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Exploring Technological Problem Solving Among Local Elementary School Children in a Robotic Program

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Abstract:- This program was conducted to analyze the effect of a robotic program in assessing technological problem solving among local primary school children. The content in the robotic and programming modules (RPGsr modules) which contain technological problem solving activities has been going through expert validation before it were applied in this study. The instrument used to measure the technological problem solving was Technological Problem Solving Inventory (PSI-TECH/TPS) which under-go back-to-back translation (English-Malay language) and scale validation. Sequential explanatory mixed-method design was implemented in this study, involved quasi-experimental within control group and experimental group which were homogeneous in selected characteristics. For the qualitative analysis, focus interviewed was done within the participants after the program. Analysis of student' reflection in modules was conducted via the robotics activities.The robotic and basic visual coding program was conducted for 5 months, with an hour of lesson each week, which was consistent with the school syllabus. For the quantitative analysis, result obtained by collecting the data before and after the program, analyze through t-test and ANCOVA. Result had shown a significance positive value within the treatment group after the program. This study contributes in the field of research design in education, in investigating the technological problem-solving skills among students. In addition, help to diversify the studies in the field of robotics.

Keywords:- *Robotic in education, technological problem solving, coding for children,sequential explanatory mixed method,scale validation.*

I. INTRODUCTION

Technological Problem Solving Inventory (PSI-TECH) is an instrument to measure technological problem solving, adapted from PSI-PSYCH-*Problem Solving Inventory* (Wu, *et al.*, (1996) and MacPherson (1998) which was invented by Heppner (1988), to access problem solving confidence, personal control and problem avoidence. In diversifying pedagogical methods in critical and creative thinking skills, robotic and graphical programming such as *Scratch*,*S4A(Scratch for Arduino)* and *mBlock* as learning aids have been proven to convey a fun way of learning to integrate academic content with the creation of meaningful content. Learning approaches based on thought and problem solving categorized into high-level thinking are stimulated by applying thinking routines such as the development of comparative and reflection tables (Ron Ritchhart & David Perkins, 2008).

The study of scholars described robotics has been applied in formal education in curriculum and co-curricular activities (Alimisis,2013; Anat Zohar, 2013; Martin Kandlhofer & Gerald Steinbauer, 2016; Afari & Khine, 2017).Theoratically, using robotics for learning embedded around constructionist learning. Constructionism is connected with experiential learning; builds on Jean Piaget's epistemological theory of constructivism (Papert,1993). Furthermore, computational thinking (CT) was related to higher order thinking Bloom's taxnomomy in application; analyze, synthesis dan evaluation (Voskoglou & Buckley,2012), encouraged problem solving in more creative way (Dede, *et al.*, 2013). Hence, CT was closely related to technological problem solving (Atmatzidou & Demetriadis, 2014) which involved basic programming/coding terms such as *(sequences), (loops), (parallelism), (events), (conditionals), and (operators)*, assisted by gadgets and applied graphical programming which are free to assess (Brennan & Resnick ,2012; Baek & An, 2011;Mioduser,2009; Voskoglou & Buckley,2012; Varnado, 2005; Harvey & Monig, 2010;Eguchi,2014; Afari & Khine ,2017); Varnado, 2005; Bers, *et al* , 2002; Bers *et al.*, 2014; Sullivan, Kazakoff, & Bers,2013). In this study, the research questions involved are stated as RQ1 to RQ4:

- (RQ1) Is there a difference in performance level of participants' technological problem solving style between control group and treatment group before and after module training?
- (RQ2) Is there a relationship between technological problem solving style and thinking skills among treatment group?
- (RQ3) Is there an effect of using the RPGsr module on student technological problem solving style among the treatment group compared to conventional teaching methods applied in control group?
- (RQ4) Until which extent the usage of the RPGsr module affects the performance of the technological problem solving styles and the thinking skills of the treatment group?

In order to answer the research questions, the null hypothesis were stated in Table 1:Null hyphothesi

1.There is no significant difference in the level of performance of technological problem solving treatment group after participating in a graphical programming training program with robotics.
2. There is no relationship between technological problem solving style and thinking skills among treatment group.
3. There is no significant effect of using the RPGsr module on student technological problem solving style compared to conventional teaching methods.

Table 1:- Hyphothesis of the study

II. METHOD

A. Research design

Sequential explanatory mixed method design was applied in this study to explore in depth the effects of robotics program in term of assessing technological problem solving performances in applying RPGsr modules as the treatment.A mixed method was chosen because it can take advantage of both “quantitative methods- quasi experimental” and “qualitative (focus interview and reflection journal)”; strenghts of the other method to complement and confirm the findings (Creswell,2014;West,2012;Walker,2014; Dhanapati,2016; Emma, 2017).

B. Participants

The sampling technique used which is a combination technique of quantitative and qualitative sampling and the bias at the final stage of the sampling was neutralized at the initial sampling stage.Populations of primary schools in Miri districts have been chosen randomly by clusters which are national primary schools. A total of 43 national primary schools are available in Miri, but only three schools have homogeneous characteristics that have exposure to robotic activities through robotic club programme (Laila Wati, 2016). The homogeneous sample was chosen based on similar achievements in science and technological designs subject. Two elementary classes consist of primary 6 classes were selected in the study as a treatment and control group with an average number of 34 participants in one class, aged 11 to 12 years old. The purposive sampling used to choose sample of student who learnt the Scratch graphical programming in school. This sampling meets the requirements of the study in answering the research questions and the requirements of the school based on the length of the program; which focusing on certain characteristics of a population with an interest and the time-frame allowed for research in the schools. (Pálinkás, 2013).

C. Data collection

Table 2 below shows the data collection methods for each research question. Research question 1,2 and 3 involved quantitative approach while research question 4 involved qualitative approach.

Research questions	Data collection methods
RQ1,RQ2,RQ3	Survey (Psi-Tech),pre and post test
RQ4	Participants interview, journaling-reflection

Table 2:- An overview of the data collection methods

D. Overview of procedure

Treatment program was done within 5 months continuously with 1-2 contact hours every weeks. All of the participants have not experienced any robotic program before. STEM teachers whom have been appointed as the program mentor had been undergo a systematic training an hour every week for that constant 5 months. However, the effects of external variables need to be controlled so as not to directly affect the research variable, which was taken into consideration that randomized division of subjects is done within uniform and homogenous population (Lauren,Allen & Mark,2015). The content in the module (RPGsr modules) which contain technological problem solving activities has been going through expert validation before it were applied in this study.The robotic activities consist of :

- Introduction to robotics kit and graphical programming
- Basic sequencing, pseudocodes and flow-charts
- Group graphical programming/coding activities involved robotic sensor (line and obstacles sensors)

➢ *Validation of TPS instrument*

Adaptation and modification of an instrument which included translation into local language may need to under-go a factor analysis procedure because the field of study may be different and the transfer process affecting some items are no longer suitable for underlying the current study variables (Awang, 2012; Hoque, *et al.*, 2016). There were 34 items in the PSI-TECH instrument which accessed individual awareness and self-concept in solving technological problems. The instrument has gone through back-to back translation followed by face validity and content validity to confirm that the items constructed represent measured measures, including the accuracy of the use of language, spelling and phrase phrases. While the validity of the content refers to the extent to which the items in the instrument have represented all aspects tested, the item meets the content of the field to which it is intended. The construct validity was conducted through the KMO (Kaiser-Meyer-Olkin) test and Barletts's test. Coakes and colleagues (2009) state that if the Barlett's test value is large and significant and the KMO test exceeds the .600 value, then the quantitative factorability can be assumed and the test can be continued (Table 3). The total estimated variance for PSI-TECH constructs is 68.735%. (Table 4). This value is good because it exceeds the minimum requirement of 60% (Awang, 2012; Hoque et al., 2016). The Cronbach Alpha value of an instrument must exceed the minimum of 0.7 for adoption in the next study. Table 5 shows the Alpha Cronbach value item that measures the construct. The items have the Alpha Cronbach value exceeding the value of minumum 0.7 and can be adopted in this study (Awang, 2012; Hoque, et al., 2016).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.882
Bartlett's Test of Sphericity	Approx. Chi-Square	3643.362
	Df	561
	Sig.	.000

Table 3:- The values of KMO and Bartlett's test

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	14.149	41.615	41.615	14.149	41.615	41.615	9.055	26.632	26.632
2	6.588	19.375	60.990	6.588	19.375	60.990	7.508	22.081	48.713
3	2.633	7.745	68.735	2.633	7.745	68.735	6.808	20.023	68.735

Table 4:- Total variants estimated.

Component	Items	Cronbach's Alpha
1	12	0.968
2	8	0.947
3	10	0.944

Table 5:- Alpha Cronbach values

Thus, after the scale and instrument validation conducted on the PSI-TECH (TPS) questionnaires, 30 finalize items used in the actual study; items 1,14,15 and 16 have been set aside.

➢ *Validation of modules*

Pilot studies for this program was done to test the feasibility of the module activities (Russell, 1974; Sidek Mohd Noah and Jamaludin Ahmad, 2005). There are 4 expert panels involved in content validity and reliability, depending on their respective areas of expertise. Expert 1 assessed in terms of scale reliability in the questionnaire and commented on questionnaire items in terms of language, repetitive and unnecessary items. Experts 2 and expert 3 are involved in more in-depth commentary and response modules, particularly in robotic pedagogy, high-level thinking skills and do-able activities applied to robots and programming. Expert 4 also provides a more detailed assessment in terms of module formats and language use in local context. Table 6 below is the percentage of consent from the panel according to the criteria for assessing the validity of the module content given (Sidek Mohd Noah & Jamaludin Ahmad, 2005).

Items	Expert Score 2 (Scale 1-10) 1- strongly disagree 10- strongly agree	Expert Score 3 (Scale 1-10) 1- strongly disagree 10- strongly agree	Computation of the validity of the content Total expert score ---------------------X100 Maximum score
1. The contents of this module conform to its target population.	9	9	92 -------x100 100 = 92% (.92)
2. The pedagogical approach of this module can be implemented perfectly.	8	9	
3. The contents of this module are in line with the time allocated.	9	9	
4. The pedagogical approach of this module can help in improving student achievement performance.	9	10	
5. The pedagogical approach of this module can change the attitude of the student towards greater excellence.	10	10	

Table 6:- Percentage of consent from the panel according to the criteria for assessing the validity of the module content given (Sidek Mohd Noah and Jamaludin Ahmad, 2005).

According to Tuckman and Waheed (1981) the validity of good content is at the level of 70% and above. This percentage is then converted into decimal form by 100 percent as 1.00 and 0 percent as 0.00, resembling the coefficient of correlation coefficients. Therefore, from the above calculation values, the value of 92 percent (coefficient of .92) is of high value and has surpassed the level of validity of good content. A total of 30 students respondents were involved in answering the module reliability instrument, with the number of items of 11 questions on a scale of 1-10. Table 7 is the alpha coefficient value for module reliability. Alpha coefficient values above .70 indicate acceptable and satisfactory levels (Mohd Majid Konting 1993).

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Items
.752	.752	11

Table **7:-** Alpha coefficient value for module reliability

III. RESULT AND DISCUSSION

A. Quantitative data analysis

Inference and descriptive statistics were used in testing the research hypotheses. Paired t-test was used to analyse the performance of technological problem solving differences in the control group and experimental group, before and after the program.Table 8 below shows the results of the pair sample t-test for the analysis of test score mean difference of the control group before and after the program. Table 9 below shows the results of the pair sample t-test for the analysis of test score mean difference of the experimental group before and after the treatment program. Table 10 below shows the results of the independent sample t-test for the analysis of test score mean difference between control and experimental group before the program. Table 11 below shows the results of the independent sample t-test for the analysis of test score mean difference between control and experimental group after the program.

		N	Min	SD	t	k
TPS	Before	34	184.1176	15.466	-.663	.512
	After	34	186.2647	20.0685		

Table 8:- T-test, control group (conventional method) before and after the program

The control group, which consists of 34 students with conventional teaching in the regular class, does not accept any additional treatment. There is no difference in the mean score of the variables studied for the control group before and after the study. There was a significant value above the specified level then the null hypothesis is accepted (t (66) = -. 663, k> .05).

		N	Min	SP	t	k
TPS	Before	34	175.7059	10.223	-6.951	.000*
	After	34	195.0588	9.730		

Table 9:- T-test, experimental group (treatment program) before and after the program

Treatment groups which consist of 34 students, undergoing the treatment and at the end of the program the performance level of technological problem solving style has been improved. Table 9 shows the significance of less than the specified level then the null hypothesis is rejected (t (66) = -6.951, k <.05).The results showed that there was a significant difference in TPS min score before and after the treatment, suggesting that the use of RPGsr modules had a positive effect on the students in the treatment group.

		N	Min	SP	t	k
TPS	Pre-control	34	184.1176	15.466	2.555	.015*
	Pre-experimental	34	175.7059	10.223		

Table 10:- T-test, analysis of TPS test score between control and experimental group before the program.

The results of the independent sample t test showed significant differences in TPS pre test scores between control groups and treatment groups (t (66) = 2.555, k <.05) before the program. The null hypothesis is rejected. Based on the result of analysis, the treatment group was at a low level of performance before the program compared to the control group. These treatment group was selected to monitor and assist in improving their performance in the technological problem solving styles. However, after the program was conducted, a higher TPS mean score among the treatment group students (195.0588) had the effect that the program had a positive impact on the performance of student technological problem styles (t (66) = -2.495, k <.05), (two-tailed), d = 0.5576.

		N	Min	SP	t	k
TPS	Post-control	34	186.2647	20.069	-2.495	.018*
	Post-experimental	34	195.0588	9.730		

Table 11:- T-test, analysis of test score TPS mean difference between control and experimental group after the program

Pearson correlation test was applied in order to find the relationship between the score of the thinking skills assessment in module with the TPS score after the program, among the treatment group. The TPS scores are the questionnaire while exercises score in the module encompasses the thinking skills assessment. Pearson correlation analysis; Pearson (r) moment correlation coefficient of coefficients between the technological problem solving style variables and values of the module thinking skills .956 shows that there is a very strong positive linear relationship exist. (Table 12).

		TPS	Module Score
TPS	Pearson Correlation	1	.956**
	Sig. (2-tailed)		.000
	N	34	34
Module score	Pearson Correlation	.956**	1
	Sig. (2-tailed)	.000	
	N	34	34

Table 12:- Pearson correlation *(**. Correlation is significant at the 0.01 level ,2-tailed).*

Ancova analysis is used to identify the effect of RPGsr modules implementation compared to conventional teaching methods using pre-test as covariant to control the effect of differences between groups; since there was a difference between the control group and the experimental group before treatment was performed. Through One Way Ancova, all homogeneity assumptions and homogeneous variants have been met. There is strong evidence to conclude that there is a significant difference in TPS mean among students between control and treatment groups when the TPS early achievement is statistically controlled (F (1,65) = 8.66, p <.05), R-squared = 0.14). The effect size of R-squared = .14 shows that 14% variance in post-test was contributed by the treatment group;RPGsr modulated teaching. This suggests that the modulized treatment method had an impact on the achievement score of the experimental group compared to the control group (Table 14). The Levene test for variance similarities was not significant (.058) (p> .05), the null hypothesis was accepted.That is, there is no significant difference in the variances of the two sample groups (Table 13).

F	df1	df2	Sig.
3.711	1	66	.058

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + PRE + Group

Table 13:- Levene test

Dependent Variable: POST

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	2490.91[a]	2	1245.45	5.31	.007	.140	10.625	.821
Intercept	6141.55	1	6141.55	26.20	.000	.287	26.197	.999
PRE	1176.18	1	1176.18	5.02	.029	.072	5.017	.597
Group	2033.70	1	2033.70	8.68	.004	.118	8.675	.827
Error	15238.32	65	234.44					
Total	2489659	68						
Corrected Total	17729.22	67						

Table 14:- Ancova

a. R Squared = .140 (Adjusted R Squared = .114)
b. Computed using alpha = .05

B. Qualitative data analysis

To explore the extent to which the usage of RPGsr modules affects the technological problem solving styles and student thinking skills among the treatment group, stated below are the structured questions for the focused interview adapted from Ebelt (2012) and Varnado (2005). It were based on the constructs in the PSI-Tech questionnaire; problem-solving style, problem solving confident and individual control. Here are the interview questions of the student participants, whom were asked in local Malay language:

(i) What have you learned during this program?
(ii) Which part do you like most during the program? State relevant topics.
(iii) What do you understand about the resolution of technological problems?
(iv) If you encounter new problems, what do you do? Why?
(v) When you have solved the problem, are you still trying again other solution to achieve better results? Why?

Questions in the reflection-journal attached in the module are adapted from Huang, Varnado, & Gillan (2013; 2014):

a) Questions about learning content, activity on that day. What has been learned.
b) Questions about the learning process that participants have passed.
c) Questions about what topics are most popular and vice versa.

- *Participants interview*

Students' ability to answer the interview questions shows that they have the awareness of their own abilities in the learning process and the problem solving process and can control their own learning situation.

TB/P/p1: 'I play with the robot, thinking how to complete the task given by the teacher. I also learned with friends to solve robotic problems while moving the robot succesfully'
TB/L/p1: .... .. 'I like programming and picture sequences because it's easy for me' ....
TB/P/p2: 'I learned how to move the robot with instructions ...... I also learned in the group to move the robot' ...
TB/L/p2: :.. For me, I like the topic "robot moves in the hallways" because our group is the earliest to finish the task... ..
TB/P/p3:......I learned the graphhical programming of S4A and mBlock… to move the robot. Then, I learned robot components as well.
TB/L/p3: I love all the stuff ...... book a lot of pictures even though this topic we just learned.
TB/P/p4: ...I've learned much ... .. learning to collaborate with friends, moved the robot .... Learning to drive robots with graphics programming and computer.
TB/L/p4:I like the "phase 3" project ... part of the project, because we can compete with friends ....
TB/P/p5: ..Okay, I've learned to play with robots. Then, I also learned graphic programming. Fun... I'm confident too.
TB/L/p5: ..I love unit "robots along the lines", it's fun to see the robot.
TB/P/p6: ..I learned robotics. I learned to drive a robot, ... oh yes! .... graphics programming
TB/L/p6:..I like it all, it's fun too .... The most fun…, the robot runs.

Then, when asked about understanding in solving technological problems, in order to show individual control and understanding individually, they can briefly explain their understanding.

TB/P/p1: ..Solving technological problems ,involves technology, as we have done.

TB/L/p2: ..I think troubleshooting and solving problems with technology ... ..
TB/P/p3: I think resolving problems with robots and technology.
TB/L/p4: I think, how to solve problems with technology, maybe a robot example. At home there is a robot vacuum cleaner.
TB/P/p5: ..solve problems with robots ... ..
TM/L/p6:.....solve problems with technology.Or solves problems with robots.

In assessing information about the performance and ability of student problem solving styles independently, they were asked about the initial action when they faced a new problem, what they would do. And then why did they do so. They could express briefly the steps to achieve such success by planning, analyzing, investigating, reviewing, thinking and asking questions. This showed the problem solving process takes place with a positive action.
TB/P/p1: First of all, I will investigate the cause and seek the cause. Then, look for a solution. Planning is important.
TB/L/p2: In my opinion, analyzing what actually happened, then look for a solution ......
TB/P/p3: As usual, examine the problem before planning the next….
TB/L/p4: .. I will think, ask my friends, teachers or parents. Then take steps to solve it.
TB/P/p5: .. I feel like asking adults for opinions ... but, I think myself too.
TB/L/p6: .... think first ... .. why there is a problem..

Furthermore, confidence in problem solving is also identified when students were interviewed whether they would still working on a solution to achieve better results. Conversations stated that they would like to succeed, like to explore, like to face challenges symbolize confidence in improving performance in their problem-solving style.
TB/P/p1: My answer is simple ...; I like to try something new.
TB/L/p2: I love the challenge ... .. To achieve better results.
TB/P/p3: It should also strive to get more good result.
TB/L/p4: .... if necessary, I will do as directed as well ... I want to succeed.
TB/P/p5: Yes, pretty much I like the best results.
TB/L/p6: .. .Yes, try more .... to succeed.

➢ *Participants' relfection-journals*

In exploring the participants' perceptions on technological problem solving activities which involved robotics and graphical programming, the reflections journal (the students' writing) after the program were summarizes as below.

- *We are delighted to be able to learn S4A / mBlock programming with robot movements.*
- *Amazing! Doing this program was flipping fun and interesting.*
- *Good to learn new things.....Fun in learning…….*

IV. CONCLUSION

The study was conducted to analyse the effect of a robotic programme for primary school children and the result obtained was statistically significance. The findings from the study shows the positive benefit of using robotic module in enhancing technological problem solving and thinking skills in low performance students. In order to answer research question 1,2 and 3, it is clear that the students in the intervention-treatment group performed better in the post-test compared to the students in the control group. Parametric tests revealed that the students who were exposed to the robotic programme demonstrated significantly better post-test mean scores, compared to their counterparts in the control group. This is true, in supporting constructionism 'active learning' by diversifying the 21st century teaching and pedagogical method in which polishing critical thinking skills in problem solving.In order to identify how RPGsr module activities affect the solving of technological problems and the thinking skills, constructionism learning was activated through collective group discussion in the problem solving in the intervention group. This strategy seems to help the construction of knowledge among the students. The collective discussion approach, derived from the social constructivist view of learning, which help the students to recognize and evaluate their own ideas and understanding.As students are aware of the strengths and weaknesses of their ideas, they become more ready to restructure it.As the study was conducted based on cognitive and social constructivist perspectives,the findings showed the significance process on how learning is considered as an active process in which learners construct knowledge through practically problem solving in robotic and programming. In examining to which extent the usage of the RPGsr module affects the performance of the technological problem solving styles and the thinking skills among the participants, individual engagement throughout the program has been accessed in the interview session. Participants could express clearly what they have learned through the interview session in expressing their emotion and experiences. It shows their engagement is good throughout the program. Their active involvement and collaborative learning take effect, allowing them to state the topics they have learned throughout the program which involved self-understanding in terms of what has been learned.

However, the overall result may be varied depending on demographical and geographical data that has been chosen. In this program, the focus group was elementary school students. To obtain more rigorous analysis,the cross-sectional studies can be run in other future research. Moreover, results may be varied depending on demography and geography of the study. However, the overall program was much more depending on the time length and budget provided. Other than that, longitudinal studies can be considered by changing the time series. Meanwhile,this specific program only involved variables which were technological problem solving and thinking skills in the module. Alternatively, other variables can be considered such as motivation and interest level of the participants.

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