher's role is also very important in maintaining the learning process as it should, as the results of studies Deep et al. (2020) and Mitani (2021) that a teacher's role as a facilitator to train students' thinking skills is important. To avoid student confusion when participating in the learning process, the teacher's role as facilitator and mediator is needed. During the learning

process, the teacher facilitates students by providing scaffolding in the form of questions that lead students to a deeper understanding such as "what if?", "why is that?", or "Where is the error?". The questions are thus given so that students evaluate the ideas they have made, the mathematical steps they have taken, and the solutions they have obtained. The frequency of giving scaffolding during the implementation of this study PB-CLM was adjusted to the conditions and abilities of the students.

In the implementation of PB-CLM, students are still not familiar with a learning activity that requires them to be more active during the learning process. Therefore, teachers tend to provide a lot of help, using questions like those mentioned above. This assistance is given to all, not only students who experience difficulties or those who make misconceptions. This condition makes them accustomed to evaluating the ideas and results they get. This can be seen in the results of the analysis of students' abilities in each aspect of HOTS which is shown in [Figure 4](#) and [Figure 3](#) which shows that the ability of students to evaluate (male and female) has increased significantly. Meanwhile, the ability to synthesize is the ability that has increased the least. This affirms that they are not yet optimally engaged in activities that require synthesize (create) abilities, such as planning the completion process, making predictions, making patterns, or making conclusions.

Based on the results related the effectiveness of PB-CLM on students' HOTS, it can be concluded that the effectiveness of PB-CLM in increasing students' HOTS is the impact of the their activities during learning process that develop HOTS. The designed activities are activities that train HOTS, supported by activities of teachers who provide facilitation and mediation to students during the learning process. In [Table 5](#), it is shown how the relationship between student activities and the abilities being trained. This means that every stage of PB-CLM trains students' HOTS.

As stated in the previous section, this PB-CLM is a modification of the PBL model. Therefore, the findings of this study indicate that PBL can be used to teach calculus. In addition, students' activities during the learning process have a positive effect on increasing their HOTS. The effectiveness of PB-CLM in increasing students' HOTS has relevance to several previous research results which revealed that PBL has a positive correlation with students' thinking skills (Mokhtar et al., 2010; Rajagukguk & Simanjuntak, 2015; Redhana, 2012; Wynn, Mosholder, & Larsen, 2014).

Comparison of HOTS among male and female students

Regarding the HOTS scores between male and female students, we find that they are not significantly different. In general, at the pretest and posttest, they have the same performance. Likewise, in terms of increasing their abilities, they showed an increase in abilities at the same level after participating in learning with PB-CLM. The results of this study are in line with the results of a study conducted by Awofala (2017), Makarova, Aeschlimann, and Herzog (2019), Alghadari, Herman, and Prabawanto (2020), and Chongo, Osman, and Nayan (2020) who did not find any significant difference between the thinking skills of male and female students in secondary school. The significant difference lies in the basic mathematical ability and mathematical self-efficacy between male and female students (Alghadari et al., 2020). However, many other studies have found significant differences between the thinking abilities of male and female students (Arslan, 2012; Istiyono, Widiastuti, Supahar, & Hamdi, 2020; Lin & Tsai, 2018; Retnawati & Wulandari, 2019). These studies found that female showed better

performance than male (Arslan, 2012; Istiyono et al., 2020; Lin & Tsai, 2018; Retnawati & Wulandari, 2019).

The results of this study suggest strongly that the question is not whether a male is more capable at mathematics than a female, but rather, how are our teaching practices in mathematics affecting the HOTS of male and female differently and who is benefiting more. Interestingly, this PB-CLM model has resulted in an increase in HOTS with an increase that does not differ between male and female. The effectiveness of PB-CLM is not influenced by gender differences, or in other words, both male and female students can be facilitated in this learning model. Meanwhile, as the results of this study showed that there was no significant difference in the increase in HOTS of male and female students. It was in line with the results of the study of Fuad, Zubaidah, Mahanal, and Suarsini (2017) that the interaction between learning models and gender does not significantly affect the thinking ability of students in high school.

Unfortunately, we did not have more comprehensive data regarding other variables that might affect the HOTS of male and female students. He and Wong (2011) mention a number of studies that have attributed gender differences in thinking ability to several factors, such as biological, cultural-historical, evolutionary, and social-environmental. To obtain more comprehensive results, we need to consider a meta-analysis to obtain a clearer picture of gender comparisons in terms of their thinking ability and various other variables that influence them. In this study we only focus on gender comparison in terms of HOTS, and how the PB-CLM model we developed affects it.

Conclusion and Implication

Based on the description of the results of this study, several conclusions were obtained. *Firstly*, students' conditioning during the learning process in PB-CLM has a positive effect on increasing the HOTS of the student. Students' abilities in the domains of analysis, evaluation, and synthesis have increased simultaneously. The increase in the synthesis aspect has not significant enough. The most significant increase occurred in the analysis aspect. *Secondly*, there was no significant difference between the HOTS of male and female students, both before and after participating in the PB-CLM.

The results of this study imply that the PB-CLM model can be used for learning mathematics in secondary schools. An increase in the HOTS of male and female students (and the increase is not different) indicates that this model is not affected by gender differences, which means that PB-CLM is suitable for both male and female students. Lastly, although this model has succeeded in increasing students' HOTS, there are some challenges in its implementation. *First*, time management is crucial in this model. *Second*, teachers need to consider various contexts related to mathematical concepts that will be studied by students. As we know, not all math concepts in secondary school can be easily found in students' daily lives, so teachers need to prepare for this properly. *Third*, students who are not familiar with learning models that require them to be actively involved in the learning process will find it difficult to participate in learning activities. With habituation, we hope that students will realize the importance of being actively involved in developing their knowledge and skills in the learning process.

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