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Examining the Effectiveness of Thinking Maps Usage by Analysing Students' Achievement in Mathematics Subject

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ABSTRACT

Teachers play a critical role in ensuring their pupils succeed in their studies. Educators must select acceptable teaching methods to ensure an effective learning experience. By applying the t-test statistical analysis, this research aimed to evaluate the efficiency of the thinking maps approach with traditional ways in increasing student achievement for a number base topic. This study involved 120 Form 4 pupils from 4 schools in Pahang. This research implemented a quantitative approach (quasi-experimental method). The research featured an experimental group (n = 60) and a control group (n = 60). As research tools, a set of pre-test and post-test inquiries were used. The application of thinking maps improved student achievement in mathematics subjects. There was a substantial difference in mean scores between the control and experimental groups, where the mean score of the experimental group seemed to be higher than that of the control group. Additionally, mean scores before and after the teaching and learning sessions showed a positive increase in both categories. Nevertheless, compared to the control group, the experimental group that utilised thinking maps showed a higher ascent in the mean score. The findings of this study can assist teachers to develop a thinking map as one of the teaching approaches for improving pupils' knowledge of a topic and, therefore, indirectly improving pupil academic achievement.

1. Introduction

Mathematics is one of the compulsory courses for all pupils regardless of their previous educational background. Mathematics knowledge and abilities are critical for a country's advancement and prosperity [2,3] because it is a discipline of study that aims to develop logical and systematic thinking skills. This discipline promotes in-depth analytical thinking and logical reasoning. Mathematical knowledge should be learned and used so pupils may apply it in various job and daily life scenarios [12]. Therefore, Mathematics is taught starting from childhood and continuing through the highest level of education in line with children's cognitive development. Nevertheless, learning Mathematics has become increasingly challenging at a higher level of education. This adversity leads

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to the declining quality of learning in Mathematics education, raising concerns among the community [27].

A pupil's excellence in Mathematics is measured based on the ability to know, understand and apply mathematical operations, evaluate and create skills, and systematically solve daily problems [26]. However, the mastery of mathematics subjects for pupils in Malaysia is alarming as there is no positive development shown by the pupils [17]. A such occasion can be proven through students' achievement in the Trends in International Mathematics and Science Study (TIMSS), which showed a 35% decrease in mathematics. This situation indicates that pupils in Malaysia still do not exceed the minimum proficiency level in Mathematics [23]. The Malaysian Ministry of Education has established various initiatives to address this problem, including efforts to enhance the thinking skills among learners.

The teaching and learning (T&L) method must evolve to improve the learners' thinking styles in critically analysing and synthesising information. Educators have received a variety of exposures, courses, and training to allow them to create adjustments in their T&L approaches and methods in the classroom. The i-Think programme is indeed one of the methods employed to present thinking maps. The programme aims to strengthen pupils' thinking skills, thus nurturing highly innovative pupils. Multi-Flow Maps, Flow Maps, Bracket Maps, Double Bubble Maps, Bridge Maps, Bubble Map, Tree Maps, and Circle Maps are eight thinking tools that educators could apply. Each thinking map has a distinct function. As a component of T&L, learners and educators will utilise thinking tools and participate in high-level thinking skills exercises. By utilising thinking maps, the i-Think programme aids in implementing components of thinking skills in T&L. This highlights the importance of utilising thinking maps to help pupils develop critical thinking skills.

Hyerle [14] introduced thinking maps as one of the materials that can help thinking skills among pupils. Pupils can utilise thinking maps to improve metacognition and continuous cognitive development and therefore equip themselves to attend educational activities more effectively [24]. As discussed above, an impactful T&L requires conducive surroundings that stimulate pupils to ponder, issue, and resolve conflict [25]. Consequently, today's instructional approaches highlight pupil-centred learning, which is strongly supported since educators will constantly engage pupils throughout the T&L process through thinking maps, permitting the educator's instructional purposes to be delivered quickly. Furthermore, the use of thinking maps assists teachers in assessing each pupil's ability before the start of T&L sessions, allowing for faster identification of student achievement. Deploying these thinking maps will also bridge the achievement gap among pupils. In this study, student achievement means the results obtained by the student are evaluated by comparing the score obtained in the pre-test (before the student uses the thinking map) and post-test (after the student uses the thinking map in their learning process). The measurement assessed whether there was an improvement or not even. This study aimed to use statistical analytic approaches to evaluate the efficacy of using thinking maps to improve high school students' mathematics achievement. The information was gathered and studied using an inferential statistics t-test.

Therefore, this study aims to identify whether there is a significant difference between the mean score of the control and experimental groups when the thinking map method is applied, compared with the traditional method, in improving student achievement for the Basic Number topic by using the t-test method.

2. Literature Review

Mathematics is defined as a field of knowledge that trains the brain to make judgments and solve questions in a systematic and clear manner [22]. The T&L process may employ various teaching techniques and thinking tools to enhance students' reasoning skills. The most commonly used thinking tools are graphic management, mind maps, question-questions, CoRT tools [29], and thinking maps.

In the subject of Mathematics, in particular, more creative, interesting, systematic teaching methods and the appropriate use of fuel can help the pupils to understand concepts. Many studies have shown an improvement in student achievement when thinking tools such as thinking maps and other thinking tools are used in T&L. Using thinking maps during the T&L process in the classroom does not incur additional time for teachers and pupils, because the thinking maps are part of the T&L process. In addition, thinking maps do not occasionally add a burden to teachers because thinking maps are thinking tools and not teaching aids [20]. However, the teacher may feel the burden if the teacher uses these thinking maps as a teaching aid.

According to Hyerle [14], the thinking maps paradigm has the advantage of being more introspective, consistent, integrative, adaptable, and developmental. Other advantages include focusing on complex thinking abilities, developing pupil independence to continue learning to utilise eight thinking maps that indicate applicability for all ages, and cross-disciplinary independence. The method has been proven to enhance students' understanding of mathematics. In his book, Hyerle [14] stated that tangible test results, observations, and research have demonstrated that thinking maps could improve students' achievement and promote life-long learning.

Using thinking maps lets pupils quickly grasp a particular lesson material and motivates them to study [21]. An exploratory approach was employed in this research, which included 60 Year Four pupils. In post-tests with a p-value (sig) less than 0.05, the t-test analysis revealed a significant difference in score mean between the control and experimental groups. In post-tests, the treatment group incorporating thinking maps earned a mean score of 53.86, whereas the control group obtained a score of 45.20. A survey in the same study revealed that the mean interest in the thinking maps was 30.43 compared to the mean interest in using bullet-point slides of 22.16.

This finding is consistent with the results of Yusop and Mahamod [30], which found that using thinking maps during the process of T & L has improved student achievement in 6 years in the writing of Malay. This research revealed a significant difference between the mean post-test score and the mean pre-test score for the treatment group, which went from 25.07 to 49.4 marks, contrary to the control group, which indicated only a 1.6-point gain in the mean score (23.96 to 25.56). In this study, the inferential statistical analysis of the t-test was used to evaluate differences in the mean scores of post-tests and pre-tests between the experimental and control groups.

Next, Long and Carlson [19] demonstrated that using thinking maps increased student achievement in an American school's action research on eighth-grade pupils. According to the participants in this research, thinking maps are an efficient means of conveying their cognitive tendencies in writing, influencing how they jot down notes and cultivating their understanding. Long and Carlson [19] argue that thinking maps allow pupils to sketch relationships between their ideas and concepts learned. In addition, it urges pupils to place their mental processes down on paper so that the process can be seen more clearly and systematically.

On the other hand, Laura [18] researched the impact of thinking maps on higher-order thinking skills (HOTS). The poll comprised 70 pupils, who were all 18 years old. The ability to make contrast comparisons and essay scores of respondents were measured before and after using the thinking maps to determine their high-level thinking skills. The results indicated that the ability to compare

pupils' differences after using the thinking maps increased by 69%, while the essay score increased by 16%. The results of the interviews also showed a positive change in the respondents' attitudes and ways of learning.

In addition, pupils' academic achievement is successfully developed through thinking maps [1,18]. Pupils can reconcile prior knowledge with new learning through thinking maps. Thinking skills applied through thinking maps can help speed up the T&L process as pupils can classify, compare and differentiate each knowledge they learn because they can use A4 papers, sticky note papers, color pencils and ideate cards to make a learning more interactive [28]. Implicitly, these thinking skills can boost pupils' capacity to recall things for a lengthy period, optimising their educational achievement.

Furthermore, using thinking maps also positively affected pupils with learning difficulties in reading comprehension [5]. Reading comprehension scores showed improvement after treatment using multiple bubble maps given to pupils. Thus, appropriate thinking maps can affect reading comprehension among pupils with learning difficulties. Indirectly, effective learning can be ensured if teachers apply appropriate thinking maps based on the objectives achieved in the T&L process.

The literature generally suggests that using thinking tools can help pupils enhance their achievement and build higher-order thinking skills. Pupils must be willing to receive new knowledge in order to comprehend what is being taught. Pupils can improve their thinking ability to combine the knowledge gained with new ideas on paper more clearly. Therefore, the teacher's teaching method is very important to ensure that a teaching strategy can achieve the optimal impact on the students.

The usage of thinking maps as a tool for thinking is supposed to assist the school in

i. identifying changes in pupils' attitudes in terms of strengthening thinking abilities
ii. expanding their creativity (thinking outside the box)
iii. enhancing the teacher-pupil relationship and pupil-pupil interaction
iv. ensuring stressless learning environment
v. improving pupils' learning interest
vi. increasing pupils' self-confidence [20].

Therefore, thinking maps can be used as one of the routines in T&L sessions to help improve academic achievement and thinking skills among pupils.

After applying any new T&L methods, it is important to measure the effectiveness of the T&L methods by an appropriate measuring technique such as statistical methods. Thus, this research focused on assessing the effectiveness of using thinking maps for the numerical base issue in secondary school mathematics instruction. The comparison between the control and experimental groups was analysed using an inferential statistics t-test. Separate samples were utilised to correlate the mean scores of the two groups, whereas a paired t-test was performed to see if the mean scores of the pre and post-test for the control and experimental groups differed.

The number base topic is easy to understand if pupils can apply thinking maps to this topic. For pupils from middle and weak classes, this topic is very helpful for pupils to answer correctly. Therefore, using thinking maps can help improve pupils' understanding and student achievement in Mathematics. Three thinking maps are suitable for use in this topic, namely, Circle Map, Tree Map, and Bracket Map. Bracket and Circle Maps are applied to comprehend the fundamental ideas of numeric bases. In contrast, Tree Maps are applied to separate number base groupings into four classifications: numbers in base two, base five, base eight, and base ten.

3. Methodology

A quantitative quasi-experimental approach is adopted throughout this research. In this research, the experimental group was introduced to and coached using the thinking maps approach, whereas the control group received traditional teaching. The structure of the Quasi-experimental investigation is depicted in Table 1.

Table 1
Quasi-experimental study design

Group	Before	During	After
Experimental	U_1	X	U_3
Control	U_2	Y	U_4

As referred to in Table 1

U_1 = Experimental Group Pre-test
U_2 = Control Group Pre-test
U_3 = Experimental Group Post-test
U_4 = Control Group Post-test
X = Thinking Maps Teaching Method
Y = Traditional Teaching Method

A pre-test should be given to both groups as a guideline to show that both groups have the same cognitive development in order to ensure that the treatment impacts student achievement. Next, a post-test will be given, and the difference between the pre-test and post-test scores will show whether there are measurable changes or effects after the treatment. Nevertheless, quasi-experiments are experiments always exposed to extraneous variables' influence. An extraneous variable is any variable that is not intentionally studied in the study but can influence the experiment's outcome. Therefore, the researcher must take measures to reduce and minimise the threat. The following are steps taken by the researcher to reduce bias in this study.

The study sample consisted of 120 pupils involving 52 males and 68 females, from four primary schools in Pahang. This study involved Form 4 pupils, consisting of pupils from middle and weak classes whose Mathematics paper score is less than ten marks. The school authorities handpicked the pupils that participated in this research [8]. The schools involved had expressed their interest in participating in the research and were ready to provide their educators and pupils as respondents. All four schools were given different teaching strategies of 150 minutes per week. This time period was chosen because many previous studies used exposure times between 60 minutes to 250 minutes per week to look at treatment effects among pupils [7,9,13,31]. Once all four schools had the same established features, an arbitrary job was assigned to decide which schools would function as the control and experimental groups. These four schools were arbitrarily assigned to an experimental or a control group in a randomised distribution.

Bias type	Action taken by the researcher
Historical impact	This study has two groups, the experimental and control groups, from different schools. Pupils in the same group will only be exposed to one type of teaching strategy throughout the intervention. For the experimental group, students were taught using the i-Think thinkingmap method, while students in the controlgroup were taught using the traditional method. Next, during the treatment that takesplace at school, there are no major events suchas motivational talks or Math workshops for students that may affect the treatment results.
Instrumentation	In this study, the evaluation sheets of studentsfrom both groups were scored and marked by the researcher correctly according to the answer scheme provided. Therefore, the possibility of students getting marks in different standards is unlikely to happen in this study.
Selection	The researcher chose two groups that have equivalent characteristics in terms of age, subjects taken, scores, learning environment and the qualifications of the teachers who teach the subject.

Two classes (n = 60) from two schools have been using the thinking maps approach, whereas another two classes (n = 60) from two schools used the traditional approach. At the start of the quasi-experimental process, all four schools, namely School A, School B, School C, and School D, had been ensured with comparable features to minimise prejudice [16].

The test consisted of 30 questions, 20 of which were objective and 10 of which were subjective. The pre-test and post-test contain identical questions. However, the placement of the questions was changed in the post-test to prohibit pupils from remembering the questions and answers. The exam questions were developed based on the DSKP Mathematics Form 4 curriculum as a reference. The time allotted for pupils to answer this question is one hour. The questions were modified in terms of numbers to suit the level of achievement of the pupils who were used as respondents in this study.

Both groups sat a pre-test to determine their level of knowledge in the number base topic. This exam sheet was re-collected to assess the pupils' responses and document the pre-test results. The T&L session began after the pre-test, with the experimental group incorporating the thinking maps teaching technique and the control group incorporating the traditional teaching techniques. The experimental group's pupils were trained to apply the three thinking tools in the number base topic throughout the T&L session. To guarantee that pupils grasp the purpose of each thinking tool, these training sessions are executed in three steps [19]. This teaching session is for pupils from the experimental group.

The first stage is giving direct instruction related to the eight thinking maps. The first level's goal is to prepare the students to utilise the proper thinking maps for every number base subtopic. Each thinking tool serves a distinct function. Pupils' competence to identify and apply adequate thinking tools demonstrates that pupils recognise ways to utilise the thinking tools.

The second stage is teachers and pupils applying thinking maps together. Thus, pupils can abide by the procedures for developing a thinking tool relevant to the covered subtopic to better grasp the subject being educated. The last step requires pupils to construct applicable thinking tools in accordance with the educator's task. Pupils can consult the materials given and seek advice from the educator. Conversely, pupils in the control group will be taught using traditional methods.

After a six-week session, pupils from both groups sat for a post-test. This post-test aims to discover whether using thinking maps improves student achievement or the opposite. Simultaneously, this procedure was executed to determine the degree of the influence of the use of thinking maps on secondary school pupils' mathematics achievement. The following is the conceptual framework of this study.

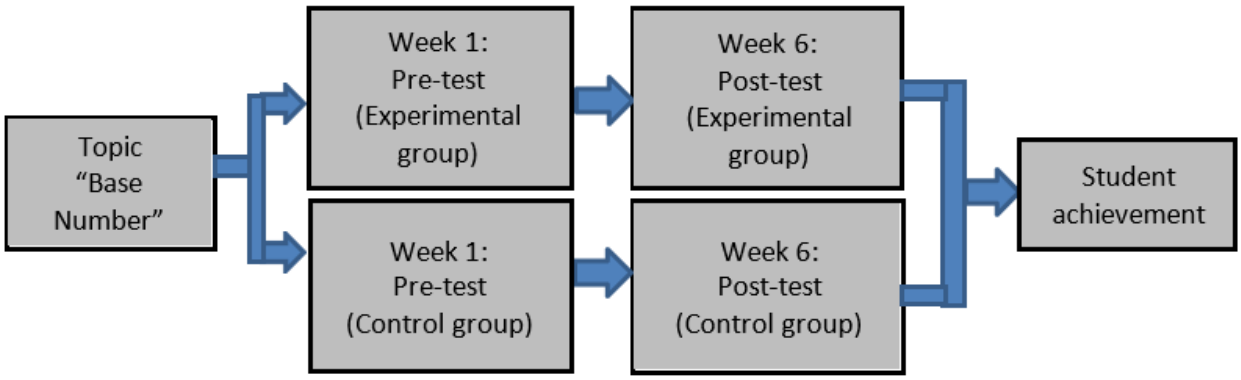

Fig. 1. Conceptual Framework

The data collected was evaluated using a variety of statistical approaches. In this research, the t-test was applied to investigate the changes in score means between post-tests and pre-tests that indicate students' achievement in mathematics subjects [15]. In addition, numerous statistical analysis procedures, referred to as parametric methods, may be carried out on the premise that the data is typically dispersed [11]. Hence, the first step in this research was to perform a normality test using the kurtosis and kurtosis approach, where the values are set at ±2.5. [10]. Thus, such values are respectable and reasonably typical data dispersions. Furthermore, assuming the subject size for each group in the separate factor is not fewer than 15, this normality requirement is fulfilled [6]. The hypothesis statements for this test are:

$H0$: $The\ data\ are\ normally\ distributed$
$H1$: $The\ data\ are\ not\ normally\ distributed$

In the meantime, Levene's test was performed to determine if the variances of two specimens were roughly equivalent prior to conducting an independent t-test since an independent sample t-test assumes that the variances in specimen groups are roughly identical. Thus, the following were Levene's test hypothesis assertions:

$H0$: $The\ variances\ of\ two\ samples\ are\ approximately\ equal$
$H1$: $The\ variances\ of\ two\ samples\ are\ not\ equal$

An independent sample t-test was adopted to evaluate the pre-test and post-test mean scores between the control and experimental group pupils. Moreover, a paired t-test was applied to determine whether the pre and post-test mean scores for the control and experimental groups differed [4]. The independent t-test alternative hypothesis assertions are as specified:

i: $H1$: $There\ is\ a\ significant\ difference\ of\ mean\ scores\ for\ pre-test\ between\ experimental\ group\ and\ control\ group.$
ii: $H2$: $There\ is\ a\ significant\ difference\ of\ mean\ scores\ for\ post-test\ between\ experimental\ group\ and\ control\ group.$

With the premise that two samples are nearly normal and have similar variances, the t-statistics of this test may be expressed as follows

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s_p\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}, \quad (1)$$

where
$\bar{x}1$: mean score of 1st sample
$\bar{x}2$: mean score of 2nd sample
$n1$: sample size of 1st sample
$n2$: sample size of 2nd sample

Meanwhile, sp is the pooled variance of the two samples as below

$$s_p = \frac{(n_1-1){s_1}^2+(n_2-1){s_2}^2}{n_1+n_2-2}, \quad (2)$$

where
$s12$: variance of 1st sample
$s22$: variance of 2nd sample
The alternative hypothesis statements of paired t-test can be written as:

i: $H1$: $There\ is\ a\ significant\ difference\ of\ mean\ scores\ for\ pre\ and\ post-tests\ in\ the\ experimental\ group.$
ii: $H2$: $There\ is\ a\ significant\ difference\ of\ mean\ scores\ for\ pre\ and\ post-tests\ in\ the\ control\ group.$

The t-statistics of this test were

$$t = \frac{\bar{D}-\mu_D}{s_D/\sqrt{n}}, \quad (3)$$

where
D̄: sample mean of the different observations
μ_D: μ_1- μ_2
s_D: sample standard deviations of differences observations
n: sample size

3. Results

This research involves a sum of 120 pupils. The number of females and males in the control and experimental groups is presented in Table 2.

Table 2
Number of respondents by gender

Gender/ Group	Male	Female	Total
Experimental	27	33	60
Control	25	35	60

Table 3 displayed descriptive statistics for Mathematics scores for both examinations premised on two groups: control and experimental. The control group's pre-test score mean was higher than the experimental group's. Even so, upon getting introduced to studying via thinking maps, the

experimental group had a higher mean score on the post-test. This finding supports our hypothesis that using thinking maps in T&L can boost student achievement in Mathematics subjects. However, is there any significant difference in the score means between groups? It can be found by conducting an independent t-test. Meanwhile, to check the significant difference between two sets of data obtained from the same group of samples, a paired t-test was conducted.

Analysis of the independent t-test

i: $H1$: $There\ is\ a\ significant\ difference\ of\ mean\ scores\ for\ pre-test\ between\ experimental\ group\ and\ control\ group.$ (rejected)
ii: $H2$: $There\ is\ a\ significant\ difference\ of\ mean\ scores\ for\ post$–test $between\ experimental\ group\ and\ control\ group.$ (Failed to reject)

Table 3
Descriptive Statistics 1

Test	Group	n	Mean	Std. Deviation	Std. Error Mean
Pre	Experimental	60	15.10	3.616	0.467
	Control	60	15.72	3.923	0.507
Post	Experimental	60	23.78	3.975	0.513
	Control	60	20.70	4.795	0.619

Results of the Skewness and Kurtosis test show that the mathematics scores of sample data follow a normal distribution in which all categories of data have a value between ±2.5, as shown in Table 4. Furthermore, the control resembles the control group, whereas the experimental resembles the experimental group, pre for pre-test and post for post-test.

Table 4
Normality Test

Group	Test	Skewness	Kurtosis
Experimental	Pre	-1.964	0.173
	Post	-1.654	0.536
Control	Pre	-2.104	0.329
	Post	-2.317	0.786

The Levene test revealed that the scores data have similar variance, with p-values (sig.) higher than 0.05 for both Mathematics exams. The scores across the groups were then compared using an independent samples t-test predicated on the similar variances premise. The analysis indicates no significant difference in pre-test Mathematics scores between the control and experimental groups. The experimental group had an M and SD value of 15.10 and 3.616, respectively; the control group had an M and SD value of 15.72 and 3.923, respectively, while the sig value was larger than 0.05. Thus, the findings revealed that at the start of the trial, both groups performed equally well in Mathematics. The control and experimental groups' pre-test achievement was not significantly different. Hence, the hypothesis that there are significant differences in mean scores for pre-test between experimental and control groups is rejected.

Given a p-value (sig.) less than 0.05, the post-test indicated a significant difference in score mean between the control and experimental groups. Considering $t(118) = 3.835$, $p<0.05$, the experimental group had a higher mean value (M=23.78, SD=3.975) than the control group (M=20.70, SD=4.795). The data indicate that the experimental group outperformed the control group upon exposure to the

thinking maps approach. As a result, there is a significant difference in mean scores for the post-test between the experimental group and control group is failed to reject. This finding is in line with the study of Alabdulaziz [1] which is a study using the thinking maps self-learning module. The method used is able to stimulate pupils' thinking to be more creative in solving a problem given but the teacher.

Table 5
Independent Samples t-test

Levene's Test for Equality of Variances		Test for Equality of Means				
		F	Sig	t	df	Sig. (2-tailed)
Pre-Test	Equal variances assumed	0.189	0.665	0.895	118	0.372
Post-Test	Equal variances assumed	1.462	0.229	3.835	118	0.000

Analysis of the paired t-test

i : $H1$: $There\ is\ a\ significant\ difference\ of\ mean\ scores\ for\ pre\ and\ post-tests\ in\ the\ experimental\ group$. (failed to reject)
ii : $H2$: $There\ is\ a\ significant\ difference\ of\ mean\ scores\ for\ pre\ and\ post-tests\ in\ the\ control\ group$. (failed to reject)

The results of the paired t-test (Table 6) revealed that there is a significant difference in pupils' Mathematics scores for both groups, with a p-value (sig.) smaller than 0.05. This difference indicates that both groups' post-test achievement continued to improve. Nonetheless, the experimental group scored a higher mean score of 19.44 than the control group, which obtained a score of 18.21. That means T&L using thinking maps can improve student achievement compared with traditional T&L methods. As a result, the hypothesis claiming there is a significant difference in mean scores for pre and post-test in the experimental and control groups is failed to reject. In conclusion, the achievement of students who follow the learning method using thinking maps is better than students who follow traditional learning methods. Pupils show positive reactions when using thinking maps in the classroom thus helping pupils improve their achievement in the classroom [30]. Perhaps, using thinking maps in the PdPc session stimulated students' thinking; thus, the student could answer the teacher's questions. However, the achievement of students who followed the traditional learning method also showed an improvement in the post-test but not as good as the improvement shown by the students of the experimental group who followed learning using thinking maps. The findings of this study are supported by studies conducted by Calvin and Gray [5] which found that the mean achievement of pupils in the experimental group was higher than the mean achievement of pupils who were taught traditionally.

Table 6
Paired t-test

Test		Mean	Std. Deviation	t	n	Sig
Experimental	Pre-Post	19.44	3.796	-18.053	60	0.000
Control	Pre-Post	18.21	4.359	-10.966	60	0.000

Figure 2 shows the activities and results of the student's work for the group involved in learning using thinking maps.

Fig. 2. Students follow the learning using thinking maps

4. Conclusions

This study discovered that thinking maps helped students perform better in the Number Base topic of Form 4 Mathematics positively and significantly. Pre-test and post-test were used in this study to determine the degree to which students have learned the content or skill area of interest. Student learning can be inferred from the difference in student achievement between the two points. The level of learning can be measured based on different criteria, such as the amount (day, time, score) and the quality of teaching between the two points in time.

Throughout the pre-test assessment in this study, the experimental group's mean score was lesser than the control group. However, the difference was insignificant, indicating that both groups' achievement was similar at the beginning of the experiment. It is critical to demonstrate that the two groups were originally at the equivalent tier to verify that the experimental group's treatment caused the disparities in the post-test.

The experimental group scored a greater mean score than the control group after the post-test, suggesting a significant difference with a p-value < 0.05. This distinction suggests that pupils understood the concepts taught better after thinking maps were employed in T&L instead of traditional methods. The findings of this research are congruent with Yusop and Mahamod's [30] views, who discovered that using thinking maps throughout the T&L process assists pupils in getting a deeper understanding of a subject and thus boosting their learning performance. Additionally, using thinking maps might make pupils more interested in mathematics.

The post-test was administered six weeks after the pre-test to determine the pupils' memory level and understanding upon utilising the thinking map learning approach. In the post-test, the mean scores for both groups continued to improve. The experimental group's mean score was substantially larger than the control group, with a p<0.05 significant difference, indicating that the experimental group could retain more memory and comprehension than the control group once they employed the thinking maps T&L technique. The technique used is able to stimulate pupils' thinking to be more creative in solving a problem given by the teacher [1].

This research revealed that pupils in the experimental group were eligible to maintain lengthier memories since the educators' usage of the thinking maps teaching technique assisted them in translating thinking map patterns into writing. Thinking maps allow pupils to connect their thinking with their studied topics, making the learning process clearer and more systematic [5,19]. Therefore, thinking maps can be perceived as a teaching method that can help to improve student achievement.

The findings of this study can help the Ministry of Education and Culture to assess the effectiveness of the i-Think program in improving students' thinking skills. Based on the findings of this study, the program launched by the Ministry of Education and Culture successfully achieved its objective of helping students improve their thinking skills in their learning and further make it a

lifelong learning culture. In addition, this study can also spread the use of thinking maps as an approach to applying HOTS elements in teaching and learning mathematics. Next, this study can encourage teachers to use thinking maps and improve student understanding. This integration of thinking maps into the T&L will be an effort to achieve the desire to produce students who have HOTS and can compete globally. Applying HOTS is expected to be more effective through i-Think thinking maps and improve students' ability to solve real-life problems, equipping the students with competitive high-level thinking skills. This study is also expected to be the basis for further studies to improve the ability of teachers to use thinking maps.

However, this study only focused on one district in Rompin, Pahang and only involved four daily high schools. This study involved Form Four students, which are 60 experimental group students and 60 control group students. A quantitative research design was only used in this study without involving interviews with the students involved. More studies should be conducted in a large area to get the overall picture of the effectiveness of the T&L technique proposed in Malaysia. Among the suggestions for further research is that further research should be conducted on different topics in Mathematics, such as statistics, function graphs, and others, to see the effectiveness of thinking maps in improving thinking skills among pupils for each topic studied. In addition, thinking maps are also suitable for use in other subjects. Therefore, further research should be conducted on using thinking maps in other subjects, such as Sports Science, Additional Mathematics, Technology Design, etc., so that all teachers can acknowledge the importance of thinking maps in T&L.

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