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EFFECTS OF USING POGIL CYCLE METHODS ON ACHIEVEMENTS OF HIGH LEVEL THINKING SKILLS IN SOLVING MATHEMATICAL PROBLEMS

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Abstract- This study aims to determine the achievement of high-level thinking skills (HOTS) using the Process-Based Inquiry Learning Cycle (POGIL) cycle method in solving mathematical problems. The objectives of this study determine the level of mastery of HOTS and determine the type of difficulty at high level in mathematical problems. This study uses a quantitative approach, namely the quasi-experimental design study cycle method involving 60 form 2 respondents who were randomly selected from one of the schools in Malaysia. The analysis of this study uses paired sample t-test inference statistics and one-way ANOVA. The findings show that there is a significant difference in the achievement of HOTS between groups using the POGIL cycle method and the control group. Furthermore, the findings show that using the POGIL cycle method can help improve HOTS achievement in solving mathematical problems among students.

Keywords – Process Oriented Guided Inquiry Learning (POGIL), High Level Thinking Skills (HOTS), Learning cycle, Secondary school, Mathematics

I. INTRODUCTION

Malaysia Education Development Plan (PPPM) 2013-2025 is a long-term strategic plan that targets the quality of education in the country so that it can be improved within 13 years of the implementation of education transformation as a whole. There are five (5) system aspirations and six (6) student aspirations have been identified as catalysts to drive National educational excellence in the future. Among the results of the implementation of educational transformation is that the Ministry of Education Malaysia (MOE) intends to place the country in the top third in international assessments such as Trends in Mathematics and Science Studies (TIMSS) and the International Student Assessment Program (PISA) within 15 years. Teachers in particular need to equip themselves with the knowledge and skills as well as new teaching and facilitator practices relevant to the development and needs of the 21st century. Nevertheless, Krishnan, BA (2014) [9] in his study stated that most teachers are willing and aware of the importance of HOTS in creating a society with high level of thinking.

The main goal of the government today, is to produce individuals who think critically and creatively. In encouraging students to think critically and creatively requires a method of active learning techniques that is student-centered. Among the commonly used methods of solving problems on a regular basis, this is not the best method in stimulating students' thinking such as giving a description of problem-solving steps on the whiteboard. Such methods cause students to be less skilled in thinking in organizing strategies to solve a given problem. Thus, teachers should be smart in imparting knowledge as well as providing a creative learning climate to achieve better achievement [15]. Among the suggested techniques that are suitable to stimulate students' minds to think at a higher level is through questioning techniques.

Student-focused learning such as inquiry, structured problem solving, projects, constructivism, contextual and future studies are core in learning [14]. Thus, one of the learning that leads students to build their own knowledge by

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actively involving students is Process-Guided Inquiry Learning (POGIL) [16]. POGIL is an instructional approach that combines guided inquiry and cooperative learning where students are involved in the learning process thus helping students to develop or enhance HOTS. Features there are similarities in the constructivist approach leading to the HOTS required in POGIL because this pedagogy focuses on the construction of knowledge so that HOTS occurs in mathematics subjects. POGIL encourages active learning in the classroom as well as enhances understanding of new concepts [1].

This study aims to identify the differences in HOTS achievement between the experimental group for POGIL method and the control group for non-POGIL method. In addition, HOTS achievement is divided according to the cognitive level of knowledge level, application level and reasoning level.

II. Objective

The objective of this study is to identify the effect of the use of POGIL cycle method on the achievement of high-level thinking skills of Form 2 students in solving Mathematical problems.

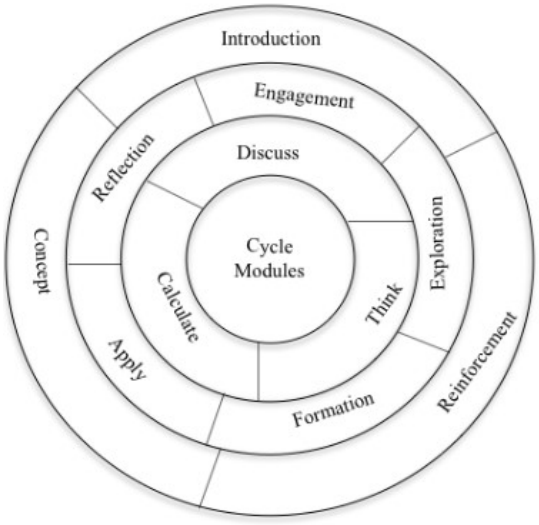
III. Statement of problem

i.Is there a significant difference in achievement score between the non-POGIL cycle method and the POGIL cycle method?

ii.Is there a significant difference in the mean of the goal achievement score based on the knowledge level, application level and reasoning level of the POGIL method?Concluding remarks are given in section IV.

IV. Literature Review

This POGIL cycle method is based on the design of POGIL learning strategy which consists of three phases namely introduction phase, concept phase and reinforcement phase. For each phase, there are five POGIL cycle method stations, namely engagement station, exploration station, formation station, apply station and reflection station. POGIL is based on learning methods that involve teacher-guided inquiry activities to encourage the restructuring of complex information to enhance students' knowledge [4]. Based on Figure 1, the POGIL cycle method is similar to Bloom's Taxonomy because there is a combination of content learning with process skills [11]. This method model is divided into three phases namely introduction phase, concept phase and reinforcement phase.



5)

V. Methodology

The study design used is a quasi-experimental design, that is, a non-equivalent pretest-posttest controlled group design (see Table 1). Through the selection of this design, researchers want to determine the extent of pre and post achievement differences in Mathematical solutions.

TABLE -1 RESEARCH DESIGN

Groups	Pre-test	Methods	Post-test
Treatment	O_1	X_1	O_2
Control	O_3	X_2	O_4

Pre-tests are given to all students. The content of the questionnaire set before and after the study was almost the same as it measured the same variables at different times. These pre-test and post-test instruments have been modified from the Trends in Mathematics and Science Study (TIMMS) 1999-2015 questions. The activities and instruments in this study have been confirmed by expert teachers in the field of form 2 mathematics. To determine the validity of the test content, a Cohen Kappa test is implemented and the value of pre-test and post-test instruments is 0.95. Thus, this achievement test is suitable as a research instrument because a value above 0.75 is considered excellent [3] quoted in [10]. Statistical inference analysis of paired sample t-test and one-way anova test to be used to test the study hypotheses.

VI. FINDINGS

Table 2, study findings show that the mean scores of pre-mathematical tests for the control group (non-POGIL) and treatment (POGIL) were insignificant, $p > 0.05$ with $t(29) = 3.648$. This indicates that these two groups are equivalent in terms of mathematical achievement..

TABLE -2 INDEPENDENT SAMPLE T-TEST FOR COMPARISON OF POST-TEST MEAN SCORES BETWEEN POGIL AND NON-POGIL METHODS

Post-test	N	Mean	Standard deviation	df	t	Sig.
Non-POGIL	30	11.10	3.670	58	3.648	0.534
POGIL	30	14.37	3.253	57.176		

*Significant at the significance level .05

Hypothesis Testing 1
H_{01}: There is no significant difference in the achievement of pre-test and post-test for POGIL method
H_{A1}: There is a significant difference in the achievement of pre-test and post-test POGIL method

Comparison of post test in Table 3, using paired t test that is $(29) = 3.715$, $p < 0.001$ shows that there is a significant difference in student achievement for groups non-POGIL and using POGIL. The mean group using POGIL is higher than the mean group non-POGIL post_POGIL=14.37 with SD=3.25 compare to post_Non-POGIL=11.10 with SD=3.67. This shows that the learning cycle method using POGIL can improve achievement scores in students' Mathematical solutions.

TABLE -3 PAIRED SAMPLE T-TEST FOR COMPARISON OF MEAN SCORE OF POST-TEST BETWEEN POGIL AND NON-POGIL METHODS

Post-test	N	Mean	Standard deviation	df	t	Sig.
Non-POGIL/ POGIL	30	3.167	4.669	29	3.715	0.001

*Significant at the significance level .05

Referring to Table 4, overall there is an increase in scores in the group using the POGIL cycle method compared to non-POGIL method. Among the most notable is the increase in scores for application and reasoning questions. This shows that guided inquiry methods can help improve students' understanding to solve HOTS (high-level thinking) questions.

TABLE -4 COMPARISON OF CORRECT ANSWERS OF PRE-TEST AND POST-TEST BETWEEN METHODS NON-POGIL AND POGIL

Questions	Non-POGIL			POGIL		
	Pre	Post	Difference	Pre	Post	Difference
	(%)	(%)	(%)	(%)	(%)	(%)
1	35	67.5	32.5	33.3	55.8	22.5
2	26.7	41.3	14.6	33.3	42.7	9.4
3	13.3	16.7	3.4	16.7	27.6	10.9
4	32.9	65.7	32.8	28.6	76.2	47.6

Hypothesis Test 2

H_{01}: There were no significant differences in the HOTS achievement scores based on the knowledge level, application level and reasoning level for the POGIL method

H_{A1}: There were significant differences in the HOTS achievement scores based on the knowledge level, application level and reasoning level for the POGIL method

Based on Table 5, it is found that there is a significant difference in the mean score of post-achievement HOTS test for POGIL cycle method. The results of F with one-way ANOVA test found that the p value was significant [F (2,27) = 63,485, p = 0.000, p <0.05] for the variables of knowledge level, application level and reasoning level. Null hypothesis rejected. The results of this analysis explain that there is a significant difference between the level of knowledge, the level of application and the level of reasoning on the achievement of HOTS. This indicates that there are score differences for each cognitive level.

TABLE -5 ONE-WAY ANOVA TEST FOR COMPARISON OF MEAN SCORES OF POST-ACHIEVEMENT HOTS TEST ACCORDING TO KNOWLEDGE LEVEL, APPLICATION LEVEL AND REASONING LEVEL FOR POGIL METHOD

Causes of variation	Sum of squares	df	Mean square	F	Sig. p
Cognitive level of achievement					
Between Groups	268.723	2	134.361	63.485	0.000
Within Groups	57.144	27	2.116		
Total	325.867	29			

*Significant at the significance level .05

IV. Discussion and Summary

In fact, HOTS takes a long time to measure but it is proven that the POGIL cycle method which is guided inquiry can help improve student mastery, especially high level questions. This method uses student-centered techniques, actively learning to achieve learning goals. In this method, students, will manage the group and always ask actively in exploring to help their peers to understand the given problem, will indirectly correct their misunderstanding in developing their understanding. Through activities in the POGIL cycle method, students can stimulate memory and thinking skills through diagrams made. In addition, students have shown interest and fun because of the POGIL cycle method activity. In this regard, we need not only thinking skills but also attitudes as a thinker [13]. Therefore,

the implementation of HOTS in our education system needs to take into account the structuring of students' thinking in the learning process.

Activities implemented in the POGIL cycle method have had a positive effect on the achievement of HOTS students in the treatment group. Carefully organized learning activities are a way to overcome student difficulties in mastering HOTS. In addition, the POGIL cycle method has encouraged the restructuring of information and knowledge as well as helping students develop understanding [8]. So this is one of the learning processes to overcome the difficulties of students in HOTS. Through this POGIL cycle method, HOTS students can also be generated through teaching and facilitating math problems. Therefore, the application of HOTS will produce students who can accept change, be able to communicate, work in a team and be able to reflect based on reasoning as well as able to innovate and create something new [5] and ensure our country is not left behind and able compete with other developed countries especially in the field of mathematics [12] .

Some suggestions to integrate this POGIL cycle method on other critical subjects such as additional mathematics, physics and and science, technology, engineering, and mathematics (STEM). In addition, this advanced study needs to be done other than high school students. POGIL cycle method is well introduced to the level of early school education such as preschool in order to cultivate active learning through the exploration of knowledge as enshrined in the National Preschool Standard Curriculum (2016) [17] has clearly explained that thinking skills as one of the 21st century skills that children need to master today. Four categories of level of thinking at the preschool level have been outlined namely evaluating, analyzing and creating. These skills are intended for students to be better prepared in solving daily problems and to be able to compete globally as described in the National Preschool Standard Curriculum.

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