ASIAN PENDIDIKAN
ISSN: 2735-2331, e-ISSN: 2805-4350
DOI: https: //doi.org/10.53797/aspen.v2i2.6.2022

Improving Problem Solving Skills Using Critical Thinking Learning Strategy in Integral Calculus

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Received 4 November 2022; Accepted 02 December 2022; Available online 02 December 2022

Abstract: This research tries to develop a Critical thinking learning strategy called CThink and to test its effectiveness in enhancing students' problem-solving ability when solving Integral Calculus topics as compared to the traditional teaching method (TRad). This study applied the Analyse, Design, Develop, Implement and Evaluate or ADDIE model to develop the CThink strategy. A mixed method approach encompassing quasi-experimental techniques and interviews was adopted. Two groups of students from a polytechnic participated in the research to create the experimental (CThink) (n=34) and control (TRad) (n=33) groups. Enhancement in students' problem-solving ability was analysed using the mean score in the pre-test and post-test. The major studies revealed that the mean scores of students who were introduced to CThink are significantly higher than those who were introduced to TRAD in the post-test t (55.16) =7.11, p<.05. Findings showed the benefits of using the CThink strategy to enhance problem-solving skills in Integral Calculus. In addition, parametric tests revealed that CThink students demonstrated significantly better mean scores in the post-test in comparison to the TRad group. This suggests that students' problem skills ability in the CThink group showed greater improvement.

Keywords: Critical thinking, problem solving, polytechnic, integral calculus

1. Introduction

Problem solving is getting more attention in learning mathematics at the higher education level. It is an activity engaged in a process of finding a solution to a problem using knowledge, skills (Ofori Kusi, 2017), understanding, techniques, ideas, results (Sullivan & Melvin, 2016), selecting relevant data, finding appropriate procedures and comparing data in different forms (Butterworth & Thwaites, 2013). Problem solving involves the ability to use the mind to find alternative ideas and steps to overcome the shortcomings or barriers to achieving the desired goals. Moreover, it is one of the scientific methods that require critical thinking, creative, reflective, analyses, syntheses (Yavuz et al., 2015) and self-efficacy (Renfro, 2014). Thus, problem solving is a practical method which aims to achieve various sound ideas to form several effective solutions.

A nonroutine problem is characterised when a person who encounters the problem does not immediately know how to arrive at a possible solution. In the act of solving a nonroutine problem, one needs to analyze the issue, connect data, reflect on the solution strategy, switch procedures if fundamental, and create new arrangements (Heller, 2013). It is characterised as a high-level skill that can be earned after acquiring problem-solving abilities routine or ordinary problems (Kusmaryono & Suyitno, 2016) and mathematical power. Hence, it can help improve overall problem-solving ability (Robinson, 2016). Consequently, students should be exposed to nonroutine problems that can lead to higher order thinking and make effective decisions during everyday life.

Integral Calculus is a topic in a compulsory Mathematics course named Engineering Mathematics 2 taken by polytechnic students studying in the engineering field. Integral Calculus is useful for students as a basis for learning other subjects in engineering (Caligaris et al., 2015), physics (Wagner, 2015; Hu & Rebello, 2013; Bajracharya et al., 2012), physical chemistry (Jukić Matić & Dahl, 2014), differential equations and other advanced mathematics courses. Hence, Integral Calculus consists of mathematical concepts that engineering students need to master (Tatar and Zengin, 2016; Serhan, 2015; Zakaria & Salleh, 2015) including polytechnic students. It is not merely a mathematical theory that needs

**Corresponding author: nurulshida@pis.edu.my* to be learned for the course, it plays an important role in everyday life such as finding the distance, velocity and acceleration. Nonetheless, there are indications of the weakness of students in Integral Calculus. The difficulties of learning Integral Calculus are not only experienced by students in Malaysia but also around the world (Zakaria & Salleh, 2015; Jukić Matić & Dahl, 2014). The difficulties encountered at the elementary level will affect students' mastery, especially in problem solving. As an educator, providing the best way to overcome learning difficulties is challenging and a great responsibility.

The culture of critical thinking is necessary to emphasise this in the context of ordinary living. Critical thinking is essential to improve students' thinking as emphasised in the Malaysian Mathematics Curriculum (Yew & Zamri, 2018) where all mathematics topics should be taught in conjunction with the underlying goal of assisting students develop critical thinking skills and mathematical abilities.

1.1 Problem Statement

The difficulties are due to their deficient problem solving abilities for example, the absence of involving problem-solving framework and weakness in reviewing past information (Hashemi et al., 2019). There are several reasons students make mistakes in tackling issues on Integral Calculus, including 1) student's error in reading the questions, composing mathematical symbols including integral symbols, and counting operations, 2) understanding of imperfect material and the concept of integral, 3) low mastery of essential and fundamental mathematical concepts 4), students have a harder time distinguishing between characters or sorts of issues to choose the right fundamental strategy, and 5) the application of formulas that aren't suited to solving problems (Machromah, 2017).

Malaysian students appear to have difficulty solving problems incorporating problem solving in Integral Calculus and has become a wake-up call for the Malaysian government. The formation of problem-solving skills is considerably more difficult than calculation skills because the issues are connected with numerous and a lot of mathematical relationships. Students' difficulties in the learning of integration appeared through problem solving and conceptual understanding, while students cannot solve most questions involving problem solving.

Students' difficulties in problem-solving were because of the casual in the class class (Khalid et al., 2007). It does not encourage learning and disregards critical thinking and problem-solving abilities. Similarly, a lack of critical thinking leads to trouble understanding problem solving. Students require knowledge to assess critical thinking when addressing problems. As a result, to improve issue solving, critical thinking must be implanted through a learning technique. Students employ critical thinking abilities to investigate difficulties and use newly taught concepts in problem solving. Because issue solving is accompanied by critical thinking, it is vital to inculcate this talent.

As a result, critical thinking learning resources are crucial for increasing problem solving in the classroom. All students should receive a mathematics education that promotes critical thinking and mathematical comprehension (Aizikovitsh & Cheng, 2015). Critical thinking can be introduced into mathematics training, according to ongoing research (Hamdu et al., 2020). The importance of this encouraged the creation of learning strategies that included critical thinking.

1.2 Research Objective

The following are the study's objectives:

a. To compare the effectiveness of problem-solving ability of the Critical Thinking Learning Strategy (CThink) to the traditional teaching approach (TRad).

1.3 Research Question

The following are the study's research questions:

a. Is there any significant difference in the pre-test and post-test for the problem-solving ability between the CThink and TRad groups?

2. Literature Review

Learning at the highest level of mathematics is problem-solving, which require the student to read the statement, extract the relevant data (Sánchez & Vicente, 2015), improve a person's capacity to comprehend and use literature, numeracy, and calculation (Spooner et al., 2017), and find and verify results (Conole et al., 2015). Mathematical problem solving is the central activity and an integral part of mathematics (Shea & Bidjerano, 2016; Ersoy & Guner, 2015). Students should cultivate multiple perspectives and apply them to solve problems when learning mathematics (Sağlam, 2014). It's a useful instrument for determining a person's mathematical reasoning and creative abilities (Ayllón et al., 2016). In this approach, problem solving is a mathematical ability that students must learn.

Activities that are classified as problem solving usually involve sentence-shaped problems found in textbooks, puzzles, irregular problems and the application of mathematics in daily life. Problem solving involves the ability to explore and solve routine and nonroutine problems (Deuchar, 2010). If the problem solver does not have a previously learned solution procedure to apply, the problem is considered nonroutine for that problem solver (DiFrancesca, 2015).

Nonroutine problem solutions cannot be guessed in advance (Saygılı, 2017). Students attempt to search for data on the given issue and comprehend and correlate with various ideas that are anticipated to address the problem (Firdaus et al., 2015). However, solving non-routines includes involving mathematics in frequently new techniques for dealing with problems in both mathematical and real-world situations (Hunter, 2011). Nonroutine problems can help develop the use of problem-solving strategy. Given the importance of problem solving, more research needs to be done, especially regarding nonroutine problem solving in Integral Calculus.

Word problems (Dewolf et al., 2014) are another approach to teach mathematical modelling and applied problem solving by bringing the actual world into the mathematics classroom. It is necessary to transfer mathematical issues described in story language into mathematics sentences or mathematical equations (Rokhimah et al., 2015). They are perplexed by the task's goal and have difficulty connecting the mathematical model to the word problem (Wahyudi et al., 2017). Furthermore, word problem solving in mathematics is particularly tough for students with mathematics difficulties (Morin et al., 2017).

Such difficulties stem from the demands of word problem solving, thereby, students ought to be given more than adequate opportunity to participate in instruction (Driver & Powell, 2017). However, most polytechnic students are yet unable to grasp these abilities as they can only perform basic mathematical operations. It has been found that students' attitudes toward problem solving are highly correlated with their teachers' approaches (Arıkan & Ünal, 2015). It is because of the traditional strategy, in which teachers focus on delivering knowledge, giving tasks, and allowing students to learn the content because of the customary methodology by which educators center around passing on data, appointing work and passing on it to the understudies to dominate the material. Jusoh et al. (2020) observed that students who are exposed only to traditional methods are seen to be less open to the challenge of problem solving in the real world and are less self-reliant. The right culture of thinking will help liberate lecturers from continuing to follow the traditional practice (Yazid & Atiqah, 2016). The results of traditional learning practise and polytechnic syllabuses that occur in polytechnics are less effective (Khalid et al., 2007), especially for developed problem solving (Isa et al., 2017). Hence, students' weakness in problem solving will have an impact on poor arithmetic fact knowledge and weak counting skills. An appropriate strategy or technique should be identified to assist students in overcoming obstacles when completing arithmetic problems.

The capacity to solve problems is an important aspect of the mathematics curriculum. Mathematics topics such as Integral Calculus majorly focus on problem solving. It requires an understanding of integrals, understanding of physics, the ability to make mathematical models, skills, and the ability to interpret the results of calculations (Arcana, 2012). One basic problem-solving method for indefinite integrals is to simplify the integrand as much as feasible, such as by making an evident substitution. Nevertheless, in polytechnic, students have difficulty choosing the right techniques in problem solving for integral (Isa et al., 2017). One of the mistakes is transformation, negligence, problems to interpret in the form of integration, failure to select the appropriate mathematical operation and lack to complete the expression perfectly. Nursyahidah & Albab (2017) reported students' difficulties in learning integration appeared through problem solving and conceptual understanding, while Hafiyusholeh et al. (2018) claimed that students could not relate to nonroutine problems, such as using tabular data or graphs to estimate an integral value. This situation gives an impact on answering difficult questions, especially problem-solving questions. This is because students are not exposed to questions that require higher thinking. Calculating volume is one of the applications of integration in real life, and though it is complicated, it can be solved if thorough and have skillful basic integration. Distinguishing the challenges experienced by students are important to develop remedial procedures to overcome these difficulties.

It is obvious from this discussion that the less capable students are probably going to require special treatment. If this is not done, the students will be more confused and in the long run, these students will not survive in higher mathematics programmes. Students should be provided adequate time to engage in learning because word problem solving is a complex process (Driver and Powell, 2017). West (2013) recommends that mathematics departments design exercises to assist students in problem solving.

The selection of the topic in a learning strategy is crucial. Through literature review, many students find difficulty in learning Integral Calculus (Tatar and Zengin, 2016; Benacka, 2016; Bressoud et al., 2016; Lutfi, 2016; Serhan, 2015; Wagner, 2015; Bajrachrya, 2014; Sealey, 2014; Hashemi et al., 2013, 2015; Hu & Rebello, 2013; Bajracharya, 2012). Evaluation of student difficulties refers to case studies reported by researchers in Hussain et al. (2019). The case study found that polytechnic students faced difficulties and various errors in Integral Calculus. The basics of calculus can be applied in advanced engineering science to become a successful professional engineer (Lee & Sabarudin, 2001). Students find it quite difficult to master topics in the Engineering Mathematics 2 course possibly due to the absence of a solid foundation in mathematics.

3. Methodology

3.1 Sample

Participants in the study are second semester students who taking Integral Calculus topic. The rationale is the researcher found that there was evidence that polytechnic students faced difficulties in solving problem solving in Integral Calculus supported by Isa et al. (2017) and Solfitri et al. (2019), mentioned that there were significant obstacles in problem solving among polytechnic students in learning Integral Calculus.

After characteristics were established as an equivalent for both classes, the student was assigned to one class. CThink group (*n*=34) whereas another class (*n*=33) was assigned as the TRad group. Both groups were chosen by purposive sampling and were observed to have similar characteristics in problem solving and critical thinking knowledge at the beginning of the quasi-experimental procedure. This step is important to reduce bias (White & Sabarwal, 2014) by implementing using the pre-test and determining the level of problem solving and critical thinking by using the developed rubric.

Sampling for actual study which was carried out with two-groups, pre-test-post-test, quasi-experimental design comparing students' learning of Integral Calculus over six weeks period. This involved 67 Engineering Mathematics 2 students and the selected group was based on the same level of pre-test results. The teaching was delivered the through CThink (experimental group; *n*=34) and through traditional lectures (control group; *n*=33). For both groups, teaching was delivered by the same mathematics lecturer in a regular classroom.

3.2 Problem Solving Tests

Before and after studying Integral Calculus, the experimental and control groups collected quantitative data through problem-solving assessments. Problem-solving tests were divided into two categories: pre-test and post-test. A pre-test was given to the students before they were taught Integral Calculus, and a post-test was given at the end of the intervention. Fig. 1 depicts the requirements study and development phases of building the problem-solving tool.

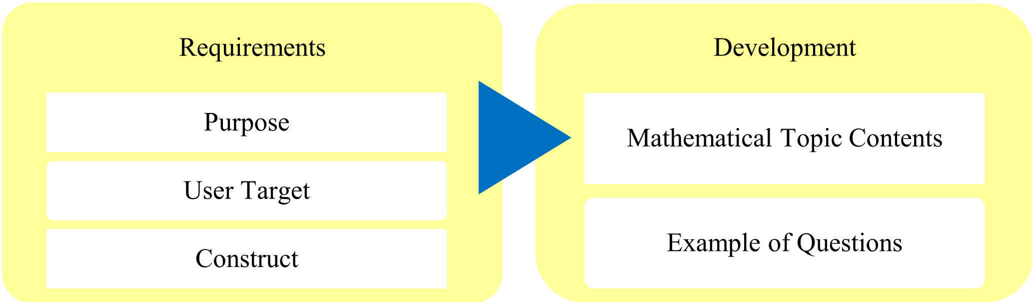

Fig 1. Development of problem-solving tests flowchart

4. Results and Discussion

This section displays the pre-and post-test results of student problem solving in the CThink and TRad groups. The scores for this problem solving are derived from a rubric and therefore converted into percentages for analysis purposes. Thus, the display of tables, figures, and graphs in this section is relevant to pre and post-test involving problem solving analysis, in groups, between the group, and individually. Data analysis is consequently proceeded by checking the pre and post-test for both groups whether their achievements are different or not. The descriptive and inferential analyses were carried out on the data received from student scores. The levels of problem-solving students are identified about student achievement in problem solving test.

Table 1. Score range and the status in polytechnic

Score Range %	Status
90-100	Very Excellent
80-89	Excellent
65-79	Credit
40-64	Pass
0-39	Fail

Source: Examination and Evaluation Division, Department of Polytechnic Studies, 2015.

The level of problem solving in Table1 has been determined by the status provided by the Examination and Evaluation Division, Department of Polytechnic (2015). The discussion further explains the change in levels that occurred to the students before and after the CThink. For this purpose, the problem-solving level of the students is classified into three categories. Scoring for problem solving and phases of problem-solving is by referring to the interpretation of the score for the problem-solving level by the status provided by the Examination and Evaluation Division, Department of Polytechnic (2015) as indicated in Table 2.

Table 2. Score range, level and category of problem solving

Score Range %	Level of Problem Solving	Category of Problem Solving
90-100	Very Excellent	High
80-89	Excellent	
65-79	Good	Moderate
40-64	Average	
0-39	Weak	Low

Adapted from the Examination and Evaluation Division, Department of Polytechnic Studies, 2015.

4.1 Analysis for the CThink Group

The pre-and post-test data were analysed to determine the level of problem-solving improvement in the CThink group. The distribution of problem-solving score shows that there is a change in the problem-solving scores the use of the CThink. The highest increment in problem solving scores was 61.7 before the CThink was conducted, where student S28 problem solving score was weak with 14.7, but after implementing the CThink, it increased to a good level with 76.3. This indirectly shows that every student has reported an increase in the problem-solving score after the CThink and none of their sores decreased after the CThink. Even though, only 1 student recorded is good, overall, all students showed an increase compared to the pre-test, and 16 has recorded from weak to average.

Table 3. Pre- and post-test percentage distribution frequency in the CThink group

Level of Problem	Score %	Pre-test	Post-test
Very Excellent	90 - 100	0	0
Excellent	80 - 89	0	0
Good	65 - 79	0	1
Average	40 - 64	0	16
Weak	0 - 39	34	17

To obtain a clearer pre- and post-test results are compared and simplifying the analysis is carried out, the data is collected in a class interval as demonstrated in Table3. No student can be categorized has very excellent and excellent for pre-test and post-test in CThink group. While the majority of students are at a weak level in the pre-test, but this has decreased from 34 to 17 in the post-test. Interestingly, the average level was observed to have 0 students to 16 students. Only one student has achieved a good level. The pre-test frequency distribution shows all students fall under the 0-39 interval while the post-test frequency distribution is scattered in class intervals between 0-79. Subsequently, the results of the analysis are further clarified in shows the CThink group's mean score and standard deviation.

Table4 which shows the CThink group's mean score and standard deviation.

Table 4. Pre-test and post-test mean scores and standard deviation in CThink group

Test	Mean	Std.	Std. Error
Pre	6.81	5.47	.94
Post	41.62	15.97	2.74

It was found that problem solving after CThink was (M=41.62) different than before with CThink (M=6.81). In addition, the difference in standard deviation values after CThink presents a larger value compared to before CThink. In other words, the score of most students after the CThink is getting further away from the average score percentage compared to the previous one. This further explains that the standard deviation of students after learning using CThink is quite high, and the value gap is very big with the overall student showing an improvement. Thus, the information obtained can be one of the indicators of CThink effectiveness. The next section explains the change in the level that occurred to students in CThink. For this purpose, the students' level of problem solving is classified according to the polytechnic grade system as displayed in Table 3.

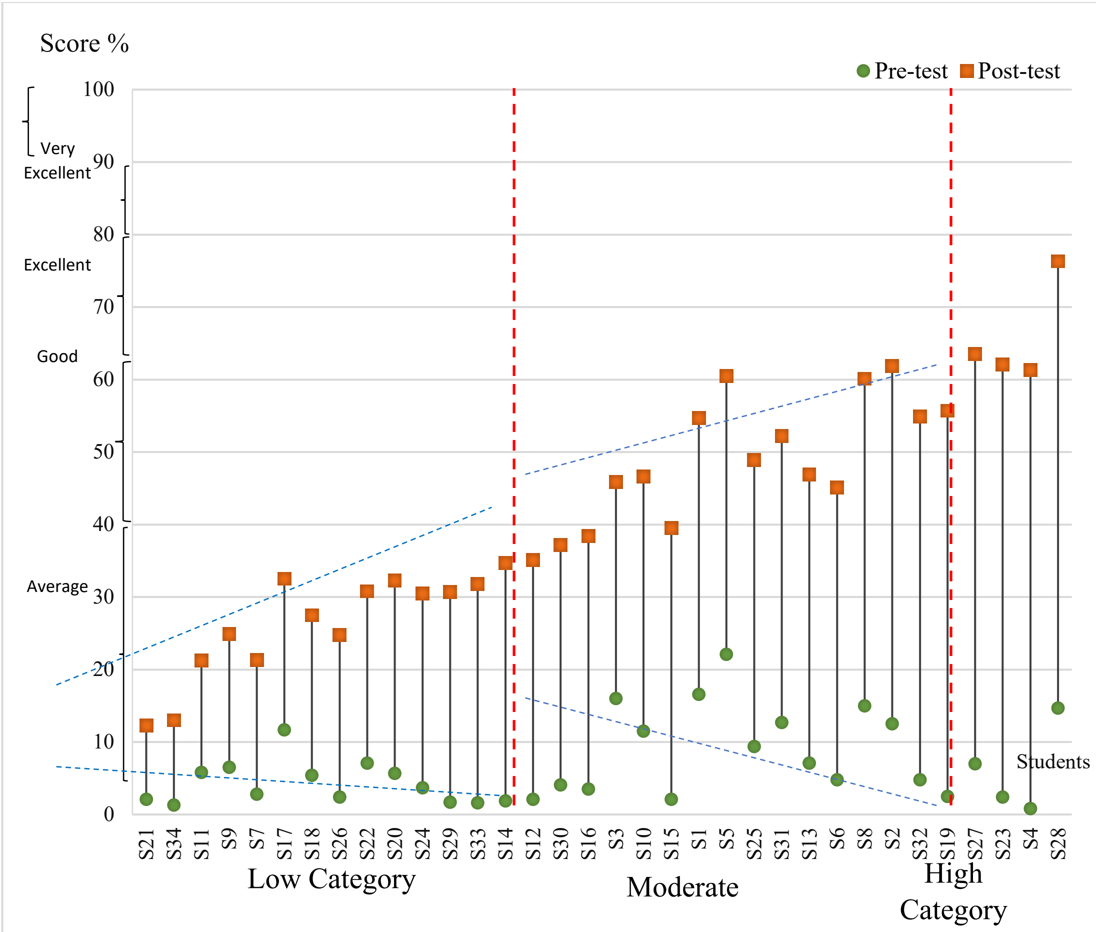

Fig. 2. Pre-test and post-test individual score improvement percentages in the CThink group

The percentage increase in problem solving score is premised on the lowest percentage score obtained by the student during pre-test 0.8 which was obtained by S04 to the percentage of the highest pre-test score achieved by S05 which is 22.1. Observed well, a positive increase after CThink when most students earn more than 12.3 of the scores on the post-test. Furthermore, the gap between the lowest and highest learner for pre-test smaller while the discrepancy between the highest and lowest post-test scores is significant. In other words, CThink has the potential to widen the divide between people, particularly among the lower socioeconomic groups. The greater gradient of the linear line created on the post-test for the low category supports this assertion. It's also worth noting that students with the lowest pre-test S04 scores outperformed other students on the post-test with a percentage score exceeding 60.5 improvement. Furthermore, it is also observed that S28 students obtained a percentage score of 76.3 on the post-test which is in a good level compared to the weak level before, which initially received the highest problem-solving score. Next, it can be observed that the problem-solving score per student involved in this study after learning using TRad.

4.1.1 Hypothesis 1

Ho_1: There is no significant difference in the pre-test and post-test for the CThink group.

Table 5. Paired samples t-test of the pre-test and post-test for the CThink group

Problem solving	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Post - Pre	34.82	13.92	2.39	29.96	39.67	14.58	33	.00

There is evidence in Table to suggest that participants experienced statistically significantly greater score in problem solving (p=0.00) when exposed to the CThink. The 95% confidence interval for the difference is (29.96, 39.67).

With the CThink: t (33) =14.58, p= .00. This suggested that after being exposed to the CThink, the post-test score improved significantly as compared to the pre-test score. As a result, the hypothesis that there is no significant difference between the pre- and post-tests of the CThink group is discarded.

4.2 Analysis for the TRad Group

This section indicates problem solving scores in the TRad group which are sorted by ascending values for the gain score. The distribution score of problem solving revealed a change problem solving scores in TRad learning. The highest increment in problem solving scores was 35.3, the student (S23) problem solving score was only weak with 1.3, but after that increased to 35.3. Every student's problem-solving score has improved. The results demonstrate that in the TRad group, the mean achievement score after the test is higher than the mean achievement score before the test.

Table 6. Pre- and post-test percentage distribution frequency in the TRad group

Level of Problem	Score %	Pre-test	Post-test
Very Excellent	90 – 100	0	0
Excellent	80 – 89	0	0
Good	65 – 79	0	0
Average	40 – 64	0	0
Weak	0 – 39	33	33

Table 6 shows how the data is collected in a class interval, to simplify the presentation and make the comparison of pre-test and post-test data more obvious. The pre-test frequency distribution is distributed in the 0-39 class interval while the post-test frequency distribution is also scattered in the same interval. This shows that the TRad group is not helping the student in terms of score improvement to get a better level. No student can be categorized in a very excellent and excellent level for pre-test and post-test for the TRad group. As a whole, the students in the TRad group is categorized as weak depending on the results of the pre-test and post-test.

The post-test shows a clear improvement, with the distribution percentage of student scores following the TRad group still at 0-39 intervals. The analysis' findings are then further elucidated in Table 7, which displays descriptive statistics of problem solving in TRad learning.

Table 7. The TRad group's pre- and post-test mean scores and standard deviations

Test	Mean	Std. Deviation	Std. Error Mean
Pre	4.00	2.83	0.49
Post	18.69	9.83	1.71

It was found in Table7 that problem solving after the TRad group earned mean with 18.69 highest than pre-test means with 4.00. In addition, the difference in standard deviation values presents a larger value compared to the prior in the pre-test. In other words, most students' scores after the TRad group are approaching the average score percentage in comparison to the prior one. This result further explains that the standard deviation of students is quite high, and the value gap for problem solving score among students after learning is huge with the overall student showing an improvement. The next discussion explains the change in the level that occurred to students in the TRad group.

Table 8. Pre- and post-test percentage scores based on the TRad group's problem-solving ability

Level	Pre				Post			
	N	Mean	Min	Max	N	Mean	Min	Max
Weak	33	4.00	1.10	13.60	33	18.69	3.70	36.60
Average	0	0	0	0	0	0	0	0
Good	0	0	0	0	0	0	0	0
Excellent	0	0	0	0	0	0	0	0
Very Excellent	0	0	0	0	0	0	0	0

Table 8 shows that following the post-test, there is a constant number of students at the weak level, which is 33. In addition to this conclusion, it is also noted that the percentage of students' scores earned for other levels is zero. The conversation continues with the display of the problem-solving enhancement graph in Figure 3, which is dependent on the successes in the pre-test and post-test, to observe the TRad's good impact on all participants.

It is noteworthy that there has been an upsurge in all students with a percentage score of problem solving is obtained by students more than 3.7 in the post-test. Furthermore, the gap between the lowest and highest learner for the pre-test is smaller while the discrepancy between the highest and lowest post-test scores is significant. This statement confirms that the gap between individuals has been increased. The TRad group showed an increased in the post-test but not as effective in improving the score. One student (S23) who receive the highest increment in problem solving score before in pre-test which is 1.3 increased to problem solving score of 36.6. However, it is still at a weak level.

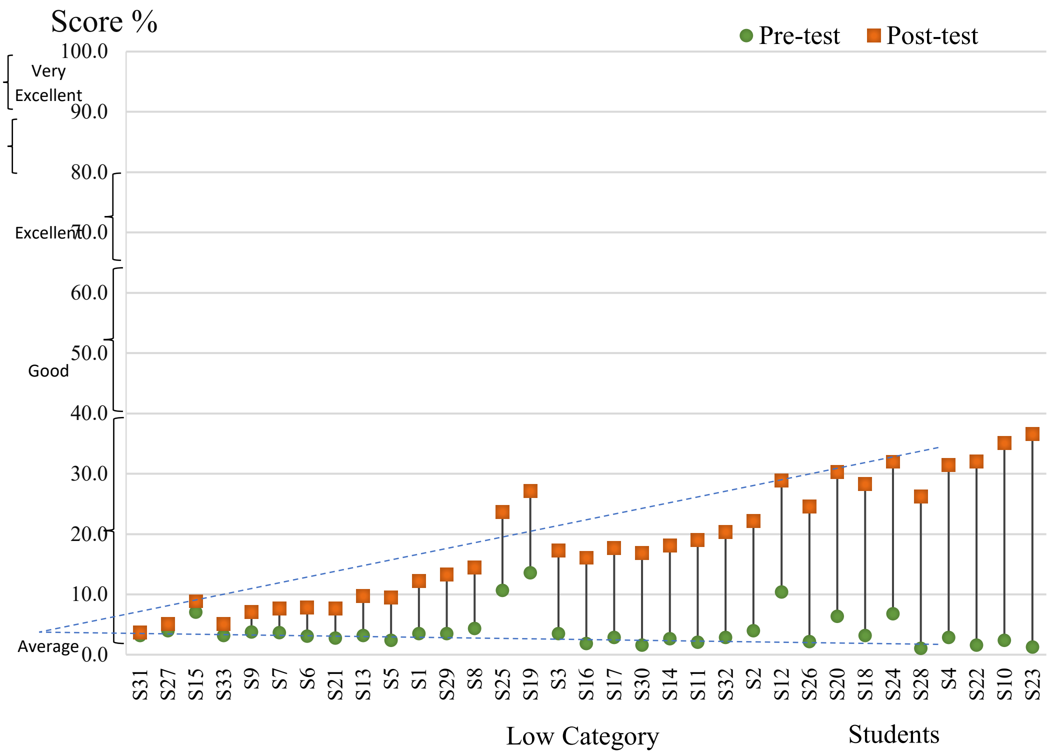

Figure 3. Pre- and post-test enhancement percentages for individual student scores in the TRad group

4.2.1 Hypothesis 2

Ho_2: There is a no significant difference in the pre-test and post-test for the TRad group

Table 9. Paired samples t-test of the pre-test and post-test for the TRad group

Problem solving	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Post - Pre	14.69	9.79	1.71	11.22	18.16	8.62	32	.00

There is evidence in Table9 that participants experienced a statistically significantly greater score in problem solving ($p=0.00$) when exposed to the TRad group. The 95% confidence interval for the difference is (11.22, 18.16), with using TRad: t (32) = 8.62, $p=.00$. This indicates that students' problem solving did increase as a result of using TRad learning but not significantly as the CThink group. Thus, the null hypothesis Ho_2 can be rejected. Even though all students claimed as fail, but the majority of students shows an increased mark compared to the pre-test. The reason is students have learned something, compared to before the pre-test, which they dont know nothing.

Despite the fact that both groups improved their scores from pre-test to post-test based on the findings of the paired samples t-test, the CThink group was much better than TRad group about the mean scores (Mean CThink=34.82 and Mean TRad=14.69). After analysing the students' scores, the researcher wanted to investigate the comparison between two groups. The reason to compare each class is to reduce the bias and to prove the effectiveness of the CThink.

To verify the hypotheses, the study proceeded with the Mann-Whitney t-test to compare the performance of the pre-test and post-test between the CThink group and the TRad group since it was not normal distribution.

4.2.2 Hypothesis 3

Ho_3: There is no significant difference in the pre-test between the CThink and TRad groups.

To provide balance classes in terms of intelligent as the TRad and CThink groups, data analysis is therefore continued by examining the pre-test scores for both groups. Even though the range of scores was similar between the two groups, but there was a necessity to know about the similarity of their scores and level of problem solving of Integral Calculus at the beginning of implementing the CThink. Despite the fact that the CThink should be implemented in the CThink group, the results were compared to the TRad group's outcomes.

If their levels of knowledge were not similar at the beginning, the results would not be trustful and the progress in the CThink group might occur because students had a better grasp of the Integral Calculus concepts. Therefore, the scores of students' pre-test in both groups were evaluated to know if their background knowledge was equipollent and to check whether their achievements are different or not. If their pre-knowledge was equipollent, later they could be possible samples. The results of the Mann-Whitney U test are demonstrated in Table11.

Table10. Mean rank of the pre-test between CThink and TRad group

Test	Group	N	Mean Rank	Sum of Ranks
Pre	CThink	34	38.32	1303.00
	TRad	33	29.55	975.00

Table 11. Mann-Whitney U test of the pre-test between CThink and TRad group

Mann-Whitney U	414.00
Wilcoxon W	975.00
Z	-1.85
Asymp. Sig. (2-tailed)	.07

The mean rank for the CThink group (mean rank=38.32) scored higher than the TRad group (mean rank=29.55). A Mann-Whitney test showed that the difference in pre-test scores between the CThink group (n=34) and the TRad group (n=33) is statistically not significant, Mann-Whitney U (414.00)= -1.85, p=0.07. Therefore, the null hypothesis has been accepted. Students' scores show that the two groups were at a similar level at the beginning of the implementation of CThink. It proves that the pre-test scores of both groups are homogeneous. This indicates that CThink and TRad groups are the same in terms of achievement in the pre-test. Thus, it can be concluded that the means rank does not differ and that the two samples come from the same population.

The results revealed that both groups have equal performance in Integral Calculus at the beginning of the learning. Thus, the hypothesis that there is no significant difference in the pre-test between the CThink and TRad groups is accepted. So, it can be concluded that both groups are equal in terms of knowledge of problem solving in Integral Calculus. So, the study can be continued by conducting the CThink to see the efficiency by giving students a post-test at the end of the learning.

4.2.3 Hypothesis 4

Ho_4: There is no significant difference in the post-test between the CThink and TRad groups.

To ascertain whether there is a statistically significant difference in the post-test between the CThink and TRad groups, respectively. The results of the independent test are expressed in the Table 12.

Table 12. Mean and standard deviation in the post-test between the CThink and TRad groups

Group	N	Mean	Standard Deviation
CThink	34	41.62	15.97
TRad	33	18.69	9.83

Table 12 shows that the CThink group has a larger mean value (M=41.62, SD=15.97) than the TRad group (M=18.69, SD=9.83). It presents the descriptive analysis of the CThink and TRad groups' post-test scores. An independent sample t-test was used to investigate the comparison of students' scores on the pre-test understanding for both groups. The independent sample t-test of parametric analysis was utilised since the post-test results between the groups were normally distributed, as shown in Table 13.

Table 13. Independent sample t-test in the post-test between CThink and TRad group

Post-test	Levene's Test for		t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	10.07	.00	7.06	65	.00
Equal variances not			7.11	55.16	.00

Levene's test revealed p.05 for the post-test between both groups; hence, both groups have score values with distinct variance. The t-test analysis result was determined from equal variances not assumed in Table 13 with p=.00 due to the difference in variance between the two groups. The post-test T-test analysis revealed that there is a significant difference between CThink and TRad in the post-test. With t(55.16)=7.11, p.05., the CThink group had a larger mean value (M=41.62, SD=15.97) than TRad (M=18.69, SD=9.83). When compared to the TRad group, the CThink group fared better after being exposed to CThink. As a result, the hypothesis that there is no significant difference between the CThink and TRad groups in the post-test is rejected.

5. Conclusion

The effectiveness of CThink can be seen through the inferential statistical analysis performed on the CThink group. For evaluation, the empirical results from the hypotheses testing support the hypotheses proposed for this study. In particular, the study discovers that the CThink has positively and significantly enhanced students' problem solving in Integral Calculus. During the pre-test, the mean score for the CThink group was higher than the TRad group with no significant difference. This indicated that the performance of both groups is equal at the beginning of the experiment. It is important to establish that both groups were initially equipollent in their background knowledge, to ensure that any differences later in the post-test are due to the intervention received by the experimental group.

The CThink group outperformed the TRad group on the post-test, with a higher mean score. This meant that after being exposed to CThink, students performed better on the topic's problem solving than students who were exposed to TRad. This study's findings are an improvement above (Alsaleh, 2020), which only employs three critical thinking skills. The findings of this study are a follow-up to a study by Roberts et al. (2016), which indicated that kids' math ability is positively connected with their critical thinking and problem-solving abilities. The study's findings and analyses suggest that using critical thinking to teach integral calculus has a favourable impact. In comparison to the TRad technique, pupils in the CThink group did higher in the post-test. The results of this study show that CThink can help students solve problems in Integral Calculus.

In the CThink group, the lecturer encourages learning through activities with the questioning for critical thinking. This strategy seems to help construct of problem solving process among the students in the CThink group. The systematic learning strategy approach, derived from the constructivist and social constructivist view of learning, helps students recognise and evaluate their ideas. As students are aware of their thinking, they become more confident to solve problems.

This study has demonstrated that social constructivism can be carried out through various procedures; one of these is through CThink, which is for all intents and purposes intended for arithmetic speakers to execute constructivist exercises of educating and gaining both from mental and social viewpoints. CThink can be carried out at all degrees of schooling, compelling in connecting with understudies in the learning climate, in little or large homerooms. This study has exhibited that consolidating clear and exact bit by bit friendly constructivism CThink with aggregate conversation with addressing has prompted preferred critical thinking over through the TRad guidance. It is accepted that different ways to deal with social constructivist instructing in the space of science training can likewise be carried out in all around planned decisive reasoning exercises. This study observed the utilization of CThink promising as a feature of social constructivism guidance.

Accordingly, captivating students in social constructivist instructional activities and presenting explicit sequences of critical thinking activities seem productive in significantly improving students' problem-solving skills. This investigation has discovered that through CThink, which shows step-wise sequences, the solution in Integral Calculus led to better problem solving than through the TRad method. Most importantly, the study revealed that problem solving question which is related to life need discussion something other than the regular educational technique to elicit more information and acquire better answers.

As a result, it is possible to conclude that the conversation, as well as the implementation of a well-designed social constructivist approach with CThink as an instructional intervention, appeared to benefit students' problem-solving abilities. The study also found that students who were taught using CThink were more likely to answer the post-test correctly and seemed to answer using critical thinking skills. This study indicated that CThink is beneficial in enhancing problem solving for polytechnic students. This study differs from Bikić et al. (2016) that reveals used a modified generalisation strategy to enhance problem solving in differentiation and integration. The present study confirms the social constructivist theory that emphasises the need for lecturers to encourage students to become independent thinkers (Amineh & Asl, 2015).

The study's data and analyses suggest that using CThink to improve problem solving in Integral Calculus has a beneficial impact. Students who were exposed to CThink had considerably higher post-test mean scores than those who were exposed to TRad, according to parametric testing. This implies that the pupils in the class CThink group has improved their problem solving skills.

Acknowledgement
The authors would like to thank fellow authors and organizations whose intellectual property was utilized for this study.

Conflict of Interest
The authors declare no conflicts of interest.

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