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Online learning environment to enhance HOTS in mathematics using Polya's problem solving model

Sudirman Mustapha[1], Mohd Shafie Rosli[1, *] and Nor Shela Saleh[2]

[1]School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia, Johor Bahru, Malaysia
[2]Centre for General Studies and Co-curricular, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

E-mail: shafierosli@utm.my

Abstract. Low Higher Order Thinking Skills (HOTS) among students is a persistent and pervasive challenge in modern classroom. The problem remains for years despite the intensive manoeuvres to solve it. Yet, the need to enhance HOTS is imperative in ensuring quality education. The purpose of this research is to enhance HOTS among students in Mathematics using an online learning environment. The online learning environment was developed based on Polya's problem solving model. However, the system is not discussed in this paper. There are three research objectives which are to investigate the current HOTS achievement among students, to study the effect of the developed online learning environment in nurturing HOTS among samples and finally to study how learning process taken place to achieve HOTS among sample while engaging the system. This research implemented experimental research design with a set of pre and posttest and the developed online learning environment as intervention. A total of 76 samples were sampled for the preliminary study and another 32 samples for the four weeks treatment using cluster random sampling technique. Samples are from three schools from a district in Malaysia. Finding shows that the current HOTS achievement among students are still low at mean = 32.05, σ = 15.87. During the intervention, samples show improvement in their HOTS from mean = 39.52, σ = 11.65 in the pretest to higher level in the posttest at mean = 77.84, σ = 12.84. The Paired-Samples T Test conducted to identify the differences between the pre and posttest shows a statistically significant difference at t (31) = -11.58, p < 0.05. Indicating that an online learning environment using Polya's problem solving for four weeks enhance HOTS among samples. The process of how samples achieve HOTS is also reported. This research shows the importance of integrating technology and inquiry in modern classroom to increase students' thinking skill ability. Finding suggests that HOTS can be nurtured via technology enhanced learning environment.

1. Introduction

Thinking process and thinking level is highly related to individual ability to solve mathematical problems [1]. The importance of mathematics and skills related to its domain are well documented. [2] concludes that mathematics is vital is making decision related to health and social judgement. Early exposure to mathematics gives significant impact to the later achievement for students [3]. Learning mathematics have evolved to include rigorous problem solving focusing on daily life and engineering

decision making as well. The prevailing education process is moving toward preparing students with vital cognitive ability such as HOTS. Thus, HOTS is nowadays must have skill for future work force.

1.1. Current Higher Order Thinking Skills (HOTS) in mathematics

The achievement in HOTS among students are currently still inadequate. Empirical report from research shows that improvement in HOTS among students are still needed. [4] reported that HOTS in mathematics among students is still low in Malaysia. Almost the same finding was reported in science with sample also from Malaysia. Students with well-equipped HOTS is an imperative objective in education [5]. However, the problem seems solvable as [6] reported that technology enriched environment improve HOTS. Later, [7] go further into exploration of technology reported that thinking level is improved after using technology enhanced learning environment. Computer oriented mathematics learning owns persuasive element, that seem appeal to students [8]. Ministry of Education Malaysia had put HOTS as one of the foremost focus of its education system [9]. Therefore, before starting this research, the fundamental issue of HOTS needs to be clarified. What is the current HOTS achievement among the samples? Is one of the research questions in this paper. It acts as the preliminary study to validate either HOTS related issue is still persistent.

1.2. The need for new tool and approach to learn mathematics

The current traditional approach is not suitable for teaching and learning mathematics. As current education is emphasizing on thinking skills [10], a newer tool to learn mathematics is required. The active integration of ICT into education had paved way for interactive multimedia to be implemented in daily classroom. According to [11], ICT and its literacy is highly needed in improving teaching and learning.

One of the best ways to increase thinking skills in learning science and mathematics is by integrating Learning Management System (LMS) into the classroom. LMS can be customized to create an online learning environment, a variation of technology enhanced learning environment. LMS in form of online learning environment is worth considered as state-of-art technology in modern education [12]. The implementation of LMS proved bring constructive impact to its users [13]. Implementation of customized LMS known as online learning environment is currently the frontier focus of research. However, its impact toward mathematics learning and HOTS in mathematics is relatively still at its early stage.

Traditional approach not able to give sufficient support to nurture HOTS development. The approach implemented in classroom is imperative in defining a constructive learning toward cognitive development. Passive approach is contradicting the nature of how HOTS being nurtured. To develop HOTS, active and interactive learning is needed. Exposure toward problem solving and information seeking are among the main activities that promote HOTS. Inquiry-based learning was found effective in enhancing thinking skills [14,15]. Several inquiry approaches are available such as guided-inquiry, structured inquiry, open inquiry and Polya's problem solving model. Previous research such as [16], concluded that Polya's problem solving model might have the biggest potential to give improvement to students in Mathematics. Thus, this research applied Polya's problem solving model in maneuver to improve HOTS among the samples.

1.3. The need for learning process to enhance HOTS

The previous research on HOTS has been well documented. However, despite of the positive report on HOTS treatment, little has been known on the learning process that enhance HOTS among students. It renders a research gap, what is the learning process that enhance HOTS among students? The goal of this research is to fill in the research gap stated earlier.

The learning process of how HOTS enhancement take place that eventually increase student's HOTS to a higher level is impactful toward education. By understanding it, educators able to implement effective approach to enhance HOTS in mathematics at gigantic scale. Through deeper

fundamental study on the process, a model on HOTS cultivation can be constructed. It would spearhead a new contribution to research in cognitive science.

Based on the problems stated before, this research is highly needed to study the effect of online learning environment toward HOTS in mathematics using Polya's problem solving model and to investigate the learning process that enhance HOTS in mathematics.

2. Research objectives and research questions

The research objectives for this research are as follows:

i. To investigate the current HOTS achievement among school students.
ii. To study the effect of online learning environment using Polya's problem solving model toward HOTS among samples.
iii. To study samples' learning process during the HOTS enhancement.

The research questions are:

i. What is the current HOTS level among school students?
ii. What is the effect of online learning environment using Polya's problem solving model toward HOTS among samples?
iii. How is the samples' learning process during the HOTS enhancement?

3. Research methodology

3.1. Research design

Experimental research design is implemented to answers the research questions. To study the effect of using the online learning environment, pretest and posttest were conducted. The data then was compared to probe into the effectiveness of the developed online learning environment in improving HOTS.

After samples were sampled, they are instructed to answer the pretest before going through the treatment process by engaging the online learning environment as the main learning tool for four weeks. Post to the treatment, samples answered the posttest questions. The whole process of data collection is two months. The flow of data collection process is as in figure 1.
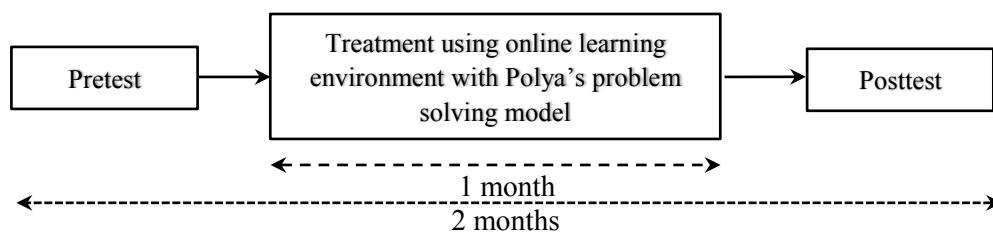

Figure 1. The flow of data collection process.

3.2. Sample

Population for this research is lower secondary school students from a district in Malaysia. The sampling for the district was made using convenience sampling. The selection of school was made using random sampling technique. From the sampled school, students who are from Form 3 which is normally aged 15 years old are involved in this research. From Form 3 students, 72 samples were sampled as sample for preliminary study and 32 students as sample for the treatment. The sample size for treatment is relatively small, however small size of samples does not jeopardize the result of an experimental study.

To prove the selected sample size for treatment is adequate, the sample size was predicted using G*Power version 3 software. The effect size was set at 0.6 as a standard in social science research. The α value was set at .05 and β value was set at 0.95. From the analysis run using the G*Power, it shows that the minimum sample size needed for this research is 32 samples. The result of the G*Power software is in table 1.

Table 1. Result of minimum sample size by G*Power.

Effect size, d	Alpha, α	Beta, β	Minimum sample size
0.60	0.05	0.95	32

In the data collection, 32 samples were involved in the treatment. However, in total 108 samples were involved as additional 76 samples were included as preliminary to measure the current level of HOTS among the students. The distribution of the samples is as in table 2.

Table 2. Distribution of samples.

Function	No. of samples	School
Intervention	32	A
Preliminary	20	B
Preliminary	20	C
Preliminary	36	D
Total	108	

4. Instrument

The instrument used is HOTS in Mathematics Test (Lower Secondary). The instrument consists of 15 HOTS questions and was developed by the researchers based on Malaysian mathematical syllabus. The instrument is used both during the preliminary study as well as during the pretest and posttest.

Reliability was measured using internal consistency technique using 10 samples. From the analysis, the Mathematics Test (Lower Secondary) is reliable with Cronbach's alpha equal to .83. Instrument was validated by three expert teachers with more than 10 years' experience teaching mathematics at secondary schools in Malaysia. From the validation process, all the experts are agreed that Mathematics Test (Lower Secondary) as valid and suitable for implementation to the samples.

Moodle log, a learning analytic tool in Moodle is used as the second instrument. The log data is used to study the learning process of samples that lead to enhancement in HOTS. The data is mined at the end of the treatment. Data was later interpreted using sequential analysis technique.

5. Data analysis technique

Quantitative data was tested using SPSS version 21.0. Meanwhile, the qualitative data on the learning process during the HOTS enhancement was analysed using sequential technique. The summary on data analysis technique is as in table 3.

Table 3. Summary on data analysis technique.

Research question	Statistics	Analysis technique
What is the current HOTS level among school students?	Descriptive	Mean and standard deviation
What is the effect of online learning environment using Polya's problem solving model toward HOTS among samples?	Inferential	Paired samples t-test
How is the samples' learning process during the HOTS enhancement?	Qualitative	Sequential

6. Research finding

6.1. Current HOTS level

Finding from 76 samples involve in this preliminary study shows that the current HOTS level among the population is low. The preliminary study had involved 3 different secondary schools using Mathematics Test (Lower Secondary) as instrument. The finding is as in table 4.

Table 4. Preliminary study result.

Mean	Standard deviation	Minimum (%)	Maximum (%)
32.05	15.87	10	65

The mean was recorded only at 32.05 with standard deviation of 15.87. The highest score scored by the sample is 65. The minimum is 10. This indicates that the population still weak at HOTS. Thus, treatment for the purpose of enhancing HOTS is imperative.

6.2. Effect of online learning environment with Polya's problem solving model toward HOTS

The measure the impact of the developed online learning environment integrated with Polya's problem solving model, the data from the pretest and posttest were analysed. It involves 32 samples that participated as samples during the intervention. The data on samples pretest and posttest are as in figure 2.
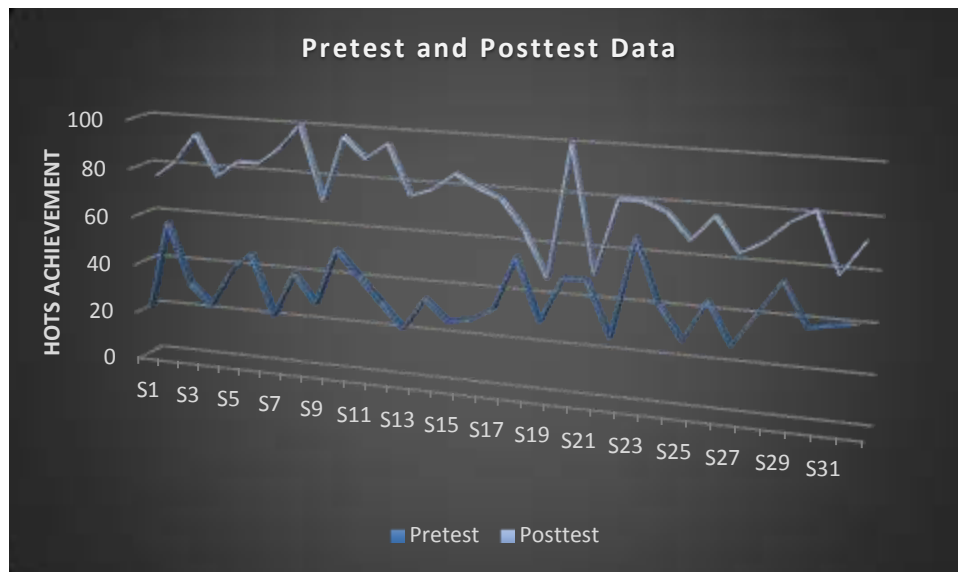

Figure 2. The samples' pretest and posttest data.

The summary and comparison between the pretest and posttest of the intervention data are as in table 5.

Table 5. The summary of pretest and posttest data.

Test	Mean	Standard Deviation	Maximum	Minimum
Pretest	39.52	11.65	68.3	21.7
Posttest	77.84	12.84	100	47

Table 5 shows that a visible score improvement in samples' HOTS between prior to the intervention and after the intervention has been completed. It might prove HOTS is enhanced after using the developed online learning environment. However, empirical statistical data is needed. To further probe into the degree of improvement, the significant difference between the two set of data need to be measured. Normality test using Shapiro-Wilk was conducted using the following hypotheses:

H_0: data are normally distributed
H_1: data are not normally distributed
degree of confidence set at .95 with α at .05

The p-value for the pretest data set is .27 and for posttest is .34, lead to the acceptance of H_0 for both data sets. The data are normally distributed, output from the Q-Q plot and histogram further support this finding. Thus, the data set are suitable to be tested using t-test. The result of t-test is as in table 6.

Table 6. The result of t-test.

Pretest – Posttest	Mean	Standard Deviation	*T*	*df*	significant
	-38.31	18.71	-11.58	31	0.00

The result shows the significant different between the HOTS score among sample before using the developed online learning environment and after using the developed system. Statistically proven that by engaging online learning environment designed based on Polya's problem solving model enhance HOTS development in mathematics.

6.3. Learning process during HOTS enhancement
To analyse the learning process, 3 samples were sampled consist of sample with the highest improvement in HOTS, followed with the one with moderate improvement and finally sample with the lowest improvement was selected. First, the time taken by each sample to complete the engagement with the developed online learning environment was analysed as in table 7.

Table 7. Total time taken by sample according to HOTS improvement.

Sample	Highest Improvement	Moderate Improvement	Lowest Improvement
Total time taken (min)	185	165	130

Sequential analysis technique was implemented to observe and construct the learning process into comprehensible flow pattern. The learning processes are as in table 8, 9 and 10.

Table 8. The learning process of sample with the highest HOTS improvement.

Session	Learning Process
I	watching video → engaging module → watching video → revise note
II	engaging module → reading note → watching video → evaluation
III	engaging module → watching video → reading note
IV	engaging module → reading note → watching video → evaluation
V	peer discussion → engaging module → watching video → reading note
VI	engaging module → reading note → watching video → evaluation
VII	peer discussion → engaging module → watching video → reading note
VIII	peer discussion → reading note → watching video → evaluation

Table 9. The learning process of sample with the moderate HOTS improvement.

Session	Learning Process
I	watching video → engaging module → watching video
II	engaging module → watching video → evaluation
III	engaging module → watching video → reading note
IV	engaging module → watching video → evaluation
V	engaging module → watching video → reading note
VI	engaging module → watching video → evaluation
VII	engaging module → watching video → reading note
VIII	engaging module → watching video → evaluation

Table 10. The learning process of sample with the lowest HOTS improvement.

Session	Learning Process
I	watching video → engaging module → watching video → reading note
II	reading note → engaging module → watching video → evaluation
III	engaging module → reading note
IV	engaging module → evaluation
V	engaging module → reading note
VI	engaging module → evaluation
VII	engaging module → watching video → reading note
VIII	engaging module → watching video → evaluation

There are differences between each sample. Sample with the highest HOTS improvement shows the most complex learning process. Where, the learning process involved chain of engagement with the system. One element is highly visible, sample with the highest HOTS improvement is actively referring to the note given in the system. This might be due to the effort to seek and construct better knowledge to plan the strategy to solve the problem given in the online learning environment as stated in Polya's model of problem solving. The lower the HOTS engagement, the simpler the learning process and at the same time shorter the engagement period. Sample with the lowest HOTS improvement show very few accesses to the reference video provided by the online learning environment. The video itself provide insight into how to plan to solve the stated problem in the system. It can be concluded that the lack of access to note and video are the main contribution to low improvement in HOTS among the samples. On the other hand, the note and the video are imperative to HOTS enhancement among samples. Thus, understanding the problem and planning the strategy are the vital part in Polya's model of problem solving in enhancing human HOTS.

7. Discussion

The main problem face by modern mathematics classroom is it require HOTS as its fundamental skill. Yet, HOTS is not readily available among the students. From the preliminary study, it was reported that the current level of HOTS among students are low. It was supported by [17] that HOTS in school is still low. The persistent finding was reported by [18] who found that HOTS is low among student for the subject of chemistry in Malaysia. Factor that might contribute to this problem might be the unsuitable teaching approach and lack of technology integration into the classroom [19].

This contradiction create conflict that render difficulties among students. To solve this problem, it seems that using online learning environment with suitable inquiry pedagogical overlay might have the potential to solve it. Polya's problem solving model was integrated into online learning environment and was engaged by samples for a month. The result shows positive impact toward samples' HOTS with significant difference between after the intervention and before the intervention. This finding shows similarity to research reported by [4]. Better students show more complex and longer learning process to nurture their thinking skills to nurture HOTS. This is inconsistent with finding by [11].

8. Summary

The persistent problem of low HOTS among students are a significant hindrance toward effective learning in modern day. Even though this issue has been addressed by the previous researches, it is focusing toward the factors that lead to low HOTS achievement among students. It creates a research gap on what can be done to nurture the HOTS from currently lower level to a better level. This research had successfully explored how human HOTS level can be nurtured using suitable pedagogy and online learning environment. Polya's problem solving model using Moodle had able to nurture the thinking skills thus showing that it is possible improve thinking skills. The learning process of the HOTS nurturation was reported which make possible by learning analytic technologies embedded in Moodle.

Acknowledgment

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