Performance of Malaysian Foundation Level Students in Mathematical Problem Solving As Well As Gender Comparison

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Abstract: Problem solving is the most important factor in mathematics learning. The results of Trends of International Mathematics and Science Study (TIMSS) and Program for International Students Assessment (PISA) show Malaysian students are facing difficulties in problem solving. This study investigates the ability of foundation level students of a public university in Malaysia in mathematical problem solving and also to examine their gender differences in problem solving. The researcher used a lecturers' developed problem solving test for a sample of 297 students that they were chosen through clustered sampling method. Data analyzed by using descriptive statistics and independent samples t-test. The results of this study represent the majority of students were not able to solve the problems completely. However, female students had better performance in problem solving rather than male students. Therefore, problem solving skills should be improved among students seriously.

Keywords: mathematics problem solving, mathematics performance, gender

INTRODUCTION

Mathematics is a core subject in all levels of education namely pre-school, primary school, middle school, high school and university (Makanda, 2018). Mathematics problem solving is the heart of mathematics teaching and learning. Nowadays in Malaysia as well as many other countries mathematics education faces some difficulties especially at foundation and university levels. A lot of understanding of the basic mathematical concepts, techniques, methods of solutions and knowledge is required at the early stage of mathematical education. However, mathematical background of students in school levels entering the university, perhaps, it is one of the key challenges faced by the educators (Alfan & Othman, 2005; Johannsdottir, 2013; Rylands & Coady, 2009). Through superficial learning and memorization method learners cannot apply and link the mathematics materials such as definitions, theorems and formulas in problem solving logically. Learners may easily get bored and dislike mathematics subjects if they could not solve mathematics problems (Salim et al., 2017). They further added that students take high marks in high schools but when they come in the foundation and first year of university their abilities are so low in mathematics problem solving. For example, most students score high in Sijil Pelajaran Malaysia (SPM) results during Form Five (grade 11), despite their poor basic knowledge in mathematics. Because usually learners know the frameworks of exam questions and memorize the solutions of many mathematics exercises that were also the questions of the previous years' exams. Meanwhile, schools and math teachers emphasize their results instead of conceptual understanding and problem solving skills among students. Therefore, students without proper ability to solve mathematics problems get high marks in SPM. It seems lack of problem solving approach in Malaysian education system is an important reason for weak performance of students in the international mathematics assessments. In Malaysia, female students obtain better results in mathematics in comparison to male students. For example, in all international assessments such as TIMSS, the performance of female students was better than male students.

LITERATURE REVIEW

PISA is a large-scale international assessment organized by Organization for Economic Co-operation and Development (OECD) which measures 15-year-old students' abilities in mathematics, science, and reading literacy every 3 years. In PISA (2012), Singapore was one of the top countries in mathematics performance whereas the average score of Malaysian students in mathematics performance was 421, below the OECD average although these two countries have similarities in ethnicity, cultures, languages, and geographical location (OECD, 2013). In fact, there is a vast gap between the mathematics performance of Malaysian and Singaporean students in the international assessments. In Malaysia, only 2% of students that participated in PISA (2018) scored at level 5 or higher in mathematics (OECD average: 11%). Four Asian countries had the largest shares of students who did so: Singapore (37%), Hong Kong (29%), Chinese Taipei (23%) and South Korea (21%). This group of students can model complex situations mathematically, and can select, compare and evaluate suitable problem solving strategies for dealing with them. Table 1 shows the results of PISA by OECD for Malaysian students in mathematics (Maidinsah et al., 2019).

Table 1: Results of PISA (2009-2018)

Year	2009	2012	2015	2018
Malaysian score	404	421	446	440
OECD average	494	511	490	489

Investigation the impact of gender on mathematics problem solving ability among learners is inconclusive because researchers reported different results regarding this issue (Friedman, 1989). Girls' students prefer to use standard algorithms and specific methods to solve the mathematical problems, while boys are more inclined to use abstract strategies to solve the problems (Fennema et al., 1998). Gallagher et al. (2000) explained that boy students were more likely than girl students to correctly solve unconventional mathematical problems by using insight and logical estimation. Some studies represented that gender has no important role on mathematics performance among students (Areepattamannil & Kaur, 2013). The results of TIMSS (2003) showed that there were no significant gender differences in the overall mathematics performance about 46 participating countries at 4^{th} and 8^{th} grades (Mullis et al., 2004). But the results of PISA (2000) indicated male students had better performance in mathematics problem solving rather than female students by 11 points across 43 participating countries (OECD, 2003). However, some studies showed that female students have better performance in mathematics problem solving in comparison the male students (Gilleece et al., 2010). In Malaysia, female students had higher mathematics scores rather than male students in all PISA assessments from 2009 to 2018. For example, in PISA (2018), females performed better than males with a statistically significant difference of 7 points. Similarly, Malaysian 8^{th} grade female students had better performance in mathematics problem solving rather than male students in all TIMSS, 1999, 2003, 2007, 2011 and 2015. Table 2 shows the results of mathematics problem solving among Malaysian 8^{th} grade students in all TIMSS assessments from 1999 to 2015 by gender.

Table 2: The Results of Malaysian 8^{th} Grade Students in TIMSS by Gender

Year	1999	2003	2007	2011	2015
Female average	521	512	479	449	470
Male average	517	505	468	430	461

In Malaysia, as well as many other countries mathematics educators emphasize on mathematics exercise solving among students through traditional method of teaching (Khalid, 2017; Mon et al., 2016). Therefore, students prefer to memorize some formulas, theorems and methods in order to apply in mathematics exercise solving and exams. In fact, students not only cannot learn mathematics conceptually but also they cannot experience the beauties of mathematics. Therefore, students should learn mathematical topics conceptually through engaging with problem solving activities.

Polya (1945) suggested four phases for mathematics problem solving namely understanding problem, planning, performing the plan, and confirming of the answer. The discovery of the use of appropriate mathematics problems and encouraging learners to explain the strategies and techniques they engage when solving problems is more pedagogically challenging among mathematics educators (Johnson & Cupitt, 2004; McDonald, 2009). So knowledgeable educators can improve the abilities and skills of students in problem solving through engaging with appropriate mathematics problems and discuss about the variety of solutions. In mathematics learning situations, problems must be on such levels that every learner would be able to solve at least some of them to some extent, to encourage his/her motivation (Bergqvist, 2011).

According to Xenofontos and Andrews (2014) a new challenging mathematics task is called mathematics problem if learners have not before learned how to solve it otherwise, this task merely is known as mathematics exercise. Meanwhile, the recognition of open-ended problems depends on the ability of students in problem solving (Asami-Johansson, 2015). For instance, the following problem after discussion in the classroom becomes a mathematics exercise.

Problem: If $\tan(x+y)=4$ and $\tan(x-y)=2$ find the value of $\tan 2x$.

Lecturers can consider many new examples related to the above mathematics exercise such as:

Exercise: If $\tan(x+y)=4$ and $\tan(x-y)=2$ find the value of $\tan 2y$.

Exercise: If $\cot(x+y)=4$ and $\cot(x-y)=2$ find the value of $\tan 2x$.

Although these examples are different, both of them considered as mathematics exercises because the idea for the solutions is clear and students know how to solve them. If lecturers consider a little change in the concept of this mathematics exercise students engage with another mathematics problem as:

Problem: If $\tan(x+y)=4$ and $\tan(x-y)=2$ find the value of $A=\tan 4x+4\tan(5x-y)$.

Traditional method in mathematics teaching emphasizes on exercise solving among students through memorization the mathematics materials. Doing non-routine problem solving activities in teaching mathematics is the most appropriate approach to generate mathematical reasoning skills among learners (Kolovou et al., 2009). Posting non-routine mathematics problems to the students engage them with some challenges that help them to learn the concept of mathematics materials meaningfully through their experiences. Mathematics learning is strongly related to the problem-solving skills among students. In foundation level, learners are supposed to deal with more complex mathematics problems than those of lower secondary levels. Thus foundation program students should improve their abilities in problem solving to have better performance in mathematics courses at university level. The aims of this study are to investigate the ability of foundation level students in mathematics problem solving and compare the performance of them by gender.

METHODOLOGY

Sample and Data Collection

In Malaysian education system, students who completed secondary school must undergo a university preparatory program which are conducted through several causeways; Foundation, Matriculation, A-level or Form Upper Six in secondary school. Students pursuing foundation or other pre-university education programs are chose based on their high school performance. Thus, choosing one particular public university for this study would also reflect, to some extent, the problem solving ability to students of other public universities. This study was conducted in a public university in Malaysia includes 952 students (326 male and 626 female) and sample size calculated as follows (Cochran, 1977):

$$n_0 = \frac{z^2 p(1-p)}{e^2}$$

Where n_0 is the estimate sample size, p is the distribution of 50% (in the sampling world it is almost always safest to stick with a 50% distribution, which is the most conservative), e is margin of errors (%), and z is confidence level score.

$$n = \frac{n_0 N}{n_0 + N - 1}$$

Where n is the true sample size, n_0 is the estimate sample size, and N is the population size. Therefore, for this study the sample size calculated as:

$$n_0 = \frac{(1.96)^2(0.5)(1-0.5)}{(0.05)^2} = 384.16 \text{ and } n = \frac{384.16\times952}{384.16+952-1} = 273.91$$

Therefore, the true sample size for this study should be at least 274 but the researcher conducted this study on 297 of students that they were chosen randomly through clustered sampling method. Also, the proportion of male and female students in the sample is much closed to the proportion of male and female students in the population. In the population size 34% of students are male and 66% of them are female. In the sample size 38% of students are male and other 62% are female.

Instrumentation

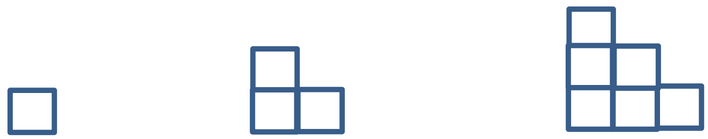
The instrument that used for this study was a lecturers' developed problem solving test contains 4 open-ended mathematics problems related to the mathematics function with half an hour time for students to answer. The researcher conducted this test for students one week after lecturers taught this topic. Table 3 shows the questions of this test.

Table 3: The Problems of the Test

Number	Item
1	Let $f = \{(1,2),(3,5),(1,m^2-n^2),(4,7),(3,2m-1)\}$ is a function. Find the value of $2m+n^2$.
2	Find the domain and range of the function $g(x) = 4x^2 - 4x + 15$.
3	Is the relation $\lvert x+y \rvert = 4$ a function? Why?

4 Look at this step pattern. In the first figure, which has one step, each side of the block is 1 cm long.

a. Find the perimeter of a figure with 47 steps.
b. Is there a figure with a perimeter 74 cm? If so, how many steps does it have? If not, why not?



(1) (2) (3)

The researcher during two sessions discussed with the Head of Mathematics Unit and a mathematics lecturer to improve the quality of questions according to the students' abilities in problem solving. So, they designed a mathematics problem solving test contains eight questions. But later the number of questions reduced from eight to four because in this educational center it was difficult to consider long time for conducting the test by lecturers. The validity of this test was confirmed by four mathematics experts from a public university in Malaysia. Also, for reliability of this test the researcher used Equivalent Forms Method and the Pearson correlation significant for this test with 35 participants outside of this research was 0.76. Finally, the questions in this test were confirmed by some experts in the Research Management Center (RMC) at the same university. In this foundation center, there were 20 classes with 45 to 50 students in each. But for English course there were 40 groups with 22 to 25 students (for English subject each class divided in two groups). The researcher conducted this test during English classes in order to have better sample size.

Also, item analysis was enforced in order to determine item difficulty. The researcher used the following formula that is more appropriate for open-ended questions.

$$p = \frac{a}{b - c}$$

In this formula, p is difficulty index and a is the total average for all scores in the item. The variables b and c are the maximum possible score and the minimum possible score for the item respectively. The item difficulty for questions 1, 2, 3 and 4 are 0.38, 0.31, 0.30 and 0.57 respectively. The item difficulty indices range from 0.30 (the most difficult item, item 3) to 0.57 (the easiest item, item 4). The difficulty indices from 0.20 to 0.80 can be used to retain the items in a standard test (Purnakanishtha et al., 2014). All the questions were in the range of standard difficulty index.

For scoring, if student doesn't understand the problem (illogical and incorrect answer) or non-answer the problem scored 0, if some steps in the solution show student understand the problem scored 1 (first step of Polya's model), if student understand and design a method for solution include some errors scored 2 (first and second steps of Polya's model) and finally completely correct answer scored 3 (all steps of Polya's model). So, the minimum and maximum scores for this test with four items were 0 and 12 respectively. Each student's exam paper was scored by two correctors. If there were no differences between their marks the researcher recorded the marks otherwise, the final mark for each student calculated according to the following rule. Assume that first and second lecturers considered two marks a and b for a student respectively the final mark (m) for this student was, $m = \left[\frac{a+b+1}{2}\right]$, where [ ] is the symbol of integral part. For instance, for two scores 9 and 10 the final mark calculated as $\left[\frac{9+10+1}{2}\right] = [10] = 10$.

In this study, the researcher first submitted the permission letter to the director of the foundation center and then coordinated with some lecturers to conduct this exam in their classes. Meanwhile, in each classroom, the researcher explained that students can participate in this exam voluntary.

Analyzing of Data

The descriptive statistics was used to find the situation of mathematics problem solving among foundation level students. The researcher analyzed the percentage of all scores of students in each mathematics problem and in overall score for this test. Also, the performances of male and female students in problem solving were compared by using independent samples t-test.

RESULTS

The results of this study discussed in two parts namely the ability of foundation level students in problem solving and the comparison of students' performance in problem solving by gender.

The Situation of Mathematics Problem Solving

In order to have better understanding about the students' performance in mathematics problem solving, Table 4 shows the mean and standard deviation of all questions and test scores.

Table 4: Mean and Standard Deviation of all Questions and Test Scores

Score	Number	Minimum	Maximum	Mean	Standard Deviation
Question 1	297	0.00	3.00	1.40	1.16
Question 2	297	0.00	3.00	1.42	0.90
Question 3	297	0.00	3.00	1.31	0.81
Question 4	297	0.00	3.00	1.68	1.13
Test	297	0.00	12.00	5.82	2.17

As respect to the Table 4, the mean of all variables are low and it seems the performance of students were poor in problem solving. The average of all mean scores for questions 1 to 4 is 1.45, it represents that the skills of students didn't allow them to solve the problems completely. Table 5 shows the students' performance for each question.

Table 5: Students' Performance for each Problem

Mark / Problem	0 Frequency (%)	1 Frequency (%)	2 Frequency (%)	3 Frequency (%)
1	80 (26.93%)	101 (34.00%)	32 (10.77%)	84 (28.28%)
2	38 (12.79%)	141 (47.47%)	71 (23.90%)	47 (15.82%)
3	37 (12.45%)	157 (52.86%)	75 (25.25%)	28 (9.42%)
4	60 (20.20%)	73 (24.57%)	66 (22.22%)	98 (32.99%)

Table 5 shows that students usually have some difficulties in mathematics problem solving and usually they have some errors in their answers. Only small percentages of students answered completely to the questions. The percentage of complete answers for questions 1, 2, 3 and 4 were 28%, 16%, 9% and 33% respectively. It means the majority of students were not able to solve the problems completely based on the levels of Polya's model. The scores of students categorized in three groups namely, low (scores from 0 to 4), moderate (scores from 5 to 8) and high (scores from 9 to 12). Table 6 shows the frequency and percentage of different groups among students in mathematics test.

Table 6: The Frequency and Percentage of Different Groups of Students

Group	Frequency	Percentage	Mean	Standard Deviation
Low	88	29	3.31	0.98
Moderate	177	60	6.36	1.04
High	32	11	9.75	0.95
Total	297	100	5.82	2.17

The mean and percentage of each group show by Figure 1.

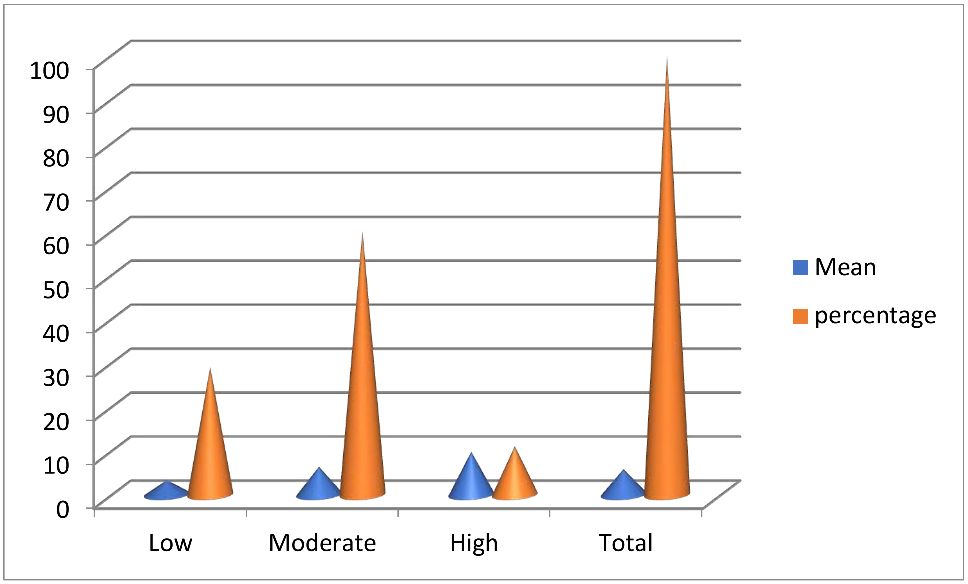


Figure 1: The Mean and Percentage of each Group

Table 6 and Figure 1 illustrate that only 11% of students had good performance in mathematics problem solving. According to the results of students in this test their abilities in mathematics problem solving should be improved.

Mathematics Problem Solving by Gender

Kim (2013) and Mishra et al. (2019) explained that by using skewness and kurtosis a Z-score could be obtained by dividing the skew values or excess kurtosis by their standard errors as:

$$Z = \frac{Skew\ value}{Standard\ error} \text{ or } Z = \frac{Excess\ kurtosis}{Standard\ error}$$

Then the normality of data based on the sample size determine as follows:

a. If the sample size is less or equal 50 ($n \leq 50$) and $|Z - score| < 1.96$ then data normally distributed.
b. If the sample size is between 50 and 300 ($50 < n \leq 300$) and $|Z - score| < 3.29$ then data normally distributed.
c. If the sample size is more than 300 ($n > 300$) and the values of skewness and kurtosis without considering the Z-scores are between -2 and 2 then data normally distributed.

Since the absolute values of Z-scores for all groups in Table 7 are less than 3.29 so the scores doesn't differ from normal distribution.

Table 7: The Normality of Scores

Group	No.	Skewness	Standard Error (Skewness)	Z-score (Skewness)	Kurtosis	Standard Error (Kurtosis)	Z-score (kurtosis)
Male	114	-0.030	0.226	-0.132	-0.356	0.449	-0.792
Female	183	0.339	0.180	1.883	0.031	0.357	0.086
All	297	0.169	0.141	1.198	-0.032	0.282	-0.113

Table 8 shows the mean and standard deviation of all mathematics problems and test scores for male students.

Table 8: Mean and Standard Deviation of problems and Test Scores for Male Students

Scores	Number	Minimum	Maximum	Mean	Standard Deviation
Problem 1	114	0.00	3.00	1.25	1.19
Problem 2	114	0.00	3.00	1.38	0.82
Problem 3	114	0.00	3.00	1.24	0.83
Problem 4	114	0.00	3.00	1.52	1.15
Test	114	0.00	10.00	5.41	2.19

Table 9 shows the mean and standard deviation of all mathematics problems and test scores for female students.

Table 9: Mean and Standard Deviation of Problems and Test Scores for Female Students

Scores	Number	Minimum	Maximum	Mean	Standard Deviation
Problem 1	183	0.00	3.00	1.49	1.13
Problem 2	183	0.00	3.00	1.45	0.95
Problem 3	183	0.00	3.00	1.36	0.79
Problem 4	183	0.00	3.00	1.77	1.11
Test	183	1.00	12.00	6.08	2.13

According to the Tables 8 and 9 the performance of female students was better than male students in all mathematics problems. Figure 2 compares the performance of students in all mathematics problems and test by gender.

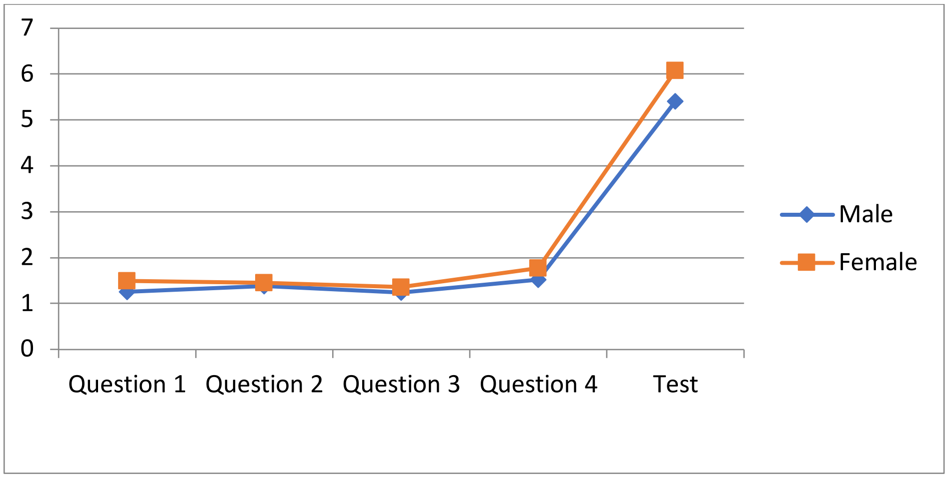


Figure 2: Performance of Students in Problem Solving by Gender

The researcher used independent samples t-test to compare the performance of students in problem solving by gender statistically. Table 10 shows the equality of variances for both groups (male and female students) statistically $F(1, 295) = 0.516$, $P > 0.05$.

Table 10: Levene F Test (consistency of error variances)

F	df1	df2	Sig
0.516	1	295	0.473

Table 11 shows the results of independent samples t-test to compare the performance of students in mathematics problem solving by gender.

Table 11: Results of Independent Samples t-test for Problem Solving by Gender

Group	Number	Mean	Standard Deviation	t	df	Sig
Male	114	5.41	2.19	-2.624	295	0.009
Female	183	6.08	2.13			

The result of Table 11 shows that there is a significant mean difference between the performance of male (M = 5.41, SD = 2.19) and female (M = 6.08, SD = 2.13) students in mathematics problem solving $t(295) = -2.624$, $p < 0.05$. In other words, female students had better performance rather than male students in mathematics problem solving.

DISCUSSION

This current study investigated the ability of students in problem solving about mathematics functions that considered as a problematic topic for students to learn. The concept of mathematics function is a central and practical but difficult topic in secondary school curricula (Akkus et al., 2008; Ponce, 2007). For example, "the topics inverse function and composite function is more conceptual and challenging among educators to transfer to students" (Oehrtman et al., 2008, p. 39). Michelsen (2006) explained that modeling the real-world problems is one of the most common applications of the mathematics functions in different areas of studies. Since mathematics function is one of important topics that used in all mathematics courses at the university level, students in foundation level need to have suitable knowledge about it. But this is an important question "how students can learn the functions conceptually?". Problem solving approach should be common in foundation centres because this level of education is the border between high school and university level. So, mathematics lecturers during one year (two semesters) of foundation program should be able to improve the ability of students in problem solving.

Mathematical problem solving is a big challenge among lecturers and usually students have some difficulties against mathematics problem solving (Gholami et al., 2021; Khalid, 2017). Many researchers have explained that students usually receive mathematics contents which emphasize on the solving of routine exercises and they follow the steps that mathematics educators explained to them (Intaros et al., 2013; McDonald, 2009; Mon et al., 2016; Tambychik & Meerah, 2010). Gholami et al. (2019) explained that "students have the impression that they only need to memorize the formulas, theorems, shortcuts and methods to apply in exercise solving and in preparing for examinations" (p. 307). In fact, students are seldom engaged with open-ended problem solving during their mathematics courses. So, usually they cannot solve the new mathematics exercise if lecturers change it slightly. It seems students have poor basic knowledge in mathematics from previous years although their grades in mathematics are usually excellent. In this situation, students cannot learn the mathematics conceptually and experience the beauties of it. Another reason for low ability in problem solving among students of this foundation centre related to the superficial teaching because lecturers need to cover a lot of topics during each semester. Lecturers prefer to teach exactly the same textbook materials. Therefore, this method of teaching encourages students to use the memorization method in learning mathematics. The results of this study confirmed that in this foundation centre, mathematics problem solving activities should be improved among students.

Also, the results of this study illustrated that the performance of female students ($M = 6.08$, $SD = 2.13$) in mathematical problem solving were better than male students ($M = 5.41$, $SD = 2.19$). This finding is in line with the results of Malaysian students in all TIMSS assessments from 1999 to 2015 (Mullis et al., 2016). More studies need to conduct in different educational levels and contexts of Malaysia to find why this issue happens in this country whereas in many of countries male students have better performance in mathematics problem solving rather than female students. It seems the situation of mathematics teaching and learning in Malaysia such as memorization method prepares better opportunity for female students to have higher marks compare male students. Because usually female students are harder working and sensitive about their results therefore female students are more likely to have better results in mathematics exams through learning some standard algorithms and specific methods.

CONCLUSION

Malaysian Ministry of Education aims to be one of top countries in the international assessments such as TIMSS and PISA in 15 next years, thus, the government is very serious to enhance the quality of mathematics teaching and learning (Ministry of Education, 2014). The low quality of mathematics problem solving in Malaysian education system is a serious alarm for Ministry of Higher Education, Ministry of Education, policy makers, administrators and mathematics educators to have better plan and strategy to improve the abilities of students in mathematics problem solving. Malaysian Ministry of Education needs to know "why female students have better performance in mathematics problem solving?". Malaysian government should enhance the ability of students in problem solving in order to obtain better results in the international assessments. In summary, likely poor basic knowledge in mathematics among students, traditional teaching methods, a lot of topics and emphasize on the grades of students instead of the learning quality are some of important reasons for the low ability of students in mathematics problem solving. Based on the results of international assessments such as TIMSS and PISA, some factors such as students' level of self-confidence in mathematics problem solving ability, the value of mathematics in the real life and their future careers, and the amount of time students spend doing mathematics homework were considered as possible factors affecting this differences. In Malaysia, most mathematics educators teach mathematical material through the traditional method. In this method, students usually follow the mathematical procedures and rules taught by the educator to perform similar exercises. In other words, students prefer to use the memorization method in learning mathematics. It seems that Malaysian female students show more responsibility in doing assignments and participating in class activities, which not only increases their self-confidence, but also makes them superior to males in the mathematical exams and international assessments. Successful countries in international assessments such as Singapore and Japan emphasize the mathematical problem solving approach among educators in order to improve the ability of students in solving non-routine problems. Mathematics educators as the responsible group for delivering the curriculum should be more competent in problem solving in the taught lessons in order to improve the ability of students in problem solving (Pineiro et al., 2021). Therefore, Malaysian Ministry of Education needs to improve the ability of mathematics educators through professional development programs in problem solving, improve the ability of students in problem solving and critical thinking by engaging them with suitable problem solving activities as well as enhancing textbook materials based on problem solving approach to see better outcome among Malaysian students in the future international assessments.

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