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The effectiveness of problem based learning flipped classroom on students' higher order mathematical thinking skills based on initial ability

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Abstract

High-order mathematical thinking skills are needed for prospective teachers to support them in becoming professional teachers. The aim of this study was to examine the effectiveness of the Problem Based Learning Flipped Classroom (PBLFC) model in improving students' Higher-Order Mathematical Thinking Skills (HOMTS) based on Initial Ability (IA) and to examine the effect of low, medium, high IA groups and the model used on improving HOMTS. This research employed a quasi-experimental quantitative approach, focusing on second-semester students enrolled in the Introduction to Probability course during the 2020/2021 academic year in the Mathematics Education Study Program at Universitas Negeri Semarang. The study utilized a Randomized Control Group Pre-test Post-test Design, with a sample of 71 students randomly assigned, comprising 35 students in the experimental group and 36 students in the control group. Data were obtained using the test method and processed with N-Gain analysis, t test, and one-way ANOVA, and two-way ANOVA. The results of this study showed that there was an improvement in students' HOMTS through the implementation of PBLFC for all IA groups, the improvement in students' HOMTS through the implementation of PBLFC was higher than that of Problem Based Learning (PBL) class, for medium and low IA, the improvement in HOMTS in PBLFC class was higher than that of PBL class, which means that the PBLFC model is effective in improvement of students' HOMTS, especially in medium and low IA. There is an influence of IA group and the model used on the improvement of students' HOMTS. The implications of this research are that PBLFC can be employed as an efficacious strategy for enhancing students' HOMTS, particularly for those with initial abilities that are below average. Furthermore, it can be utilized as an alternative learning approach that facilitates the advancement of future teacher professionalism. The findings of this study also have the potential to be pursued with qualitative research to elucidate the underlying factors that contribute to the lack of significant improvement in HOMTS among high IA.

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Introduction

One of the provisions that students must have in facing the problems and challenges of social life is Higher Order Thinking Skills (HOTS). HOTS is very important in learning in the 21st century (Tyas & Naibaho, 2021). Meanwhile, according to Lu et al. (2021), HOTS are a cornerstone of a strong learning environment in higher education. By developing HOTS, students become more effective learners, capable of boosting their academic performance and overcoming their learning gaps. HOTS are necessary for effective learning. In addition, HOTS can be a tool for students to contribute to the academic world, the economic sector, and their careers (Lu et al., 2021).

The ability to think critically is not something students automatically possess. It is a skill that needs to be nurtured and developed through dedicated training. Students equipped with strong higher-order thinking skills are well-positioned to navigate their studies with success and ease. Hobri et al. (2020) stated that educators must provide tasks to students that involve higher order thinking that requires students to think creatively and critically.

Rozi et al. (2021) argue that one of the common problems in learning is the application of HOTS. The activity of developing HOT is an activity that is difficult for students to carry out, not a few students have difficulty in developing higher-order thinking. This is corroborated by findings from the study conducted by Tanudjaya & Doorman (2020) who reported that students have difficulty in interpreting mathematical problems related to higher order thinking, difficulty in designing strategies in solving these problems, difficulty in applying knowledge to new contexts, which ultimately causes students to be unable to state their answers. This happens especially when the problem requires more than just the application of rules or algorithms.

Likewise, what happens to students majoring in Mathematics at Unnes, especially in the Introduction to Probability course, is that many students still experience difficulties when facing problems that require higher-level thinking. This was seen from the outcomes of student learning during lectures for the subject of Random Variables and Probability Distribution for the 2019/2020 odd semester, where only 33 percent of students could work on problems that require higher order thinking, as well as in the 2020/2021 odd semester lectures, where only 34 percent of students could work on problems that require HOT.

Suhirman et al. (2020), Baidil and Somakim (2020) stated that the characteristics of HOTS include creative thinking and critical thinking. Indicators of critical thinking skills in this study, which used Perkins and Murphy (2006), include (1) clarification, (2) assessment, (3) inference, and (4) strategies. Many researchers refer to Perkins and Murphy's critical thinking skills including Chou et al. (2018) and Darhim et al. (2020). Meanwhile, mathematical creative thinking skills are based on aspects, namely, fluency produces many relevant ideas, flexibility is able to produce a variety of ideas with different approaches, originality provides unusual answers that are different from others, which are rarely given by many people (Sowden et al., 2015).

One of the strategies that can be employed to cultivate students' HOTS is by applying the Problem Based Learning (PBL) model. PBL can enhance HOTS, which includes critical and creative thinking (Suhirman et al., 2020). According to Adelia et al. (2020), PBL entails using problems as the foundation for cooperatively and independent student learning, aimed at nurturing their problem-solving abilities. PBL is a learning model that encourages students to analyze and integrate a problem.

Flipped Classroom (FC) is a form of blended learning (through face-to-face and online interaction) that combines synchronous learning with asynchronous self-directed learning. In flipped classroom learning there are virtual classes that are online and face-to-face classes in schools (Ramadhani et al., 2019). In this study, synchronous learning occurs live in the classroom, whereas asynchronous learning takes place independently outside the classroom. According to Palinussa et al. (2021) implementing FC learning can enhance students' higher-order mathematical thinking skills (HOMTS).

The impact of PBL and FC on learning outcomes has been widely studied by researchers, including Barrios et al. (2022), Algarni and Lortie-Forgues (2023), and Boye and Agyei (2023). Likewise, research related to HOMTS has also been studied by many experts, including Ahmad et al. (2021) and Palinussa et al. (2021), but there has been no research linking the combined impact of PBL and FC on student HOMTS, so researching related to PBL, FC and HOMTS is interesting and very useful.

The stages in FC learning, as outlined by Ramadhani et al. (2019), Palinussa et al. (2021), and Van Alten et al. (2019), entail students solving problems at home independently. In accordance with the findings of Lonergan et al. (2022), and Adelia et al. (2020), the stages in PBL learning do not entail any preparation related to material and problems, as both are provided by lecturers in class. The combination of PBL and FC can enhance the effectiveness of learning. In FC, students are provided with material and example problems in advance, which prepares them for in-class learning. This approach allows students with PBL to more effectively solve these problems in class. Moreover, FC facilitates comprehension of fundamental concepts, whereas PBL motivates students to apply these concepts in problem-solving, thereby enhancing effective learning and developing HOTS.

Initial ability (IA) also determines student success in lectures. Agoestanto et al. (2024) in their research found that, classically, students were complete in their learning, but after being traced based on IA it turned out that low IA was not complete, while medium and high IA were complete. This indicates that the IA group must also be considered in seeing the success of learning.

The combination of the analysis of the impact of PBL and FC on students' HOMTS represents a novel approach to this research, as previous studies have not explored this particular area. Furthermore, this study incorporates the IA factor as a significant variable influencing learning outcomes, offering a novel perspective on how the integration of PBL and FC can optimally enhance HOMTS, particularly for students with different IA levels. Consequently, this study not only underscores the efficacy of learning methods but also elucidates the necessity for a more individualized approach in designing learning experiences that can meet the diverse needs of all students.

The objectives of this study are (1) to examine the effectiveness of the Problem Based Learning Flipped Classroom (PBLFC) model in improving students' HOMTS based on IA, and (2) to examine the effect of low, medium, high IA groups and the models used, namely, PBLFC and PBL, on improving HOMTS. This research is beneficial for educators and prospective teachers seeking to enhance the effectiveness of HOMTS through PBLFC learning. Additionally, it underscores the significance of educators taking into account students' initial mathematical abilities and contributing to the advancement of mathematics education at the university level.

Methodology

This study employed a quantitative research methodology utilizing a quasi-experimental design. The research utilized a Randomized Control Group Pre-test Post-test Design, with the experimental group employing PBLFC and the control group employing PBL. The research population was 2nd semester students who took the Introduction to Probability course in the 2020/2021 lecture year, majoring in Mathematics, UNNES Indonesia. The sample consisted of 71 students selected through random sampling, with 35 students in the experimental group and 36 students in the control group. Student IA data using GPA. The experimental group employs the PBLFC model for the learning process, whereas the control group utilizes the PBL model, excluding the FC stage. From the PBL phase according to Lonergan et al. (2022) and FC according to Van Alten et al. (2019), in this study, the PBLFC model syntax is as shown in Table 1.

Before being given the treatment, the two classes were tested to be in a balanced state using IA scores through normality tests, homogeneity tests and mean similarity tests. After the two classes were balanced in IA, each class was grouped into three IA, namely, high, medium and low. IA grouping using Lestari and Yudhanegara (2019) is displayed as Table 2.

Table 2 IA grouping

IA Group	IA score limit (x)
Low	$x < \bar{x} - SD$
Medium	$\bar{x} - SD \le x < \bar{x} + SD$
High	$\bar{x} + SD > x$

Note: x = IA score.
$\bar{x}$ = average of IA score.
SD = standard deviation of IA score.

Table 1 PBLFC Learning Syntax

Step	Phase	Student's Behavior
0	Viewing the material themselves, whether it is a video or something else	Access the video links or teaching materials provided by the lecturers and conduct an independent search for learning resources related to the material studied
1	Orientation of the problem to students	Clarify the problem by describing or defining the problem
2	Organize students to learn	Describe and organize learning tasks related to the problem given by the lecturer.
3	Guide investigations conducted by students both individually and in groups.	Collecting appropriate information to solve problems
4	Develop and present solutions	Devising plans and working on problem solving
5	Analyze and evaluate the problem-solving process	Reflecting and evaluating and giving the reason for the solution process they used

The research instruments include Semester Learning Plan, learning observation sheet, and HOMTS test. The HOMTS test contains four description questions on mathematical expectation material, two questions measuring critical thinking skills and two questions measuring creative thinking skills, with the questions as follows: (1) In a game someone will get Rp. 500,000 if all the numbers or pictures appear and the dice eye is 6, if a coin and a dice are rolled once and he has to pay Rp. 200,000 if something else appears, what is the expectation of victory for that person?; (2) In a game a person is paid Rp. 200,000 if he draws a jack or queen and Rp. 500,000 if he draws a king or ace from a set of 52 bridge cards. How much should he pay to play if the game is fair?; (3) In a game of rolling two dice once a person wins the game if both sixes appear, how much should the player pay for the game to be fair?; (4) In a game one person wins the game if he draws an ace or queen and loses if he draws any other card from a set of 52 bridge cards. Determine the minimum a player must pay for him to have any hope of winning?

Before being used, the Semester Learning Plan instrument and the learning observation sheet were tested for validity and the test instrument was tested for validity and reliability. Validation was conducted by three experts from Universitas Negeri Semarang. Semester Learning Plan validation includes the suitability of the formulation of learning objectives, the suitability of the material, the suitability of the time used, the suitability of the syntax of the learning model, and the clarity of language. The validation of the learning observation sheet includes the clarity of the aspects observed, the suitability of the plan and the implementation of learning and language clarity. Validation of the HOMTS test includes aspects of substance, construction and language. The results validation of instrument are displayed in Table 3.

Assessing the reliability of the test instrument through the utilization of Cronbach's Alpha test obtained .845 > .70 so it is reliable. Thus, the test instrument test is valid and reliable. Criteria for improving HOMTS using Hake's Normalized Gain (1998).

$$\text{Normalized Gain (g)} = \frac{\text{Posttest Score-Pretest Score}}{\text{Maximum Score-Pretest Score}}$$

Table 3 Research Instrument Validation Results

Instrument	Expert 1	Expert 2	Expert 3	Average	Category
Semester Learning Plan	3.8	3.8	3.6	3.73	highly valid
Observation Sheet	4	3.67	3.67	3.78	highly valid
HOMTS Sheet	3.75	3.75	3.625	3.71	highly valid

Normalized gain criteria displayed in Table 4.

The enhancement of HOMTS was assessed by comparing the post-test scores between the experimental and control groups. The disparity in HOMTS improvement was analyzed using independent t-tests, one-way ANOVA, and two-way ANOVA, facilitated by SPSS.

Table 4 Normalized Gain Criteria

Gain Index	Criteria
$g \geq .7$	High
$.3 \leq g < .7$	Moderate
$g < .3$	Low

Note: g = normalized gain.

Results

Description of HOMTS through the Application of PBLFC Model Based on IA

The description of students' HOMTS through the application of PBLFC is presented in Figure 1, Table 5, and Table 6.

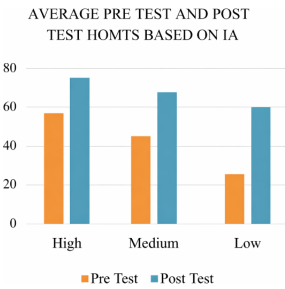

Figure 1 Pre-Test and Post Test of HOMTS of students based on IA in PBLFC

Table 5 Improvement of students' HOMTS based on IA in PBLFC class

IA	HOMTS Improvement
High	18.75
Medium	24.90
Low	36.50

Table 6 Gain score of improving HOMTS in PBLFC

HOMTS on IA	Average Gain	Category
High	.42	Moderate
Medium	.43	Moderate
Low	.48	Moderate

Based on Figure 1 and Table 5, there was an improvement in students' HOMTS from high, medium, and low IA groups, with the highest improvement achieved in the low IA group.

The improvement of students' HOMTS through the implementation of PBLFC based on IA was analyzed using the Gain test according to Hake (1998), the outcomes of which are outlined in Table 6.

According to Table 6, the results of the increase in HOMTS of students given the PBLFC model are in the moderate category, with an average Gain for high IA groups of .42, medium IA .43, and low IA .48. This shows that the low IA group has the biggest increase in HOMTS after the implementation of the PBLFC model.

Improvement of Students' HOMTS through the Implementation of PBLFC Based on IA

To test the improvement of students' HOMTS through the implementation of PBLFC based on MIA, one-way ANOVA test was used, with the SPSS output results displayed in Table 7 (Descriptive output of HOMTS improvements based on IA), Table 8 (Homogeneity test output in the HOMTS improvement test based on IA), and Table 9 (HOMTS improvement test output based on IA with ANOVA).

Based on Anova test, $p = .00 < .05$ is obtained, so there is a significant difference in the average improvement of students' HOMTS for high, medium and low IA in PBLFC class. Based on Table 7, it is obtained that the largest average improvement in HOMTS occurs in low IA.

Differences in the Improvement of Students' HOMTS through the Implementation of PBLFC and PBL

After being given PBLFC learning in the experimental class and PBL in the control class, both classes were given a post test. To test the difference in the improvement of students' HOMTS through the application of PBLFC and PBL, t-test was used, the results of which are in Table 10.

From the output of Levene's Test for Equality of Variances obtained $p = .091 > .05$ then the data on the improvement of HOMTS in PBLFC and PBL classes are homogeneous, From the output of the t-test for Equality of Means obtained $p = .001 < .05$ then there is a difference in the improvement of HOMTS classes given PBLFC and PBL with PBLFC classes better than PBL, namely, the mean improvement of PBLFC = 25.89 > 20.19 = mean PBL, so the PBLFC model is effective in improving HOMTS.

Table 7 Descriptive output of HOMTS improvements based on IA

HOMTS on IA	N	Mean	*SD*
High	7	18.29	5.469
Medium	21	24.81	5.724
Low	7	36.71	2.059

Note: N = number of students.
SD = standard deviation.

Table 8 Homogeneity test output in the HOMTS improvement test based on IA

Levene Statistic	df1	df2	*p*
1.330	2	32	.279

Table 9 HOMTS improvement test output based on IA with ANOVA

Source of variation	Sum of Squares	df	Mean Square	F	*p*
Between Groups	1249.448	2	624.724	23.243	.000
Within Groups	860.095	32	26.878		
Total	2109.543	34			

Table 10 Output of the difference test for the improvement of HOMTS

Class	N	Mean	*SD*	Standard Error Mean
PBLFC	35	25.89	7.877	1.331
PBL	36	20.19	5.810	.968
Independent Samples T Test				
	Levene's Test for Equality of Variances		t-test for Equality of Means	
p	.091		.001	

Note: N = number of students.
SD = standard deviation.

Improvement of Students' HOMTS through the Implementation of PBLFC and PBL Based on IA

In this section, an examination is conducted to determine if there exists a discrepancy in the enhancement of students' HOMTS between PBLFC and PBL classes for each IA utilizing the t-test with assistance from SPSS. The findings are outlined below.

Differences in HOMTS improvement in high IA

Normality test of HOMTS improvement in high IA displayed in Table 11.

Table 11 Normality test of HOMTS improvement in high IA

HOMTS	Kolmogorov-Smirnov Z	*p* (2-tailed)
High	.883	.417

From the One-Sample Kolmogorov-Smirnov Test output in Table 11, it is obtained that the HOMTS data for high IA comes from a normally distributed population.

Mean Difference test of HOMTS Improvement in High IA is displayed in Table 12.

From the Independent Samples Test output in Table 12, $p = .897 > .05$ is obtained, so there is no difference in the improvement of students' HOMTS at high IA for PBLFC and PBL classes.

Difference in HOMTS improvement in medium IA

Normality Test of HOMTS improvement in Medium IA displayed in Table 13.

From the One-Sample Kolmogorov-Smirnov Test output in Table 13, it is obtained that the HOMTS data for medium IA come from a normally distributed population. Table 14 shows Mean Difference Test of HOMTS Improvement in Medium IA.

From the Independent Samples t Test output in Table 14, $p = .004 < .05$ is obtained, so there is a difference in the increase in HOMTS of students in medium IA with the mean improvement in HOMTS of PBLFC class = 24.81 > 19.48 = mean improvement in HOMTS of PBL class. So PBLFC is effective in increasing students' HOMTS for medium IA.

Difference in HOMTS improvement in low IA

Table 15 shows Normality test of HOMTS improvement in low IA.

From the One-Sample Kolmogorov-Smirnov Test output in Table 15, it is obtained that the HOMTS data for low IA come from a normally distributed population.

Table 16 shows Mean Difference test of HOMTS Improvement in Low IA.

Table 12 Mean Difference test of HOMTS Improvement in High IA

HOMTS	Model	N	Mean	*SD*	Standard Error Mean
High	PBLFC	7	18.29	5.469	2.067
	PBL	7	18.00	1.732	.655
Independent Samples T Test					
	Levene's Test for Equality of Variances				t-test for Equality of Means
p	.050				.897

Note: SD = standard deviation.

Table 13 Normality Test of HOMTS improvement in Medium IA

HOMTS	Kolmogorov-Smirnov Z	*p* (2-tailed)
Medium	.918	.368

Table 14 Mean Difference Test of HOMTS Improvement in Medium IA

HOMTS	Model	N	Mean	*SD*	Standard Error Mean
Medium	PBLFC	21	24.81	5.724	1.249
	PBL	21	19.48	5.555	1.212
Independent Samples T Test					
	Levene's Test for Equality of Variances				t-test for Equality of Means
p	.680				.004

Note: SD = standard deviation.

Table 15 Normality test of HOMTS improvement in low IA

HOMTS	Kolmogorov-Smirnov Z	*p* (2-tailed)
Low	1.017	.252

Table 16 Mean Difference test of HOMTS Improvement in Low IA

HOMTS	Model	N	Mean	*SD*	Standard Error Mean
Low	PBLFC	7	36.71	2.059	.778
	PBL	8	24.00	7.426	2.625
		Independent Samples T Test			
		Levene's Test for Equality of Variances			t-test for Equality of Means
p		.003			.001

Note: SD = standard deviation.

From the Independent Samples t-test output in Table 16, $p = .001 < .05$ is obtained, so there is a difference in the improvement in HOMTS of students at low IA with the mean improvement in HOMTS of PBLF class = 36.71 > 24.00 = mean improvement in HOMTS of PBL class. So PBLFC is effective in improvement students' HOMTS for low IA.

Interaction of Applied Model with IA on HOMTS

To test the interaction of the applied model with IA on HOMTS, 2-way ANOVA was used with the help of SPSS, the results are in Table 17.

From Table 17, the *p* of Class*IA = .01 < .05, so there is an interaction between the IA group and the model used on HOMTS. This means that there is an influence of the IA group and the model used, namely, PBLFC and PBL, on improvement of student HOMTS.

Discussion

The Effectiveness of the Problem Based Learning Flipped Classroom (PBLFC) Model in Improving Students' HOMTS Based on IA

The improvement in HOMTS for all IA groups was in the medium category after being given the PBLFC learning model. In terms of IA, the highest improvement was obtained by low IA with a Gain value of .48 followed by medium IA of .43 and high IA of .42. Thus, the low IA group had the biggest improvement in HOMTS. This is due to the PBLFC model, where students have early access to learning materials through independent learning resources before class meetings. In line with the findings of Yurniwati & Utomo (2020), learning with a combination of PBL and Flipped Classroom models provides opportunities for students to develop HOTS through independent learning activities from videos and reading sources carried out outside the classroom. This provides opportunities for low IA students to learn the material at their own pace and strengthen their basic understanding. When they engage in problem-solving activities in class, they can focus more on applying the concepts they have learned, which in turn improves students' HOMTS. This finding is corroborated by the study conducted by Chang et al. (2022), who revealed that the combination of PBLFC learning helps students in providing an enjoyable experience. Students not only receive knowledge from the teacher, but they also engage in discussion, problem solving, and collaboration with other students. Their learning performance will also improve, and they can think more deeply (Wei et al., 2020).

The ANOVA test revealed a statistically important difference between the groups in the average improvement in students' HOMTS for high, medium and low IA in the PBLFC class. This confirms descriptively that there is a difference in the average improvement in HOMTS between IA groups. Although the biggest improvement in HOMTS is from low IA, judging from the post-test results, low IA is still far below medium and high IA. This is caused by students with low IA usually starting with a more limited understanding of basic mathematical concepts compared to students with medium and high IA. Thus, an alternative is needed that can assist students to collaborate to improve their problem solving skills. By applying the FC model, students with low IA are also supported in developing problem-solving skills and increasing student collaboration in mathematics learning activities (Diana et al., 2023).

In addition, although the biggest increase in HOMTS occurred in the group of students with low IA, the results of the low IA posttest were still far below the medium and high IA. This is because the improvement process takes a longer time compared to students who have medium or high IA. They do not fully have a good understanding if they study independently. They need to adapt because

Table 17 2-way ANOVA results testing the interaction of the applied model with IA

Source	Type III Sum of Squares	df	Mean Square	F	*p*
CLASS*IA	287.046	2	143.523	4.959	.010

they study independently at home, consequently they are not ready for active learning in the classroom (Güler et al., 2023). Therefore, despite the significant improvement, students with low IA may still take longer to reach the same level of proficiency as students with higher IA.

There is a difference in HOMTS improvement in classes that apply PBLFC and PBL models. The class that applied PBLFC experienced a more significant increase in HOMTS than the class that only used PBL, so PBLFC was effective in increasing HOMTS compared to PBL. A study by Oliván-Blázquez et al. (2022) found that combining Flipped Classroom with Problem-Based Learning led to significantly better test scores and pass rates compared to classes using other learning models. This occurs because FC enables students to actively participate in the learning process prior to the class, while PBL allows students to collaborate and think critically when solving problems. Limniou et al. (2018) stated that there is an effect of learning using FC on students' HOTS. Meanwhile, Palinussa et al. (2021), stated that through the implementation of FC, students enhance their HOTS by addressing problems.

The combination of PBL and FC models increases student engagement and motivation to learn. This can be seen in the implementation of the PBLFC model, where students have more opportunities to collaborate and discuss with other students during class time. Collaboration can greatly benefit students' grasp of math. By exchanging ideas, discussing concepts, and even debating approaches, students are exposed to diverse problem-solving strategies. This not only expands their comprehension of mathematics but also nurtures their critical thinking abilities. This is reinforced by Tang's opinion (2023) which states that the integration of FC teaching method with PBL is beneficial for enhancing classroom teaching effectiveness, fostering students' self-learning skills, and boosting their motivation to learn.

The syntax of the PBLFC learning approach is intentionally crafted to enhance HOMTS. During the initial stage, students are prompted to engage with materials through video presentations and instructional resources. This fosters knowledge construction, wherein the development of HOMTS is involved, as it necessitates students to generate their own understanding (Zain et al., 2022). Deep understanding of mathematical concepts will also increase (Egara & Mosimege, 2023). The next phase, which is student orientation to the problem, can develop the ability on the aspect (clarification) to clarify the problem by describing or defining it. In the next stage, students will be directed to be encouraged to actively gather appropriate information. Then, in the phase of developing and presenting solutions, they are asked to plan and apply solutions appropriately. The process encourages critical and creative thinking to determine problem solutions by discussing various new ideas (Cevikbas & Kaiser, 2020). In addition, it encourages the emergence of new ideas and problem solutions according to the elements of creative thinking, namely, flexibility, fluency, and originality. This phase will also encourage the ability in the assessment aspect so that students can make decisions, express arguments, and connect one problem with another. The ability in the aspect (inference) to generalize conclusions and make hypotheses appropriately will also increase. The last phase, analyzing and evaluating problems, will facilitate being able to propose, discuss, or evaluate possible actions or strategies. Every post-activity reflection process facilitates the attainment of critical thinking skills (Evendi et al., 2022). Thus, the PBLFC model is considered superior to the PBL model.

There was no difference in HOMTS at high IA after PBLFC or PBL models were implemented, so PBLFC was not effective in improving HOMTS for students at high IA. In contrast to this, at medium IA, PBLFC is effective in improving HOMTS. Likewise, for low IA, PBLFC is more effective than PBL in improving HOMTS. Thus, overall, PBLFC is more effective than PBL in increasing HOMTS, but seen from IA, the PBLFC model is effective in increasing HOMTS for medium IA and low IA, while high IA has the same HOMTS in PBLFC and PBL. This is because in PBLFC, students are encouraged to understand mathematical concepts through solving real problems. This forces medium and low IA students to think critically, analyze information, and find the right solution, which can increase students' HOMTS. Such is reinforced in the opinion of Lestari (2021), who states that students experience improvements in critical thinking skills, creativity, responsibility, teamwork, and punctuality after being involved in activities in the Flipped Classroom. In addition, when students feel an improvement in their understanding of mathematics and successfully solve more complex problems, it can increase their motivation to engage in further learning. Students with medium IA and low IA who experienced an increase in HOMTS felt more confident and motivated to continue improving their abilities.

The Effect of Low, Medium, High IA Groups and the Models Used, namely, PBLFC and PBL, on Improving HOMTS

Partially, PBLFC was effective in improving HOMTS compared to PBL. Based on the two-way ANOVA test, it was found that there was an effect of the applied model, namely, PBLFC and PBL as well as high, medium and low IA groups on increasing students' HOMTS. According to Thompson (2008) in his research, the distinction between students exhibiting high-level and low-level thinking skills lies in their capacity to comprehend given problems or materials and effectively apply them, both in problem-solving scenarios and in real-life situations. In addition, some students need interesting learning media to help improve their understanding of the material. The PBLFC model provides more time for feedback to students (Al-Zoubi & Suleiman, 2021). The flipped classroom model transforms students from passive learners to active participants. It facilitates the creation of online educational resources and promotes the strategic utilization of technology tools to enhance the learning process at each stage (Salas-Rueda, 2023). Technology allows lecturers to use various assessment formats, including online tests, digital project assignments, online forum discussions, and so on. This allows lecturers to tailor assessment to learning styles and enrich students' evaluation experience. Consequently, this can bolster students' grasp of concepts and foster the development of HOTS.

Conclusion and Recommendation

The conclusions drawn from the conducted research findings are as follows: (1) The PBLFC model is effective in improving students' HOMTS, especially low and medium IA, which is characterized by (a) Students' HOMTS through the implementation of PBLFC improved for all IA (high, medium, and low), with an average Gain for high IA group of 0.42, medium IA of 0.43, and low IA of 0.48, (b) the improvement of students' HOMTS through the implementation of PBLFC is better than the PBL class, (c) the improvement of HOMTS in PBLFC class being higher than that in PBL class occurs in medium and low IA, while the high IA group has no difference in HOMTS improvement; (2) There is an influence of IA group and the model used, namely, PBLFC and PBL, on the improvement of students' HOMTS.

As the research on the implementation of PBLFC was carried out using two classes with a total sample of only 71 students, so that the results are more perfect, it is recommended that similar research can use more samples. The results showed that high IA was not influenced by the increase in HOMTS in PBLFC, so it is necessary to explore in depth with qualitative research what the causes and solutions are. The findings of this qualitative study could potentially lead to a quantitative investigation concerning scaffolding. The results of this study can also be referenced by lecturers in designing lessons in order to improve students' HOMTS.

Conflict of Interest

The authors declare that there is no conflict of interest.

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