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The Effects of Thinking Styles and Inventive Problem-Solving on the Problem-Solving Skills for Design and Technology Students

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Abstract: The creative critical thinking skills model aims to apply a critical and creative thinking style to students so that they can solve inventive problems well. However, teachers overlook the importance of this thinking style because they focus on inventive problem solving. Thus, a teaching module based on the Meyer Model has been developed to help teachers teach inventive problem-solving skills. This module has been developed by combining critical and creative thinking styles and the Theory of inventive problem solving (TRIZ) which is a theory that uses structured and systematic methods to solve inventive problems. This study aims to evaluate the effect of module implementation on the achievement of inventive problem-solving skills of standard four design and technology students in five aspects (i) problem situation (ii) problem cause (iii) strategy and approach (iv) solvability (v) innovation. This study used a quantitative approach with a quasi-experimental design. A total of 106 students were selected by cluster of random sampling and divided into 2 group which is control group (CG) and treatment group (TR). The research instrument used pre-test and post-test set to measure inventive problem-solving skills (IPSS) achievement. The results of the test analysis show that there is a significant improvement in the five aspects of the student's IPSS. In conclusion, the TRIZ-based thinking style module help teachers in teaching and learning in the classroom, especially in generating ideas to solve problems. The exposure of critical and creative thinking styles in this module also indirectly guides users to have a balanced style which has the potential to solve problems more effectively.

Keywords: Thinking style, problem solving skills, inventive problems, Meyer Model, module

1. Introduction

The 12th Malaysia Plan which emphasizes the development of human capital that will increase productivity, produce a highly skilled workforce, and generate the economy for social development. This is where Technical and Vocational Education and Training (TVET) programs play an important role. TVET is an educational program focused on the production of quality and workforce skills to drive the national economy toward Vision 2020 (Yunos, 2023). This means that TVET is a foundation or preparation space for graduates who will meet the job market later. However, the issue that arises now is the marketability of graduates after graduation (Bikar et al., 2023). There have been many previous studies such Nadarajah (2021); Mohd et al. (2020); Jamaludin et al. (2021) who emphasized the reasons why Malaysian graduates do not find a place in the market. More sadly, most studies show graduates' weakness in problem-solving skills which is the main reason why graduates are not employed (Fajaryati & Akhyar, 2020; Haron et al., 2021; Açıkgöz et al., 2022; Salahuddin et al., 2023)

At the same time, the results of the TIMMS (Trend in International Mathematics and Science Study) and PISA (Programme for International Student Assessment) benchmark studies show that the level of achievement of Malaysian students is at a low level (Egan et al., 2022) has caused the government to take several actions follow up. Among them is transforming the existing curriculum into the latest curriculum which is the Primary School Standard Curriculum (KSSR) and drafting the Malaysian Education Development Plan (PPPM) 2013-2025. KSSR has been enacted by introducing the Content and Assessment Standard Document (DSKP) to be a guide for teachers for each subject. This DSKP is a document that integrates curriculum and assessment. DSKP lists content standards, learning standards, and performance standards.

Meanwhile, in PPPM, based on the low results of TIMSS and PISA Malaysia, the form of examination questions and evaluations in the Malaysian education system has been revamped. This overhaul focuses on increasing questions based on higher level thinking skills (HOTS), especially in application and reasoning in line with TIMSS and PISA questions. According to Alyahya & Alotaibi (2019), TIMSS questions show that teachers should teach students to solve problems, think critically, apply knowledge, and integrate new knowledge with existing knowledge. This clearly shows that problem-solving skills are the main skills that should be emphasized in the national education system.

In the meantime, to meet the need for a skilled workforce in line with the objective of establishing TVET, like bending bamboo from a bamboo shoot, the Ministry of Education has started technical education as early as primary school (Salleh & Sulaiman, 2020). This is evidenced by the existence of design and technology (RBT) subjects in primary schools. RBT is a non-core subject that is compulsory for fourth-year students. The existence of this RBT subject is to cultivate good values, do-it-yourself (DIY), sensitivity to surrounding problems as well as a positive attitude when carrying out activities to produce students who are technologically literate, creative, and have entrepreneurial characteristics.

If you look back at the purpose of RBT's existence, it is found that do-it-yourself (DIY) has introduced students to the kit model. This kit is a ready-made tool. For example, racing car model kit. This kit is introduced to students to expose students to the function of the components, the consequences, and the problems if they are installed incorrectly (Acedillo & Saro, 2023). Unfortunately, students are more excited to complete this kit than to find the cause and detect the problem if it is installed incorrectly (Stanciu et al., 2020). It is even more unfortunate when the results of the researcher's interview with the RBT education officer stated that the main problem in the RBT workshop is the lack of problems. For example,

nowadays there are many suppliers who provide kit models required for each topic or project found in the textbook. The existence of this kit model, although it helps the teacher to achieve the objective of completing the project, in terms of the student's experience when the process of making the project does not happen. Students do not have the opportunity to explore the problems that exist in the project because the kit has already been designed to be completed. This is what the RBT education officer said when interviewed.

According to the findings of the researcher's initial investigation, which involved interviewing two education officers and ten Malaysian RBT lead trainers for the description of RBT subjects, most RBT instructors still struggle to identify problem-solving techniques. If students do a project effectively, one teacher thinks they already have problem-solving abilities. Furthermore, it is well known by the general public that the project KIT dump that the providers are selling is an installed-ready project. It would seem sense that a student's ability to solve problems well cannot be determined by their ability to finish a pre-made assignment. In addition, the results of the interviews with ten head coaches (JU) at RBT Malaysia. Researchers also discovered that the RBT itself lacks Based Assessment Instrument Schools (PBS). In addition to making this claim, Nordin (2013) acknowledged that there isn't a single model that can be applied with any degree of certainty when developing curricula in educational institutions. According to the National Education Philosophy (FPK) and the most recent curriculum, KSSR, PBS is a comprehensive kind of evaluation that looks at cognitive (intellectual), affective (emotional and spiritual), and psychomotor (physical) elements of learning (Ahmad, 2014). PBS evaluation is separated into two categories: non-academic and academic. As a result, the School Assessment component under the academic field is where assessment is found in RBT.

Although the existence of Kit helps teachers achieve teaching and learning objectives, this closes the opportunity for teachers to be more creative. This is proven by the results of an online survey that shows Malaysian RBT teachers are less creative (Saien et al., 2017). So, it is not surprising if the teacher thinks that the student's success in completing the project is a sign that the student is skilled. This is driven using Kit Model earlier. Things that exist in front of the eyes will facilitate the teaching and learning process of the teachers. With the available time constraints, all the teachers must teach according to the DSKP and textbooks. However, according to (Zahriman & Rasul, 2017), even if the teacher has a good teaching style, the attitude of a few teachers who are not creative during the teaching session will make the students bored. Besides, the novelty come with originality. The integration of thinking style and TRIZ is undeniably pompous. Critical and Creative Thinking Styles have been incorporated into the Thinking Skills Model and adopted by Malaysian educators since 1991. The integration of Thinking Style (TS) with Inventive Problem-Solving Theory (TRIZ) is an innovation that facilitates educators to inculcate students with critical and creative values. Next, this is the first module that integrate the pompous pairing. Thirdly, this module is open to any age. Nevertheless, the instrument called KPMI instrument is the invention together with PMI table that can help on solving the problem.

2. Research Objective

The objectives of this study are:

i. Developing Thinking Style and Inventive Problem-Solving Skills Module for standard four students for RBT subjects on Inventive Problem-Solving Skills.
ii. Evaluating the effectiveness of the Thinking Style and Inventive Problem-Solving Skills Module of standard four students for RBT subjects on Inventive Problem-Solving Skills

3. Methodology

The research approach taken to complete this investigation. This study utilized a quantitative strategy with a quasi-experimental design. Quasi-experimental is a strong design because it can examine inequality between groups (Fraenkel & Wallen, 2009). This chapter also covers research operations, teaching and learning process flow, validity and pilot studies, population and sampling, research tools, and data analysis techniques. This selection is aimed at evaluating the effectiveness of Thinking Style (TS) and Inventive Problem-Solving Skills (IPSS) using modules on inventive problem-solving skills in a comparison between pre-test and post-test between two groups. According to Creswell (2013), this design involves two groups namely the treatment group (TG) and the control group (CG) where the sample selection does not use simple random assignment.

Two schools and four separate courses are involved in the teaching and learning process. The fourth-year students in the RBT Class (TG) will use the Thinking Style and Inventive Problem Solving (MP) Module. The Control Class (CG), which comprises of standard four students from Classes (CG), exclusively uses traditional teaching methods without the use of modules, is made up of these pupils. Using SPSS software, the data collected from each test instrument was processed, and the descriptive data was then displayed in table format. To effectively explain descriptive findings and conclusions using SPSS software, the final report is written using tables. Threats to the study's external validity include the study sample's poor population representation and the use of cluster random sampling, which will not accurately represent the population.

3.1 Research Procedure

In this research, two schools with four distinct TG courses are included. comprises standard four students using the Thinking Styles and Problem-Solving Skills Module Inventive (MP) from classes A and B (TGa and TGb). In contrast, CG is made up of standard four students from classes C and D, where there is no usage of modules and pupils exclusively follow traditional teaching methods. These four student classes were chosen at random from the cluster.

By using a quasi-experimental design, all research groups TGa, TGb, CGc, and CGd sit the pre-tests U1, U3, U5, and U7 before TGa and TGb get therapy. To reduce the influence of any legal threats on interactions between groups, a pretest was administered to both TGa and TGb concurrently prior to the Thinking Styles and Inventive Problem-Solving Skills Module (MP) that they utilized (Fraenkel & Wallen, 2009). To prevent risks to internal validity and external validity, the post-test was administered to both groups concurrently following a four-week course of therapy for TGa and TGb. Each student's achievement level is determined by this test. Experts advise that the best time to collect data for a pre-test and post-test is eight weeks.

All standard four primary school pupils in Malaysia who are enrolled in RBT courses make up the study's population. The population is chosen using modest academic attainment standards to reduce the impact of bias on cognitive ability, linguistic proficiency, and experience interpreting pre- and post-item assessments. The investigator used cluster random sampling to choose two schools, designated as A and B. Based on UPSR scores from every school in Malaysia for three years running, this decision was made. The state with the average grade of UPSR scores for three years in the middle position is chosen by the researcher, who then selects the middle-ranking school for the state. Despite the criterion for selection, the researcher should consider the fact that the selected institution should offer many classes, allowing for an enrolment of not fewer than thirty.

3.2 Instrument

A pre-test and a post-test of accomplishment were used in this investigation. The Brain-Dominance questionnaire was also employed in this study to determine the type of thinking that each student must possess. To determine the teacher's mode of thought in the interim the creative-critical instrument of Chua Yan Piaw is applied. The instructor's pertinent response, they will be introduced to the distinction between critical and creative thinking through this device, inadvertently. This is significant because teachers need to be more aware of their own ideas to assess how well their pupils think. In addition, the thinking type and solving skills module incorporates creative problem-solving techniques that call for the instructor to be aware of the thinking type of each student in advance. The TRIZ idea was adhered to by researchers who had experience with the title of invention year four to construct an instrument that measures innovative problem-solving proficiency. Researchers also make sure that this KPMI instrument (pre-test and post-test) has been examined for validity and reliability to reduce risks to the validity of the instrument's items.

Prior to the real test, a pilot study is conducted. The purpose of this exam is to verify if the instrument's language adjustment and content are appropriate for the pupils. Students get the chance to remark on the instrument's lack of clarity, ambiguity, and other linguistic issues. Observations are also made by researchers during the testing process. Researchers can then use this to modify any current flaws. Involving fourth-year students from schools included in the research population, a pilot study was carried out. Testing the validity level of the instrument is crucial, according to Fraenkel & Wallen (2009), to make sure the items have been tailored to the students taking the exam. Students can provide feedback on inadequacies, misunderstandings, and unclear instrument wording in pilot research. As a result, the pilot study's findings enable researchers to address the shortcomings that have been found. Several areas of weakness have been discovered, including the time factor, language, cognitive level, and attitude of the students.

The data in this study were analysed using the ANCOVA test. By accounting for additional variables that may also have an impact on the dependent variable, the analysis of Covariance Test, or ANCOVA test, is used to determine the relationship between an independent variable and a dependent variable. Groups (an independent variable), the mean KPMI pretest score (a variable control), and the mean KPMI post-test score (a dependent variable) are the variables used in this test. The groups made up of nominally scaled CG and TG are the independent variables, and the mean post-test score KPMI is the dependent variable. Pretest results can be utilized in an ANCOVA test, according to Best & Kahn (2006), to statistically adjust for any prefix differences between groups that were present at the start of the trial.

The research data that included many dependent variables that were assessed repeatedly over a period of time or under various conditions were analysed using the MANCOVA test. Every dependent variable in the research is measured upwards at least once to enable comparisons both within and across the dependent variables. At least two groups (categories) of independent data are measured on a nominal or ordinal scale for the independent variable. In the meanwhile, the post-test mean difference between groups including five features was determined using MANCOVA.

To get more information on the mean difference between the pretest and post-test, a MANOVA test was run. When analysing data from research where the dependent variable is primarily assessed on an interval or ratio scale, the MANOVA test is utilized. Over a predetermined period of time, many measurements are taken for each dependent variable. In contrast, at least two groups (categories) of independent data are measured on a nominal or ordinal scale for independent variables.

4. Data Analysis

4.1 Thinking Style Patterns of Standard 4 Design and Technology (RBT) Students

Table 1 shows the frequency and percentage of students for each thinking style pattern which is critical, balanced, and creative. It was found that in CG, there are 41 students with a critical thinking style, 4 students with a balanced thinking style and the remaining 7 students with a creative thinking style. Meanwhile, TG showed that 47 students have a critical thinking style, 3 students have a balanced thinking style, and 6 students have a creative thinking style.

Table 1 - Thinking style patterns of CG and TG

Group	Thinking Style						Total
	Critical TS		Balance TS		Creative TS		
	Freq	%	Freq	%	Freq	%	
CG	41	78.8	4	7.7	7	13.5	52
TG	47	84	3	5.3	6	10.7	56
	88	**83**	**7**	**6.7**	**13**	**12.3**	**106**

Overall, 83% of the 106 students have a critical thinking style. 7 students with 6.7% have a balanced thinking style pattern and 13 students with 12.3% have a creative thinking style pattern.

4.2 Mastery Level of IPSS Standard 4 RBT Students

Based on Table 2, the mean score of IPSS mastery level for CG is 1.49 and the standard deviation is 0.336. While for TG, the mean score of the IPSS mastery level for TG is 1.65 and the standard deviation is 0.278. The level of mastery of IPSS is divided into five levels, namely very weak, weak, satisfactory, good and excellent. Overall, the results of the IPSS pre-test show that the level of mastery of IPSS for standard four students is very weak with a value of 129 mean 1.57 with a standard deviation of 0.307. In this case, the student's level of mastery covers the entire aspect of identifying the problem situation, identifying the cause of the problem, stating strategies and approaches to problem solving, solvability and innovation.

Table 2 - Level of IPSS CG and TG

Group	Mean	Std Dev	Level
CG	1.49	0.336	Very weak
TG	1.65	0.278	Very weak

Table 3 shows the IPSS level for CG and TG for the pre-test and post-test according to five aspects. The pre-test analysis data shows that CG is at a very weak level for all five aspects. However, the post-test analysis showed that there was an increase in one level, from very weak to weak in the aspect of identifying problem situations only. The other four aspects are still at the same level which is very weak. For TG, the pretest analysis data shows a weak level only in the first aspect which is identifying the problem, while the other four are at a very weak level. The post-test data showed that TG showed an improvement of one level in the aspect of the problem situation from weak to satisfactory. In the meantime, the remaining four aspects also show a level of improvement from very weak to weak. In other words, there is an increase of one level for all aspects for TG. Overall, there was no level increase for CG, instead there was an increase from very weak to weak for TG. The explanation for the rising degree of the problematic scenario is that instruction and learning under the design title are still taking place in classrooms (DSKP, 2013). Such that even a partial statement of the problem circumstance may be made by the students. However, in the following areas, students fall short of demonstrating development since, as was previously said, their effort ceases at the "generate ideas" phase. In order to answer a question, students with a critical thinking style use facts, knowledge, and prior experience to think structurally and see something tangible that can be felt. Something like that is putting them at a standstill as, in the design process, idea creation is where students' creative sides shine rather than their critical sides (Wardi, 2016).

Table 3 - IPSS level by aspect for CG and TG

Group	IPSS level mean											
	Problem Situation		Problem Cause		Strategy and Approach		Solvability		Innovation		Total	
	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)
CG	1.76 (VW)	2.00 (W)	1.68 (VW)	1.47 (VW)	1.55 (VW)	1.80 (VW)	1.30 (VW)	1.46 (VW)	1.18 (VW)	1.36 (VW)	**1.49 (VW)**	**1.62 (VW)**
TG	2.02 (W)	2.84 (S)	1.48 (VW)	2.49 (W)	1.77 (VW)	2.07 (W)	1.55 (VW)	1.86 (W)	1.42 (VW)	2.00 (W)	**1.65 (VW)**	**2.25 (W)**

VW=Very Weak; W=Weak; S=Satisfactory; G=Good; E=Excellent

4.3 The Mean Difference in Post-Test Achievement Scores Between the Control Group and the Treatment Group

Table 4 shows the data analysis for the post-test for CG with a mean value of 1.62 and a standard deviation of 0.336. The IPSS level for CG is very weak. While TG has a mean value of 2.25 with a standard deviation of 0.398. The IPSS level for TG is Weak. This student's IPSS level post-examination covers five aspects, namely identifying the problem situation, identifying the cause of the problem, stating the problem-solving strategy and approach, solvability, and innovation.

Table 4 - Post-test IPSS levels for CG and TG

	Mean	**Std. Dev**	**Level**
CG	1.62	0.225	Very Weak
TG	2.25	0.398	Weak

Table 5 shows the ANCOVA test analysis of the difference in mean post-test scores be-tween CG and TG. The results of ANCOVA test data analysis show that there is a significant difference in mean post-test scores between CG and TG ($p<.000$).

Table 5 - ANCOVA test analysis of mean post-test score difference between CG and TG

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10.644[a]	2	5.322	50.249	.000
Intercept	12.139	1	12.139	114.61	.000
Average	0.097	1	.097	0.915	.341
Group	**9.432**	**1**	**9.432**	**89.049**	**.000**
Error	10.909	103	.106		
Total	422.36	106			
Corrected Total	21.554	105			

a. R Squared = .494 (Adjusted R Squared = .484)

Table 6 shows that the level of IPSS CG is weak for the aspect of identifying problems and very weak for the other four aspects, which are the aspects of identifying the cause of the problem, problem solving strategies and approaches, solvability, and innovation. TG, on the other hand, has a satisfactory level for the aspect of identifying the problem and weak for the other four aspects, namely the aspect of identifying the cause of the problem, strategy and approach to problem solving, solvability and innovation.

Table 6 - IPSS level for CG and TG according to aspects for post-test

IPSS Aspects	Mean Marks (level)	
	CG	TG
Problem Situation	2.00 (W)	2.84 (S)
Problem Cause	1.47 (VW)	2.49 (W)
Strategy and Approach	1.80 (VW)	2.07 (W)
Solvability	1.46 (VW)	1.86 (W)
Innovation	1.36 (VW)	2.00 (W)
Total	**1.62 (VW)**	**2.25 (W)**

4.4 The Mean Difference in Pre-Test and Post-Test Achievement Scores for the Control Group

Table 7 shows the mean and standard deviation of the pre-test and post-test for CG. The level of inventive problem-solving skills for CG shows no change in level, which remains at the very weak level.

Table 7 - Pre-test and post-test IPSS levels of CG

Test	Mean	Std. Dev	Level
Pre	1.49	0.33	Very Weak
Post	1.62	0.22	Very Weak

The level of IPSS CG covers five aspects, namely from the aspect of identifying the problem situation, identifying the cause of the problem, stating the strategy and approach to solving the problem, solvability, and originality/innovation. Table 8 shows the mean and level for pre-test and post-test for five aspects of IPSS. Overall, this data shows that CG has a very weak level in all five aspects at the beginning. However, the level of IPSS owned by CG after the post-test shows that only one aspect has improved, which is in the aspect of identifying problems. While the other aspects have not improved.

Table 8 - IPSS pre-test and post-test CG levels by aspect

Group	IPSS level mean											
	Problem Situation		Problem Cause		Strategy and Approach		Solvability		Innovation		Total	
	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)
CG	1.76 (VW)	2.00 (V)	1.68 (VW)	1.47 (VW)	1.55 (VW)	1.80 (VW)	1.30 (VW)	1.46 (VW)	1.18 (VW)	1.36 (VW)	**1.49 (VW)**	**1.62 (VW)**

Table 9 shows the MANOVA analysis of the mean difference between pre-test and post-test scores for CG. There is a significant mean difference for pre-test and post-test for CG ($F(1,51) = 4.881$; $p<.05$) with a significant value of .032.

Table 9 - MANOVA test analysis of the mean difference between pre-test and post-test IPSS CG scores

Source	Measure	prepost	Type III Sum of Squares	df	Mean Square	F	Sig.
prepost	**Control**	**Linear**	**0.401**	**1**	**0.401**	**4.881**	**.032**
	Treatment	Linear	9.312	1	9.312	92.505	0
Error(prepost)	Control	Linear	4.193	51	0.082		
	Treatment	Linear	5.134	51	0.101		

Table 10 shows the MANOVA analysis of the difference in mean post-test scores for each aspect. There is a significant difference in mean post-test scores for the five aspects in CG, however, it is still at the same level, which is the very weak level.

Table 10 - MANOVA test analysis of the mean difference in pre-test and post-test IPSS CG scores according to aspects

Source	Measure	prepos	Type III Sum of Squares	dmf	Mean Square	F	Sig.
prepos	Kps	Linear	1.502	1	1.502	13.484	**.001**
	Kpc	Linear	1.228	1	1.228	9.052	**.004**
	Ksaa	Linear	1.701	1	1.701	12.805	**.001**
	Ks	Linear	0.678	1	0.678	8.082	**.006**
	Ki	Linear	0.85	1	0.85	13.539	**.001**
Error(prepos)	Kps	Linear	5.683	51	0.111		
	Kpc	Linear	6.917	51	0.136		
	Ksaa	Linear	6.774	51	0.133		
	Ks	Linear	4.282	51	0.084		
	Ki	Linear	3.2	51	0.063		

Kps - CG problem solving aspect
Kpc - CG problem cause aspect
Ksaa - CG strategy and approach aspect
Ks - CG solvability aspect
Ki - CG innovation aspect

4.5 The Mean Difference in Pre-test and Post-Test Achievement Scores for the Treatment Group

Table 11 shows the mean and standard deviation of the pretest and post-test for TG. Overall, the IPSS level for this TG shows an improvement level from very weak to weak.

Table 11 - Pre-test and post-test IPSS levels of TG

Test	Mean	Std. Dev	Level
Pre	1.65	0.28	Very weak
Post	2.25	0.39	Weak

Table 12 shows the mean and level for the pre-test and post-test. Overall, this post-test data shows that TG has a Satisfactory level in terms of identifying problems. However, in all four other aspects, it received a weak level. This also shows that all aspects experience a level of improvement.

Table 12 - IPSS pre-test and post-test TG levels by aspect

Group	IPSS level mean											
	Problem Situation		Problem Cause		Strategy and Approach		Solvability		Innovation		Total	
	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)	Pre (Level)	Post (Level)
TG	2.02 (W)	2.84 (S)	1.48 (VW)	2.49 (W)	1.77 (VW)	2.07 (W)	1.55 (VW)	1.86 (W)	1.42 (VW)	2.00 (W)	**1.65 (VW)**	**2.25 (W)**

Table 13 shows the MANOVA analysis of the mean pretest and posttest score differences for TG. There is a significant mean difference for pre-test and post-test for TG ($F(1,51) = 92.505$; $p<.05$) with a significant value of .000.

Table 13 - MANOVA test analysis of the mean difference between pre-test and post-test IPSS TG scores

Source	Measure	prepos	Type III Sum of Squares	df	Mean Square	F	Sig.
prepos	Control	Linear	0.401	1	.401	4.881	.032
	Treatment	**Linear**	**9.312**	**1**	**9.312**	**92.505**	**.000**
Error(prepos)	Control	Linear	4.193	51	.082		
	Treatment	Linear	5.134	51	.101		

Table 14 shows the MANOVA analysis of the difference in mean post-test scores for each aspect. There is a significant difference in mean post-test scores for all five aspects in TG and shows an increase of one level for all aspects.

Table 14 - MANOVA test analysis of the mean difference of pre-test and post-test IPSS TG scores according to aspects

Source	Measure	prepos	Type III Sum of Squares	df	Mean Square	F	Sig.
prepos	Rps	Linear	17.614	1	17.614	115.968	**.000**
	Rpc	Linear	26.1	1	26.1	201.533	**.000**
	Rsaa	Linear	2.222	1	2.222	19.111	**.000**
	Rs	Linear	2.28	1	2.28	20.659	**.000**
	Ri	Linear	8.712	1	8.712	58.357	**.000**
Error(prepos)	Rps	Linear	7.746	51	.152		
	Rpc	Linear	6.605	51	.13		
	Rsaa	Linear	5.928	51	.116		
	Rs	Linear	5.63	51	.11		
	Ri	Linear	7.613	51	.149		

Rps - TG problem solving aspect.
Rpc - TG problem cause aspect
Rsaa - TG strategy and approach aspect
Rs - TG solvability aspect
Ri - TG innovation aspect

5. Discussion

The discussion in this chapter focuses on aspects of the problem situation, problem causes, problem solving strategies and approaches, solvability, and originality/innovation. Each research question is discussed in detail through the findings obtained. The development of the module is based on the Meyer Model with extensive applications in the technical field. The effectiveness of this module is proven in the improvement of students' post-test achievement. This module, even for

teacher teaching, is evaluated based on students' ability to solve problems. Modules designed with the Meyer Model make it easy for teachers to use the step-by-step guidance. Physical modules are more effective because they can be accessed without additional technological devices.

This module provides a detailed description of problem situations, causes, solution strategies, and solvability, preparing users with a mindset before learning problem solving. With three units and four phases, the module ensures that information is comprehensively covered. The provision of 14 Inventive Principles in the module content encourages a more creative idea generation process. With the ability to generate ideas, students are expected to improve their ability to solve problems.

5.1 The Effectiveness of the Thinking Style Module and Inventive Problem-Solving Skills of Fourth Year Students for Design and Technology Subjects

5.1.1 Thinking Style Patterns of Year 4 Design and Technology Students

The thinking style patterns of standard 4 Design and Technology students are mostly critical, in line with the critical features in the KPM Thinking Skills Model such as comparison, difference, priority, order, and analysis using existing facts. This pattern also reflects the student's ability to use problems or existing knowledge to develop the latest knowledge. Although the learning environment tends to be more teacher-directed, with a focus on information delivery and test preparation, exposure to detail and structure in instruction is necessary to develop critical abilities.

In addition, some students show creative and balanced characteristics. Creative students tend to think outside the norm, show an interest in rules with curiosity and a willingness to take risks. They are also associated with unique artistic skills and the ability to create new products. Balanced students, with critical and creative characteristics, able to answer and solve problem situations effectively and think strategically. The results of this study also illustrate weaknesses in higher order thinking skills, such as reasoning, which affect the performance of TIMMS and PISA in Malaysia. Reasoning skills, which depend on critical and creative characteristics, show the need for the development of a balanced thinking pattern in students to improve performance.

5.1.2 Mastery Level of IPSS 4th Year Students Design Technology

Overall, standard four students in the subject of Design and Technology (RBT) showed a very weak level of mastery of Higher-Level Thinking Skills (HOTS) in five aspects, namely identifying problem situations, identifying the cause of problems, expressing problem solving strategies and approaches, solvability, and originality/innovation. This finding is consistent with previous studies such as Murad & Abdullah (2016), Vadivalu & Osman (2015), and Jais, Yahaya, Ibrahim & Hassan (2014) which show the general low level of HOTS of primary school students. In the aspect of identifying the problem, students have difficulty identifying the problem accurately due to a lack of understanding of the difference between the problem and the cause of the problem.

In the aspect of identifying the cause of the problem, the same pattern occurs with the lack of students' ability to differentiate between these two aspects due to the lack of critical thinking style. In the aspect of expressing strategies and approaches to problem solving, problems arise when students face difficulties in generating their own ideas. Exposure to the structure of work steps in learning sometimes hinders their ability to produce creative ideas spontaneously. This indicates the need to develop creative thinking skills and generate better ideas in teaching RBT.

An increase in the mastery of HOTS can be achieved using the Thinking Style and Inventive Problem-Solving Module which is proven to improve student performance in the five aspects. This study shows that the structural approach and exposure in Phase 3 and Phase 4 of TRIZ in the module has been able to stimulate students' creative abilities in answering with more unique ideas that go beyond the usual limits. Although there are some practical obstacles, the improvement results show the important value of increasing idea generation in fostering critical and creative skills among students.

5.1.3 The Mean Difference in Post-Test Achievement Scores Between the Control Group and The Treatment Group

The analysis shows a significant difference in post-test scores between groups of students who have a critical (CG) and creative (TG) thinking style. The use of the Thinking Style and Inventive Problem-Solving Module by teachers can improve students' ability to identify some problems, recognize the root of the problem, provide solution strategies, and provide creative ideas, although some of them may be less accurate and original. Step-by-step education, as proposed by Makmur (2015) and Ahmad & Jinggan (2015), proved to have a positive influence in improving students' thinking and problem-solving skills. Despite this, there are obstacles in the steps of idea generation in experimental projects in the standard four RBT textbook, which are overcome by Module that offers a choice of ideas and approaches, in accordance with the views of Abidin, Razali & Abdul Rani (2016) and Chechurin (2016).

The use of Module that contains four phases has helped students combine critical and creative thinking skills in problem solving. The generation of ideas becomes more helpful, and the use of the answer options provided in module

provides guidance in creative thinking. Although in some respects, such as solvability and originality, there are still challenges, the use of Module proves its value in helping students stimulate ideas and creative thinking in the context of RBT learning. While several approaches of teachers in creative teaching have been exemplified in previous studies, Module has proven its effectiveness as a systematic and structural tool in developing innovative problem-solving skills in students.

5.1.4 The Mean Difference in Pretest and Post-Test Achievement Scores for The Control Group (CG)

Comparative analysis between pre-test and post-test scores in the group of students with critical thinking styles (CG) showed a one-step increase only in the aspect of recognizing problem situations. This increase can be explained by the existence of a teaching and learning approach that still involves steps taught in Design subjects (DSKP, 2013), which allows students to recognize problem situations with some success. However, for the other four aspects, namely identifying the causes of problems, strategies, and approaches to solving problems, permissibility, and originality/innovation, CG students are still at a very weak stage. This failure is largely related to their inability to generate ideas, where their critical thinking focuses more on scientific steps and approaches in the learning process (Romeli, 2012).

The following aspects in the assessment, namely problem-solving strategies and approaches, permissibility, and originality/innovation, also showed similar weaknesses. The inability of students to recognize the root causes of problems in depth is related to the process of generating ideas that are still weak. Although a scientific approach to teaching can build critical abilities, it is not sufficient to help students sustain ideas effectively. Therefore, tools are needed that can guide students in producing more effective ideas. These findings indicate that a teaching approach that only focuses on critical abilities is not enough to develop the creative abilities of CG students, which tend to be hampered by steps and structured thinking. Thus, a more structured and targeted approach is needed to help students develop their creative thinking skills and generate more innovative solutions.

5.1.5 The Mean Difference in Pretest and Post-Test Achievement Scores for The Treatment Group (TG)

After analysing the comparison between pre-test and post-test scores in the group of students with a reflective thinking style (TG), it was found that there was a one-step increase for the five aspects tested. In the first aspect, namely recognizing the problem situation, TG students can present a better description of the problem they are facing. This can be explained using the module which consists of four phases, which guides students in analysing the components and functions of the problem. In the first phase, students are taught to identify the components of a problem, so that they can more effectively identify the root of the problem. Critical characteristics of students such as the ability to logically analyse facts and evidence, and have a structured approach in understanding facts, become a support in Phase 1 and Phase 2.

The second phase of the module provides students with an understanding of the obstacles that may arise in problem solving. This allows students to better understand the obstacles or contradictions that can hinder the achievement of goals, so that they can choose the best solution in Phase 3. In Phase 2, students are no longer bound by rules or structures that bind the steps of completion, which ultimately enriches their creative abilities. In the last phase, students are given 14 choices of problem solutions that they can choose from and develop. The characteristics of student creativity are honed through the choices of solutions provided, and up to Phase 4, students can identify problem solutions, present triggers for ideas, and describe the feasibility and creativity of solutions. This can be seen in the four initial aspects of the assessment.

However, in the last aspect, namely originality and innovation, it takes relationship characteristics, predictions, and hypotheses. These characteristics support the Thinking Proficiency Model (Rahman et al., 2002) which confirms that a combination of critical and creative abilities will guide students to consider well and ultimately be able to solve problems well too, including considering the factors of cost, time, and effort.

6. Conclusion

The findings of the study show the result of an innovative teaching tool that combines critical and creative thinking styles with TRIZ Theory, namely the Thinking Style and Inventive Problem-Solving Module that can be used by RBT teachers effectively. As a conclusion from the implementation of this study, it proves that the module that has been developed in a structured and planned manner based on the Theory of Inventive Problem Solving (TRIZ) and the KPM's Critical and Creative Thinking Skills Model is able to improve students' problem-solving skills. The results of this study also have a positive effect on students' thinking styles because by following the modules developed, students tend to have a balanced thinking style. The module that was developed in a planned and systematic way by combining thinking styles in its content and with teaching that is suitable for age and cognitive level has had a positive effect on student learning to solve problems and this shows that Module developed by researchers has an impact and is useful for improving skills student problem solving. The implication of this research, it can provide references contribution to the knowledge and education regarding Thinking Styles and Inventive Problem-Solving on the Problem-Solving Skills. It is hoped that can be a

consideration for other researchers in conducting further research in a plot. Suggestions for additional research should employ basic random sampling. This is due to the fact that the cluster random sampling research is unfeasible. The population's background and setting ought to be more diverse. Additionally, it is advised to diversify the instructional modules.

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