



# THE INTEGRATION OF PROBLEM-BASED AND COLLABORATIVE LEARNING ASSISTED BY GEOMETER'S SKETCH PAD: ITS EFFECTS ON STUDENTS' HIGHER-ORDER THINKING SKILLS AND COLLABORATIVE SKILLS

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## Abstract

*Students showed poor performance in applying higher-order thinking skills (HOTS) in solving Additional Mathematics problems. Therefore, this study examined the effects of Problem-Based Learning (PBL) and Collaborative Learning (CL) assisted by Geometer's Sketch Pad on the four levels of HOTS of Form Four students, namely Applying, Analysing, Evaluating and Creating. In addition, the effects of PBL-CL on the four collaborative skills (CS) constructs, namely Academic Benefits, Social Benefits, Generic Skills, and Negative Aspects, were also examined. A PBL-CL module was developed as a guide for teachers. A HOTS test and CS questionnaire were developed to assess the level of HOTS and collaborative skills of students, respectively. This study used a quasi-experimental pre-test and post-test control group research design involving 270 Form Four students in Sabah, Malaysia. The assessment of HOTS involved three intervention groups, namely PBL-CL, PBL and Conventional Learning (Conv) group, while the assessment of CS involves two intervention groups, namely PBL-CL and PBL groups. The results showed that the PBL-CL group produced significantly higher post-test mean scores compared to the PBL and Conv groups in all four levels of HOTS and also produced a significantly higher post-test mean score than the PBL group in all four CS constructs. This shows that the PBL-CL method has a positive effect in helping the development of HOTS and CS of Form Four students. Therefore, Additional Mathematics teachers are strongly recommended to integrate PBL-CL in their classroom to increase the level of HOTS and CS among students.*

**Keywords:** collaborative learning, collaborative skills, higher-order thinking skills, form four students, Geometer's Sketch Pad, problem-based learning

## Introduction

Mathematics is one of the most crucial subjects for 21st-century human capital development. Accordingly, the way that mathematics is taught and learned has changed as a result of the shift in emphasis in the field from cognitive algorithm skills to higher-order thinking skills (HOTS) (Yasin et al., 2021). Thus, it is believed that implementing HOTS in the Additional Mathematics elective subject can contribute to the realisation of this goal. Compared to Mathematics, Additional Mathematics places a greater emphasis on mathematical

applications and real-world problem-solving, which is closely related to solving non-routine problems. This coincides with the change of the Malaysian Integrated Secondary School Curriculum to the Standard Secondary School Curriculum in 2017 so that students had an opportunity not only to increase their understanding, skills and interests but also apply elements of HOTS in the curriculum (Bahagian Pembangunan Kurikulum, 2018). However, the results of the Additional Mathematics subject in the Malaysian Certificate of Education (MCE) since the Ministry of Education introduced HOTS are of great concern to all parties, especially in the state of Sabah. It was found that 46.67% of students have poor application skills, while 37.36% have poor analytical skills (Jabatan Pendidikan Negeri Sabah, 2020). In addition, the weak categories of evaluating and creating skills showed 52.49% and 39.48%, respectively. In conclusion, more than 40% of students out of all MCE candidates are still weak in answering HOTS questions.

Several approaches, such as problem-based and collaborative learning, and incorporating technology into the classroom, should be prioritised to address this issue. According to Suanto et al. (2019), problem-based learning (PBL) is an authentic (real) problem-learning approach that helps students organise their knowledge, develop high skills and inquiry, and boost their self-confidence. PBL uses a variety of activities and investigations based on the theories, concepts, and principles that students learn to give students real-world situations to solve real-world problems while also assisting them in developing the critical thinking and teamwork skills necessary for success (Masek, 2015). Students are exposed to pertinent and significant real-world problems using this approach. The instructor's only role is to facilitate the students' knowledge-building activities while actively solving problems, communicating, and debating which solution is best in groups (Mokter, 2019).

One strategy to address this issue is the collaborative learning approach. However, Ahmad et al. (2019) claimed that less effective collaborative learning, students' lack of HOTS skills, and subpar academic performance are the main issues with the implementation of teaching at the secondary school level. According to Zhou et al. (2019), collaborative learning methods are complex and rarely implemented because teachers think that collaborative learning methods are a waste of time. Teachers take the easy way out by telling students the answers without explanation to save time and be able to finish the syllabus quickly. As a result, collaborative learning methods that can train students about HOTS are neglected. In conclusion, the success of improving students' HOTS depends on the teacher's role in planning and preparing group learning activities that involve all students (Fitriani & Novitasari, 2017).

Based on the problems above, this study was conducted by focusing on learning strategies in the classroom. One of the alternatives to existing learning strategies is a collaborative problem-based solution method. Past studies show that problem-based solution methods are needed by students to train critical thinking to create skills that help in understanding concepts in depth (Shafii & Jaafar, 2018). In addition, Amiruddin (2019) stated that the engagement between students can improve student performance and student interest. However, research on the use of collaborative problem-based solution methods is less conducted at the secondary school level. Thus, the researcher sees a need to develop a learning module using elements of problem-based solution methods and collaborative learning with the help of technology such as Geometer's Sketch Pad (GSP) to encourage active learning in the classroom. According to Awalludin (2021), students' enjoyment while learning Mathematics by exploring using GSP shows that students must know how to use technology. Therefore, a suitable module guided by technology, such as GSP, needs to be produced to encourage students to think of problem-based solutions in a collaborative approach to improve students' HOTS and collaborative skills.

## Literature Review

### *Problem-Based Learning (PBL)*

Generally speaking, PBL is a teaching and facilitating learning (TFL) method where students solve problems in the real world and gain the knowledge needed to do so. According to Barrows (1980), PBL as a TFL method serves as the primary information source and a catalyst for learning. According to Schmidt (1983), PBL has the following cognitive effects on students' learning: it activates prior knowledge, expands it through discussions in small groups, reorganises prior knowledge to address the issue at hand, learns in context, and fosters the formation of a desire to learn. Therefore, Schmidt (1983) introduced seven steps of the PBL model which are 1) Clarifying of terms and concepts that are not easy to understand - any problem should have an explanation of a concept that is not understood at first glance which can be achieved through the knowledge of group members; 2) Defining the problem – to produce a precise definition of the problem; 3) Problem analysis – group members discuss the structure of the problem to get a clear picture of the situation described; 4) Draw a systematic inventory of the explanations deduced from step 3 – made based on the various explanations of the problem. The inventory acts as a summary and organizes the product of the problem analysis; 5) Formulate learning objectives – provide answers to the questions raised by the problem analysis, and the group chooses the objectives and finally knows which learning resources supply the necessary answers; 6) Gather additional information outside the group – Group members gather information outside the group regarding learning objectives; and 7) Synthesize newly acquired information – groups share their findings, add knowledge, and discuss misconceptions if necessary.

PBL is meant to assist students in gaining the critical thinking and communication abilities required for success in real-world circumstances by means of a sequence of tasks and investigations founded on the theories, concepts, and principles studied. In Malaysian classrooms, this is achieved (Masek, 2015). Unstructured PBL problems can improve students' cognitive processes when paired with high-quality investigations (Mahamod & Hassan, 2018a, 2018b). Numerous studies, particularly in the field of mathematics education, have shown that when students use PBL to develop their mathematical thinking skills, their achievement scores improve (Kalaivani & Tarmizi, 2014; Zakariya et al., 2016).

### *Geometer's Sketch Pad*

One of the dynamic geometry software programmes for generating, examining, and analysing different mathematical ideas in algebra, geometry, trigonometry, calculus, and other subjects is called Geometer's Sketch Pad (GSP). Moreover, GSP is a dynamic geometry programme that lets educators and learners create and modify geometric objects or object parts by dragging various objects onto the computer screen. Furner and Marinas (2007) state that GSP is an interactive tool that promotes students' discovery process by having them describe and analyse problems before coming to conclusions. Using a variety of examples, GSP enables students to build their own sketches and identify patterns (Stols, 2007). In contrast to students who were taught geometry without GSP, the mean assessment of secondary students' interest in teaching geometry using GSP software differed significantly, as demonstrated by the study conducted by Iji et al. (2018). Dekker (2011) examined the effect of GSP on the knowledge and attitudes of students at Calvin Christian High School in Grandville, Michigan, United States, and discovered that the pre-test and post-test mean scores differ. According to Heidi (2004), the use of technology increases students' interest and enjoyment. Therefore, using technology is one way to increase students' excitement and achievement in geometry.

### *Higher-order Thinking Skills (HOTS)*

According to Hassan et al. (2016), the highest level of cognitive process, or HOTS, is the primary element of creative and critical thinking ability. Knowledge, Understanding, and Application are the three lowest levels, while Analysis, Synthesis, and Evaluation are the three highest. Following the formation of 21st-century learning in all schools in Malaysia, the revised edition of the taxonomy was introduced in 2001. This revised edition of Anderson and Krathwohl (2001) has updated the six levels of Bloom's thinking into verbs and also divided the top four levels into the high-order thinking skills group (HOTS) and the two lowest levels into the low-level thinking skills group (LOTS). The HOTS assessed in Form Four Additional Mathematics is based on the top four levels of the revised edition of the taxonomy, which are Apply, Analyse, Evaluate and Create (Bahagian Pembangunan Kurikulum, 2019).

In HOTS, the Application level refers to thinking skills by applying information to solve problems. The Analysing Level is the student's thinking skills in breaking down ideas into simple parts with the support of evidence and facts. The Evaluating level is a skill where students can give an opinion on certain information obtained. The Creating level is the skill in entering information obtained, and then improving it into new information based on existing information. This new information is an improvement of an idea or some other piece of information that is included in the existing information to form or create new information.

In an earlier study, Kassim and Zakaria (2015) noted a number of issues that teachers encountered when integrating HOTS into mathematics instruction. Teachers have identified three issues: students' basic knowledge, students' comprehension of complex questions, and teachers' challenges in formulating complex questions. The findings about teacher concerns about students' foundational knowledge align with a study by Saad et al. (2012), which discovered that teachers believe they must make sure students grasp all of the material and concepts before urging them to think critically. This is because, despite prompt questions, students still have difficulty understanding complex questions, and only a small number of students are able to continue learning while others come to a standstill. Moreover, the lack of modules or other reference materials that define the subject is the main obstacle to learning HOTS in the classroom (Kassim & Zakaria, 2015).

### *Collaborative Learning*

Collaborative learning (CL) is an approach that attempts to make learning interesting and pleasurable. Other names for it include small group learning and cooperative learning. Gokhale (1995) defined collaborative learning as an instructional approach where students in small groups with varying performance levels work together to accomplish a shared academic goal. Learning that comes from peers cooperating to accomplish tasks is another way to define collaborative skills. The focus is on what students can do to take charge and manage learning through group collaboration, according to Ingleton et al. (2000). Four categories can be used to group students' perceptions of collaborative learning in Brown's (2008) study: Academic Benefits, Social Benefits, Generic Skills, and Negative Aspects. Academic benefits include students assisting one another in understanding what they are learning, exchanging experiences and knowledge, receiving insightful feedback, and developing fresh perspectives as a result of speaking with peers. Social benefits include a more laid-back learning environment that influences students' ability to collaborate on group projects like problem-solving. Students who possess generic skills find it easier to solve problems, are more focused on group projects, and are able to think critically. Students who believe that teaching friends is a waste of time and that group members are not actively engaged in completing their tasks (collaborating) are referred to as the Negative Aspect.

According to Brown's (2008) study, the majority of students reported improving their performance and comprehension in the classroom. Furthermore, it was observed that students gained general skills through enhanced problem-solving and communication abilities. According to Pattanpichet's (2011) experimental study, practically all students felt that collaborative learning benefited their academic, social, and general learning.

### *Research Aim and Objectives*

This study was carried out to determine the effects of the integration of problem-based learning and collaborative learning (PBL-CL) with the help of Geometer's Sketch Pad on the higher-order thinking skills and collaborative skills of Form Four students. The operational definition of HOTS in this study was based on Revised Bloom's Taxonomy by Anderson and Krathwool (2001) which is the level of Applying, Analysing, Evaluating and Creating. Meanwhile, the operational definition of student collaborative skills (CS) refers to constructs adapted from Brown's study (2008), namely Academic Benefits, Social Benefits, Generic Skills, and Negative Aspects. Specifically, the objectives of this study were as follows:

1. To determine the effects of problem-based learning and collaborative learning, using Geometer's Sketch Pad, on the four levels of HOTS of Form Four students, namely Applying, Analysing, Evaluating, and Creating.
2. To determine the effects of problem-based learning and collaborative learning, using Geometer's Sketch Pad, on the four constructs of Collaborative Skills of Form Four students, namely Academic Benefits, Social Benefits, Generic Skills, and Negative Aspects.

## **Research Methodology**

### *Design*

The study used a quasi-experimental pre-test and post-test control group design to evaluate the impact of three different TFL methods on the higher-order thinking and collaborative skills of Form Four students. The TFL groups were divided into three categories: PBL-CL; PBL; and Conv. In PBL, a teaching module was developed by the researcher. Students in the PBL module were exposed to GSP-supported problem-based learning using collaborative learning techniques such as Think Aloud Pair problem solving, Send A Problem problem solving, Structured Problem solving and Group investigation. Form Four students in PBL were exposed to problem-based learning using GSP without the use of collaborative learning techniques. Students in the PBL group received the same assignments as those in the PBL and Conv groups, but the group activities were more focused on the teacher. In Conv, students followed the traditional teaching and learning process using GSP but without the module, where most of the learning activities were fully controlled and directed by the teacher. All students were given the intervention in the same week but with different TFL methods for eight weeks between November - December 2021.

### *Population and Sample*

The research population consisted of 487 Form Four students in Lahad Datu district, Sabah, Malaysia (Sabah State Education Department, 2020). In this research, students from five out of 10 national secondary schools in the Lahad Datu district were randomly selected as samples to sit for the pre-test. The HOTS Test was used as an instrument to determine the



research sample. Next, the HOTS Pre-Test and CS Pre-Test were administered to Form Four students for the five schools involved. From the test scores, students from three schools with the same or almost the same score values were selected as a sample in this research. The selected schools were then randomly divided into three groups, namely the PBL-CL, PBL and Conv groups. In addition, the selection of three schools was also assessed from the aspect of the number of students taking the subject of Additional Mathematics at the school. Each selected school had a minimum of 90 students as research subjects. This means, three schools provided 270 students as research subjects. Next, each selected school was divided into three classes consisting of 90 students, with each group having 30 students. According to Chua (2008), the Multivariate Analysis of Variance is robust against violations of normality when the sample size is/or greater than 30. The TFL methods, namely the PBL-CL method ( $n = 30$ ), the PBL method ( $n = 30$ ) and the Conv method ( $n = 30$ ), were implemented in each selected school.

#### *Higher-Order Thinking Skills Test (HOTS-T)*

The HOTS-T instrument (Basari & Siew, 2022) was used to measure higher-order thinking skills. The HOTS-T instrument developed by the researcher was guided by the top four levels in Revised Bloom's Taxonomy by Anderson and Krathwohl (2001), namely Applying, Analysing, Evaluating and Creating. All items were developed based on the Additional Mathematics Curriculum and Assessment Standard Document concerning the topics found in the Form Four Additional Mathematics textbook. Each HOTS level has two subjective type items with different question forms. In total, eight items were constructed representing all levels of HOTS: 1) Applying (2 items) – Example: “A water rocket is released from the surface of the ground. The movement of the water rocket is represented by the quadratic equation  $h(t)=7+8t-2t^2$  where  $t$  is time (seconds), and  $h$  is the height of the water rocket from the ground (meters). Find the maximum height of the water rocket movement from the surface of the ground.”; 2) Analyse (2 items) – Example: “Draw the movement of a fish jumping out of the water surface represented by the function  $f(x)=4-x^2+3x$ . Next, find the maximum value of the fish's jump from the surface of the sea.”; 3) Assess (2 items) – Example: “The figure below shows fireworks being released in a hall. The height of the ceiling of the hall from the ground is 10 meters. Given the equation of motion of a firework,  $h(t)=-t^2+6t$ , as shown in the diagram on the side, represents the height, in meters, of the firework,  $t$  seconds after launch. Point O is the origin, and the firework explodes at the maximum position. Will the fireworks explode before hitting the ceiling of the hall?”; and 4) Creating (2 items) – Example: “Ahmad wants to make a parabolic-shaped pottery using clay. He plans to make the pottery with a depth of 15 cm and a water surface diameter of 20 meters. Sketch the shape of the pottery that Ahmad will make. Justify your answer.”.

The scoring criteria for the HOTS refer to the analytical scoring rubric that has been modified in assessing students' HOTS issued by the Malaysian Examinations Board (2013). It is based on the total marks obtained from two items according to the HOTS construct, where each item contains a total of four marks, which makes each level contain a total of eight marks. The following rubric details the student's achievement level based on the cognitive assessment of the student's HOTS level: 1) 1 - 2 marks: Inability to solve problems accurately; 2) 3 - 4 marks: Lack of ability to solve problems accurately; 3) 5 - 5 marks: Able to solve problems accurately; and 4) 7 - 8 marks: Very capable of solving problems accurately.

Using the Rasch Measurement Model, item fit analysis was used to analyse the validity of the HOTS-T instrument. 1) Outfit Mean Square Values (MNSQ) – the value must be between 0.50 and 1.50; 2) Outfit Z-Standardized Values (ZSTD) – the value must be between -2.00 and 2.00; and 3) Point Measure Correlation (PTMEA-CORR) – the value must be between 0.40 and 0.85 are the three criteria used to assess the appropriateness of the items (Boone et al., 2014;

Fox, 2015). The item should be kept if it satisfies any one of the three requirements (Sumintono & Widhiarso, 2015). The results of the Rasch analysis's evaluation of item fit indicate that every item in the HOTS-T instrument satisfies every requirement for Outfit MNSQ, Outfit ZSTD, and PT-MEASURE CORR. All of the items are therefore kept. In the meantime, the item reliability ( $r = .98$ ) and person reliability ( $r = .91$ ) of the HOTS-T instrument, which was also evaluated for reliability using Rasch analysis, showed good index values.

### *Collaborative Skills Questionnaire (CSQ)*

The CSQ instrument in this research was adopted from Brown's (2008) questionnaire, which surveyed students' perceptions on collaborative learning. The CSQ questionnaire instrument contains 18 items and is divided into four collaborative skill constructs, namely: 1) Academic Benefits (7 items) – Example: "Working in pairs and groups helps to understand learning."; 2) Social Benefits (3 items) – Example: "Working in pairs and groups is fun."; 3) Generic Skills (6 items) – Example: "Working in pairs and groups stimulates critical thinking."; and 4) Negative Aspects (2 items) – Example: "Working in pairs and groups is not difficult to ask members to participate actively in the task.". Items in Negative Aspects that use negative statements have been modified into positive statements.

Students can indicate how much they agree or disagree with the CSQ questionnaire using a 5-point Likert scale, where 1 means "Strongly Disagree," 2 means "Disagree," 3 means "Neutral," 4 means "Agree," and 5 means "Strongly Agree." On the basis of the item fit analysis, the validity of the CSQ instrument was also examined. According to Sumintono and Widhiarso (2015), the results of the Rasch analysis assessment of item fit show that every item in the CSQ instrument satisfies at least one of the requirements for Outfit MNSQ, Outfit ZSTD, and PT-MEASURE CORR. For this reason, every item was used in the study. Furthermore, the CSQ instrument's reliability, which was also examined using Rasch analysis, revealed item reliability and person reliability index values ( $r = .98$  and  $r = .90$ , respectively).

### *Data Analysis*

In order to meet the goals of the study, the data was subject to inferential analysis. MANOVA (Multivariate Analysis of Variance) was applied to the data to see if there was a significant difference in Form Four students' Pre-HOTS-T mean scores based on the construct. MANCOVA (Multivariate analysis of Covariance) was applied to determine whether three different groups had a significant effect on students' HOTS and CS. Four covariates (Pre-Applying, Pre-Analysing, Pre-Evaluating, and Pre-Creating) were used to account for any differences between the groups. ANCOVA tests were used to see if the TFL groups had a significant impact on each of the dependent variables and if the overall results of the ANCOVA were statistically significant.

The next stage of statistical analysis involves using a post-hoc comparison technique to identify which TFL group is significantly different from the other group for HOTS and CS if the ANCOVA results in the three TFL groups are statistically significantly different. When the researcher set the level of significance at  $p < .05$ , it indicated that they had found a difference between the TFL groups. Before evaluating multivariate statistical findings, the researcher conducted a preliminary analysis in which the prerequisite assumptions of the MANOVA/MANCOVA were fulfilled and these assumptions included the identification of outliers, normal distribution, equality of covariance, linearity of variables, multicollinearity, and homogeneity of variance (Tabachnick & Fidell, 2019). All prerequisite assumptions of MANOVA/MANCOVA had been met except the assumption of equality of covariance where the assumption of equality of matrices in this research had been violated in the HOTS-T pre-test [Box's  $M = 125.551$ ,

$F(20, 255895.975) = 6.142, p < .01$ ], and the HOTS-T post-test [Box's  $M = 207.763, F(20, 255895.975) = 0.164, p < .01$ ]. Grice and Iwasaki (2007) state that Pillai's Trace can be used to easily overcome common violations of the covariance equality of group members. Based on the value proposed by Cohen (1988), the effect size (ES) was also used to measure the strength of the effect and provide significant information in statistical analysis. To meet the demands of research objective 2, a t-test analysis was conducted on the dependent variables of CSQ, namely Academic Benefits, Social Benefits, Generic Skills, and Negative Aspects after a quasi-experimental study was conducted. The preliminary analysis was also carried out where the prerequisite assumptions of the t-test of the research, which is that the sampling is random, has a normal data distribution and the use of a periodic scale or a ratio scale must be met. All t-test assumptions were met for the CSQ data.

### Research Results

Table 1 shows the comparison of pre-test and post-test mean scores for the four levels of high-order thinking skills, namely Applying, Analysing, Evaluating, and Creating. Overall, there was an increase in the mean score at the post-test for each HOTS construct in each TL method.

**Table 1**  
*Descriptive Statistics for the HOTS Test in the Pre-test and Post-test*

Construct	TFL method	N	Pre-test		Post-test	
			M	SD	M	SD
Applying	PBL-CL	90	4.12	1.279	6.49	1.343
	PBL	90	4.22	1.695	4.79	1.764
	Conv	90	4.06	1.692	4.22	1.701
Analysing	PBL-CL	90	4.07	1.512	5.96	1.398
	PBL	90	4.12	1.585	4.49	1.782
	Conv	90	3.88	1.621	4.21	1.532
Evaluating	PBL-CL	90	3.73	1.766	5.86	1.678
	PBL	90	3.69	1.771	4.10	1.601
	Conv	90	3.50	1.711	3.64	1.801
Creating	PBL-CL	90	3.33	1.722	4.89	1.394
	PBL	90	3.37	1.940	3.54	1.657
	Conv	90	3.14	1.726	3.87	1.745

The findings of Pillai's multivariate test, as determined by MANCOVA analysis (Table 2), indicate that, on the whole, the independent variable (TFL method) has a significant impact on the HOTS [ $F(8, 522) = 29.458, p < .05$ ]. While the findings also show that there is no effect between the covariate that is Pre-Test on the dependent variable Pre-Applying [ $F(4,260) = 4.140, p > .05$ ], Pre-Analysing [ $F(4, 260) = 6.282, p > .05$ ], Pre-Evaluating [ $F(4, 260) = 4.103, p > .05$ ], and Pre-Creating [ $F(4, 260) = 9.598, p > .05$ ]. The TFL method is a factor in achieving HOTS (Applying, Analysing, Evaluating, and Creating) by controlling the pre-test for each construct of HOTS.

In order to determine whether the TFL method has an impact on the constructs of HOTS: Applying, Analysing, Evaluating, and Creating, the researcher also performed an ANCOVA test. The ANCOVA analysis demonstrates that the TFL method has a significant effect on the



Applying [ $F(2, 266) = 81.780, p < .05, \eta^2 = .311$ ], Analysing [ $F(2, 266) = 90.185, p < .05, \eta^2 = .383$ ], Evaluating [ $F(2, 266) = 104.291, p < .05, \eta^2 = .440$ ], and Creating [ $F(2, 266) = 65.025, p < .05, \eta^2 = .246$ ]. A strong correlation was observed between the TFL method and the dependent variable, indicating that the TFL method contributed 31.1%, 38.3%, 44.0%, and 24.6% of the variance found in Post-Applying, Post-Analysing, Post-Evaluating, and Post-Creating, respectively.

**Table 2**  
*Summary of MANCOVA and ANCOVA Results for the TFL Methods and the Covariates*

Effect	MANCOVA			ANCOVA			Partial ETA Square ( $\eta^2$ )
	Pillai's Trace <i>F</i>	<i>df</i>	<i>p</i>	<i>F</i>	<i>df</i>	<i>p</i>	
TFL method	29.458	8, 522	$p < .05$	81.780	2, 266	$< .05$	.311
Pre-applying	4.140	4, 260	.487	90.076	1, 266	.086	.473
TFL method	29.458	8, 522	$p < .05$	90.185	2, 266	$< .05$	.383
Pre-analysing	6.282	4, 260	.631	150.787	1, 266	.042	.550
TFL method	29.458	8, 522	$p < .05$	104.291	2, 266	$< .05$	.440
Pre-evaluating	4.103	4, 260	.577	126.858	1, 266	.074	.609
TFL method	29.458	8, 522	$p < .05$	65.025	2, 266	$< .05$	.246
Pre-creating	9.598	4, 260	.603	80.243	1, 266	.081	.543

To ascertain how the independent variable affected the dependent variable, a post-hoc analysis was also carried out. The results of the pairwise comparison post-hoc test and the effect sizes pertaining to the impact of instructional strategies on the Applying, Analysing, Evaluating, and Creating constructs are displayed in Table 3. All constructs in HOTS demonstrate a significant increase in the PBL-CL method compared to the PBL method ( $p < .05$ ). Concurrently, the pairwise comparison demonstrates that, for every construct, the PBL-CL approach outperforms the PBL method by a significant margin ( $p < .05$ ). The same conclusion can be drawn from the pairwise comparison of the PBL and Conv methods, where the PBL method outperforms the Conv method in every construct ( $p < .05$ ) with the exception of the Analysing construct. In terms of effect size analysis, students using the PBL-CL approach for each of the four constructs—Applying ( $d = 1.084$ ), Analysing ( $d = 0.918$ ), Evaluating ( $d = 1.073$ ), and Creating ( $d = 0.882$ )—showed larger effect sizes than students using the PBL method. Based on statistical analysis, it can be inferred that the PBL-CL approach is successful in raising students' levels of high-order thinking abilities.

**Table 3**  
*Pairwise Comparison Post Hoc Test Results*

Construct	Pairwise Comparison	MD	p	ES	Cohen Interpretation
Applying	PBL-CL vs PBL	1.791	< .05	1.084	Big
	PBL-CL vs Conv	2.206	< .05	1.481	Big
	PBL vs Conv	.389	.416	.328	Small
Analysing	PBL-CL vs PBL	1.518	.062	.918	Big
	PBL-CL vs Conv	1.570	< .05	1.193	Big
	PBL vs Conv	.052	< .05	.169	Small
Evaluating	PBL-CL vs PBL	1.217	< .05	1.073	Big
	PBL-CL vs Conv	1.508	< .05	1.275	Big
	PBL vs Conv	.291	< .05	.270	Small
Creating	PBL-CL vs PBL	1.372	< .05	.882	Big
	PBL-CL vs Conv	1.556	< .05	1.082	Big
	PBL vs Conv	.185	< .05	.212	Small

Table 4 displays the results of the paired sample t-test for the PBL and PBL-CL methods. The results of the analysis found that there is a significant difference in the mean score of the Pre and post-test for the PBL method in each construct, namely Academic Benefits ( $t = -8.301$ ,  $p < .05$ ), Social Benefits ( $t = -5.689$ ,  $p < .05$ ), Generic Skills ( $t = -3.939$ ,  $p < .05$ ), and Negative Aspects ( $t = -19.446$ ,  $p < .05$ ). The same results are also found in the PBL-CL method where there is a significant difference for the mean scores of Pre and post-test for the construct of Academic Benefits ( $t = -27.741$ ,  $p < .05$ ), Social Benefits ( $t = -14.801$ ,  $p < .05$ ), Generic Skills ( $t = -28.761$ ,  $p < .05$ ), and Negative Aspect ( $t = -6.934$ ,  $p < .05$ ).

**Table 4**  
*Paired t-test Analysis for Pre- and Post-test of Collaborative Skills for PBL and PBL-CL Methods*

Construct	Pre and Post Test	M	SD	t-value	p
Academic Benefits	Pre PBL	3.605	0.353	-8.301	< .05
	Post PBL	3.719	0.383		
	Pre PBL-CL	3.552	0.390	-27.741	< .05
	Post PBL-CL	4.552	0.132		
Social Benefits	Pre PBL	3.422	0.653	-5.689	< .05
	Post PBL	3.556	0.601		
	Pre PBL-CL	3.367	0.746	-14.801	< .05
	Post PBL-CL	4.433	0.154		
Generic Skills	Pre PBL	3.639	0.387	-3.939	< .05
	Post PBL	3.678	0.364		
	Pre PBL-CL	3.583	0.354	-28.761	< .05
	Post PBL-CL	4.478	0.182		
Negative Aspects	Pre PBL	2.917	0.610	-19.446	< .05
	Post PBL	3.283	0.797		
	Pre PBL-CL	3.067	0.632	-6.934	< .05
	Post PBL-CL	4.583	0.293		

The post-test collaborative skills construct mean score for the PBL and PBL-CL approaches is displayed in Table 5. In each collaborative skill construct—Academic Benefits ( $t = 19.520, p < .05$ ), Social Benefits ( $t = -5.689, p < .05$ ), Skills Generic ( $t = 18.625, p < .05$ ), and Negative Aspect ( $t = 14.527, p < .05$ ), the research findings indicate a significant difference in the post-test mean scores for the PBL and PBL-CL methods. The mean score of the PBL-CL method is higher than the PBL method. These findings also demonstrate that the PBL-CL method significantly outperformed the PBL method in terms of the Post-Academic Benefits, Post-Social Benefits, Post-Generic Skills, and Post-Negative Aspects scores.

**Table 5**

*Independent t-test Analysis for the Comparison of Post-Constructs of Collaborative Skills for the PBL and PBL-CL Methods*

Construct	TL method	<i>M</i>	<i>SD</i>	<i>t</i> - value	<i>p</i>
Post Academic Benefits	PBL	3.719	0.383	19.520	< .05
	PBL-CL	4.552	0.132		
Post Social Benefits	PBL	3.556	0.601	13.410	< .05
	PBL-CL	4.433	0.154		
Post Generic Skills	PBL	3.678	0.364	18.625	< .05
	PBL-CL	4.478	0.182		
Post Negative Aspects	PBL	3.283	0.797	14.527	< .05
	PBL-CL	4.583	0.293		

## Discussion

In principle, the PBL-CL, PBL and Conventional learning (Conv) method have an overall positive effect on the four levels of higher-order thinking skills for Form Four students, namely Applying, Analysing, Evaluating, and Creating. The results of the analysis also found that the mean scores of Form Four students who were taught through the PBL-CL method were significantly higher compared to their peers who were taught through the PBL and Conv method in all levels of higher-order thinking skills. Through the PBL-CL method, students learn to do activities actively in an engaging learning environment. To master the level of Applying in the topic of quadratic functions in particular, students need to master algebraic factoring, using the correct formula and the method of perfecting the square in solving non-routine problems (Abdul Rahman & Mohamad Foad, 2021). Therefore, through the activities in the PBL-CL Module, students write in their sentences about the process of the square completion method and apply in the various forms of graphs given. The activity is optimally implemented to encourage students of the PBL-CL group to think, communicate, and write. As a result, effective learning occurs as each group member helps each other and participates actively to criticize and complement each other in completing the given task (Nuraeni & Luritawaty, 2016).

In this research, four activities in the PBL-CL module require students' exploration outside the classroom to strengthen students' understanding of quadratic graphs in real life. Students are asked to take a parabola-shaped picture and enter it into the GSP software to investigate and analyse the characteristics of quadratic graphs learned previously. Indirectly, the use of this GSP medium can be a good link in understanding concepts related to real life in learning Mathematics by the visual learning style (Yahaya & Husni, 2010). Because of that, analysing skills through exploration and investigation in the formation of mathematical concepts can increase the level of analysing of students (Gani, 2018). Therefore, the formation of mathematical concepts linked to the students' experience based on the activities that happen around them needs to be given priority in the process of learning and teaching mathematics.

In addition, the implications of the seven-step PBL Schmidt process approach applied in the PBL-CL module encourage students in the PBL-CL group to explore non-routine problems given in a planned systematic manner. This can assist students in recognising and analysing the solution to the given problem and enabling them to confidently respond to inquiries based on the problem or circumstance. Nasution et al. (2017) concur, stating that problem-based learning is an effective strategy for encouraging students' critical thinking in information analysis. Consequently, in terms of the analytic level of thinking, the mean score of Form Four students taught using the PBL-CL method was significantly higher than that of students taught using the PBL and Conventional learning methods.

The students of the PBL-CL group share ideas in making conclusions and hypotheses through a systematic problem-based learning process. During the problem-solving process, students are more able to justify and share ideas systematically and more easily integrate the thoughts that occur to make evaluations and conclusions (Hyerle & Alper, 2011). For example, the activity of solving problems in the evaluating level is done inductively such as identifying the shape and characteristics of graphs that are applied in real life. Next, students draw conclusions based on investigative methods by relating specific situations to make an assessment (Ramli & Mustapha, 2014). In order to accomplish this goal, students formulate and support hypotheses, offer reasoned justifications, analyse, form opinions, and assess and defend the mathematical tasks. As a result, this process indirectly increases the thinking level of evaluating. In this research, the activities in the PBL-CL module also encourage productive interaction among Form Four students who have different knowledge backgrounds to improve the thinking level of evaluating. Intelligent and proactive students acting as experts explain solution methods by including clear and accurate mathematical concepts to be shared among group members in making conclusions and evaluations. Through positive interaction and effective communication among group members, students generate ideas, and this social process affects their creativity, cognition, and potential (Vygotsky, 1986).

The activity of the PBL-CL module encourages the students of the PBL-CL group to pitch their creative ideas in solving problems in the form of questions through group presentations. During the presentation session, the reciprocal process from the responses of other groups refreshes and further expands their ideas (Ismail & Hamzu, 2020). This causes students to always think about producing the best method to be highlighted among them and further fosters the thinking level of creativity among the students of the PBL-CL group. In addition, the PBL-CL method can provide a learning environment where real experience helps Form Four students to produce logical problem-solving methods because they think abstractly and have a clear understanding of concepts (Pradani & Nafi'an, 2019). In the fourth activity of the PBL-CL module, for example, students carry out activities outside the classroom by exploring graph-shaped objects. Next, they investigate the shape of the graph in a creative way using GSP. Students in groups are given the freedom to choose their methods to determine the characteristics of their chosen graph with accurate mathematical justification to be presented in a later presentation. Indirectly, students also learn to produce quadratic graph sketches creatively in their minds and represent through the shape and characteristics in each graph. Furthermore, the mutual interaction of students with their environment and daily routine has a positive effect on developing their higher level of thinking (Ariandari, 2015).

Compared to students who learnt via the Conv method, students carry out conventional and teacher-centred learning activities where all activities have been planned by the teacher. Tasks are completed individually with the help of GSP, however, no task specialization is given to each student. Students are also exposed to routine problem-solving. As a result, students in this group could not apply the formula well because peer guidance was limited. This is because group interaction in Conv group is not emphasized with positive interdependence, individual responsibility, dealing with positive interactions, and social skills in groups (Zakaria & Habib, 2006), as evidenced in the PBL-CL group.

In terms of academic benefits, social benefits, generic skills, and negative aspects, Form Four students' development of collaborative skills is generally enhanced by both PBL-CL and PBL approaches. The findings also revealed that, across all collaborative skill constructs, the Form Four students who received instruction via the PBL-CL method had mean scores that were noticeably higher than those of their PBL-taught peers. In the aspect of Academic Benefits in particular, collaborative learning is seen as a methodology that provides greater benefits in the academic achievement of students compared to the PBL method. In this regard, the students of the PBL-CL group are actively involved in the group by discussing solutions or information with their peers. Students with lower achievement are helped by their other group members to create a complete picture with unique and interesting information and its meaning is understood by each member. The nature of openness to the ideas and views of each student forms a positive practice in the process of acquiring knowledge. The results of this research are supported by Swan (2006) who suggests that students who are exposed to collaborative learning are exposed to different relationships such as giving and receiving help, learning other people's perspectives, expressing their views, and finding new ways to solve problems. This finding is also supported by Chandra (2015) who states that the collaborative learning technique as an alternative to the active teaching approach encourages students to think logically, critically, and creatively in solving problems.

In terms of Social Benefits, the results also show that Form Four students who are taught through the PBL-CL method outperform students who are taught through the PBL method. This suggests that collaborative learning can be a powerful method to bring teams together in a social environment for a better educational experience. In the PBL-CL group, collaborative learning sessions can build a positive environment in the classroom. This is also the best way to improve social aspects and help students discover new ways of working as a team (Widjajanti, 2008). This is because collaborative learning respects the strengths and weaknesses of each student, allowing them to grow as part of a group. While interacting with each other, students learn more in the process and discover the importance of communicating with each other. In addition, collaborative learning reduces misbehaviour in the classroom because students have more time to focus on learning activities (Baltes et al., 2000). Therefore, students will be more highly motivated to follow active learning in class, subsequently improving the Social Benefits aspect of students.

In addition, the results of the research also show that Form Four students taught through the PBL-CL method outperform students taught through the PBL method in the aspect of Generic Skills. In the learning process of the PBL-CL method, the Form Four students of the PBL-CL group are found to be more tolerant by helping to explain to other friends if there is something that is not understood in learning through collaborative learning techniques. Students have the confidence to engage with their peers in class and are constantly moving and talking about learning issues with one another. As a result, every group member supports one another and works together to learn how to accomplish the goals of the group. The result is that the PBL-CL group's students benefit from this circumstance in terms of generic skills. In addition to this, students always share the information obtained and always give a high commitment to group activities that have been systematically planned. This study supports the findings of Dewi et al. (2018) that face-to-face interaction between group members is necessary for collaborative learning. Speaking with someone face-to-face is one of the communication skills. Students need to be given the chance and time to engage in group interactions in order to support, motivate, and enhance one another's efforts to learn as much as possible. Because of this, PBL-CL group members always perform at their best when giving a presentation in front of the class and have a high level of confidence when interacting with one another.

In terms of Negative Aspects, the results of this research also show that Form Four students who are taught through the PBL-CL method outperform students who are taught through the



PBL method. Negative aspects among some students consider teaching other friends as a waste of time and group members are not actively involved in carrying out their tasks (collaborate). Student characteristics such as selfishness and impulsiveness are seen as factors that make group work difficult (Negoro, 2017). PBL-CL module activities that have systematic guidance and training make it easier for students in the PBL-CL group to improve the development of positive self-concepts such as doing group work. Group work is done based on collaborative learning principles such as positive interdependence, helping to foster high-level thinking and mutual review of solution methods as well as providing support to each other and not just focusing solely on personal views. As a result, group work in collaborative activities teaches students to consider the views of others and realize their responsibility towards their group in achieving learning objectives.

Compared to students who only follow the PBL method, they are seen not to cooperate properly because they feel bored. This happens because the learning environment is not active and there is no clear learning guide by the teacher. In addition, the students in the PBL group are less active in making discussions among group members. Students who do not contribute to group work and depend on the work create a negative perception among students. As a result, PBL sometimes doesn't work as expected. A few students of the PBL group who are capable have a strong competitive culture and only allocate a large part of their time to individualistic learning. Students think that PBL group collaboration is difficult to do in this social context. This is supported by Kyndt et al. (2013) who found that individualistic cultures often lead to less cooperative cultures. As a result, negative factors on individuals in the group hinder the flow of collaborative learning.

## Conclusions and Suggestion

According to the research, the PBL-CL approach outperforms PBL and conventional learning methods in enhancing the four levels of higher-order thinking skills: applying, analysing, evaluating, and creating. Additionally, it was shown that the PBL-CL approach outperforms the PBL method in enhancing collaborative skills related to learning Additional Mathematics in the areas of Academic Benefits, Social Benefits, Generic Skills, and Negative Aspects. This demonstrates how non-routine investigation, exploration, and problem-solving activities, as well as presentations carried out in a collaborative learning manner, can enhance teaching effectiveness when PBL and GSP-assisted collaborative learning are incorporated into the TL process. With the aid of GSP, students can learn how to integrate PBL and collaborative learning through the PBL-CL approach, which improves their capacity for higher-order thinking and teamwork when tackling challenging problems.

It is advised that studies be conducted in the future on students at different levels, such as junior high school students, or at various school locations with both urban and rural students. Future research may also take the shape of different instructional techniques like creating active questions and alternate explanations. Since it adds to general data, the research sample can also be expanded to look at Form Four students in institutions that are not affiliated with the Ministry of Education, like private and foreign schools. Since this study only used quantitative methods, similar research can be done in the future using qualitative or mixed methods to determine how well PBL methods and collaborative learning work when viewed from different angles.

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## Declaration of Interest

The authors declare no competing interest.

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