Relationship between scientific reasoning skills and mathematics achievement among Malaysian students

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Abstract

The role of reasoning in mathematical performance is a continuing topic of interest for researchers in mathematics education. This present study explored the link between scientific reasoning skills and mathematics performance as measured by students' responses to a series of novel problems. Results indicated the existence of a moderate positive correlation between the two variables. All participating students exhibited low levels of scientific reasoning. Despite this, students in the high-achievement group performed significantly better than their peers in the low-achievement group in the mathematics test. The results suggest that while scientific reasoning is necessary, these set of skills may not fully explain the kind of reasoning that underpins mathematical problem solving among Malaysian secondary students. We draw implications for instructions to support the development and use of reasoning in mathematical learning in Malaysian classrooms.

Keywords: gender, knowledge transfer, Malaysian classrooms, mathematics problem solving, scientific reasoning skills, secondary mathematics

Introduction

There is a consensus about the need to support higher level engagement of secondary mathematics, specifically in mathematical problem solving (Santos-Trigo & Moreno-Armella, 2013). However, the nature of engagement with mathematics is a complex processes. One way to examine student engagement is by analyzing the processes that students activate during mathematical performance. In this study, we focus on reasoning and the transfer of reasoning among a cohort of high school students during problem solving, an area of higher order thinking skills that has not received a great of attention (Bieda, Ji, Drwencke & Picard, 2013; Stylianides, Stylianides & Shiling-Traina, 2013).

In discussions about cognitive processes that support mathematical learning and problem solving, a category of skills, namely, higher order thinking skills, is now emerging to be a significant area of interest for researchers and teachers. The development of higher order thinking skills is necessary in order to facilitate the transfer of students' prior mathematical knowledge. With calls for increasing attention to creativity, proof development and logical arguments, the study of higher order thinking skills could improve current understandings about processes that are involved during the search for solution (Schoenfeld, 2013; Bieda *et al*., 2013; Lester, 2013; Tularam, 2013).

Higher order thinking skills: Malaysian context

The Malaysian Government has given the development of scientific talent a national priority. Towards that end, the Malaysian Mathematics Integrated Curriculum for Secondary School focuses on fostering

critical thinking and creativity, reasoning and higher order thinking skills. Mathematics at a higher level of the school curriculum involves the use of abstract concepts which, in turn, requires formal logical reasoning that draws on concepts and principles.

Findings of international studies of student achievement such as Trends in Mathematics and Science Study [TIMSS] and Programme of International Student Assessment [PISA] showed that most high school students in Malaysia had not reached a satisfactory level of higher order thinking. In the analyses of Malaysian students' performance in TIMSS in a number of years, Mullis, Martin, Foy & Arora (2012) found that only 2-10% of the students are capable of interpreting the information, drawing conclusions and generalization in solving complex problems – activities that collectively reflect low levels of activation of higher order thinking. Mullis and colleagues also showed that 60% of students achieved the low international benchmark. These results suggest that the students understand the basic mathematical concepts but, in general, they are not able to transfer that knowledge to non-routine problem situations (Ministry of Education [MOE], 2013). Likewise, another international study, namely, the PISA 2009 showed that Malaysia students' performances were located in the bottom one third of all the 74 participating countries (Walker, 2011).

As in the TIMSS study, PISA's report for mathematics achievement showed that only a small proportion (8%) of Malaysian students achieved advanced levels of thinking. Overall, trends in TIMSS and PISA provide evidence of Malaysian students' continuing difficulty in solving mathematical tasks which involve complex interpretation and synthesis – key aspects of higher order thinking. The solution of complex mathematical problems involves the transfer of prior learning to new contexts, and this transfer, we argue, can be facilitated by the acquisition of higher order thinking skills.

In addition, the gender gap in mathematics achievement among Malaysian students had widened over the last five years (MOE, 2013). Girls have consistently outperformed boys at every level. The gap in performance is evidenced at the Primary School Assessment Test (PSAT) level and increased over a student's lifetime up to university level, where females comprise approximately 70% of the cohort. While this phenomenon is not unique to Malaysia, it does require attention to ensure that the country does not have a cohort of 'lost boys' who either leave school early or with low attainment levels. The trend in the performance of girls vs boys is also evident in international measures of mathematics attainment. For example, PISA 2012 international studies have shown that Malaysia is one out of five countries where girls outperformed boys in mathematics (Organisation for Economic Co-operation and Development [OECD], 2013). Similarly, the TIMSS 2011 results indicated that Malaysian Year 8 girls outperformed boys in mathematics in tasks that involved application and reasoning (Mullis et al., 2012). The findings of MOE, TIMSS and PISA are significant in that they generated important directions for future study in better understanding gender-related differences in mathematical performance. We take up this issue by analysing the link between reasoning and performance in the solution of mathematical problems by boys and girls.

The Malaysian situation highlighted two core issues. Firstly, there is limited evidence of use of higher order thinking skills for Malaysian students when they attempt to perform mathematical tasks. Secondly, the difference between girls and boys in mathematical performance has not been analysed in terms of processes that underpin their performances. The present study is grounded in the above issues by exploring the link between the higher order thinking skills and mathematics achievement. Specifically, we focused on a range of reasoning skills called Scientific Reasoning Skills [SRS] and examined Gender as a variable in analyzing mathematical performance and reasoning skills.

Scientific reasoning skills

The range of SRS that students bring to learning and problem solving can be expected to assist them making progress in multiple ways. In this sense, SRS "encompasses the reasoning and problem-solving skills involved in generating, testing and revising hypotheses or theories, and in the case of fully developed skills, reflecting on the process of knowledge acquisition and knowledge change that result from such inquiry activities" (Morris, Croker, Masnick & Zimmerman, 2012: 65). Scientific reasoning

differs from other skills in that it requires additional cognitive resources as well as an integration of cultural tools. Further, scientific reasoning emerges from the interaction between internal factors (e.g., cognitive and metacognitive development) and cultural and contextual factors. According to Lawson (2004), scientific reasoning pattern is defined as a mental strategy, plan, or rule used to process information and derive conclusions that go beyond direct experience. Hand, Prain and Yore (2001) argued that scientific reasoning abilities and habits of mind lie at the heart of scientific literacy, which involves the abilities and habits of mind to construct understanding of problems at hand, understanding the central concepts and unifying theories of science, and the ability to communicate and persuade others to take action related to those concepts and theories. Thus, this skill is related to cognitive abilities such as critical thinking and reasoning and can be described as processes of producing knowledge through evidence–based reasoning.

SRS and knowledge transfer in mathematical performance

The Science, Technology, Engineering and Mathematics [STEM] education community considers that transferable general abilities such as reasoning are at least as important for students to learn as is the STEM content knowledge (Chen & Klahr, 1999; Kuhn & Dean, 2004). This view is consistent with our assumption that reasoning skills act as a layer of general skills that assist students in the use of content knowledge.

As stated in the section of SRS above, Hand, Prain and Yore (2001) describe that scientific reasoning involves the abilities to construct understanding of the content knowledge and to give justification on actions that individuals have adopted. As such, scientific reasoning pattern plays an important role informing habit of minds as suggested by the NCTM (2009). Thus, our expectation is that students' scientific reasoning abilities could be utilised when solving complex mathematical problems. Accordingly, higher scientific reasoning levels among students could be expected to enhance mathematical problem solving performance.

Purpose of the study

We have argued that solving mathematical problems is a complex process that is influenced by various factors including reasoning. However, review of literature indicates that the nature of reasoning that supports problem solving is somewhat unclear. One school of thought argues that reasoning processes are located within maths. The alternative view is that reasoning skills are general in nature and are transferable across domain. The present study is based in the latter assumption that reasoning are general skills that learners need to activate during the course of mathematical problem solving regardless of the particular area of mathematics. These set of reasoning skills that we focus in the present study is SRS.

The purpose of the study was to identify the level of SRS attain by a cohort of upper Malaysian secondary school students (form four students, 16-17-year-old). In addition, we were interested to examine the impact of Achievement Group and Gender on levels of SRS and Mathematics Test. We sought data relevant to the following four research questions:
1.   What are the levels of SRS among upper secondary school students?
2.   Is there a relationship between SRS and Mathematics Achievement?
3.   How does Achievement Group affect students' SRS and Mathematics Achievement?
4.   How does Gender affect students' SRS and Mathematics Achievement?

Methodology

Design

This study employed a descriptive research design as our interest to generate information about the current status of the relationship between independent and dependant variables. Students responded to two test dependent variables. In addition, the correlational exploratory design was used to explore "the extents to which two or more variables co-vary, that is, where changes in one variable are reflected in changes in the other" (Creswell, 2008: 358) which was relevant to research question no. 2. The two key dependent variables are measures of SRS and Mathematics Achievement.

Participants

A total of 351 students from 14 Malaysian secondary schools participated in the present study. Participants in this study were upper secondary school students or Year 11 students (16-17-year-old). A stratified sampling technique was chosen as the population in this study was not heterogeneous. The technique is appropriate in order to obtain selection representative sample from each stratum reflecting Achievement Group and Gender (Wiersma & Jurs, 2005). The validity of stratified sampling could also provide a more accurate sample because the sample size distributions are quite similar within each stratum (Bryman & Cramer, 2005). Moreover, the advantage of stratified random sampling procedure was reduced sampling error.

All secondary students in Malaysia were required to complete a common mathematics curriculum in the first three years of high school. At the end of the three years all students were required to sit for a centralized examination, Lower Secondary Evaluation Examination (LSEE). Participants were assigned to two groups on the basis of their performance in mathematics and science in LSEE. Those students who obtained Grades A or B in mathematics and science in this examination were assigned to the High-Achievement group and their counterparts who obtained Grades C or D were the Low-Achievement group. Table 1 presents the distribution of participants based on Achievement Group and Gender.

Table 1. Distribution of participants based on achievement group and gender

Achievement Group	Gender	Number of student	Percentage (%)
High	Male	42	12
	Female	56	16
Low	Male	134	38.2
	Female	119	33.9
Total		351	100

Tasks

This section provides details of tasks that were used in this study. As discussed earlier, there were two tests used in order to generate scores for two dependent variables:
Test 1 - Scientific Reasoning Test (SRT).
Test 2 - Mathematics Test (MT).

Test 1 - Scientific Reasoning Test (SRT)

The SRT was used to measure the students' level of SRS. It has been adapted from Nor'ain, Norashiqin and Amalina (2012) which based on LCTSR (Lawson, 2000). This test was validated by mathematics education experts and had a high Kuder-Richardson 20 internal-consistency reliability coefficient index value of 0.856. The test consisted of 12 pair items and was designed in a 'two-stage' multiple-choice

format to illustrate problem scenarios. With each scenario, the first question focuses on the scenario content specifically, while the second question asks for reason the first answer is correct. Each answer for the first question has a corresponding reason in the second question.
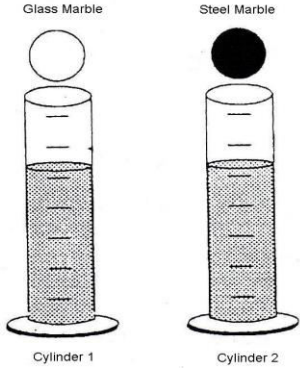
Figure 1 shows an example of the item for SRT. This example evaluates the conservation of volume reasoning skills. Firstly, students have to think based on their experience or previous knowledge or facts where the water will rise when the glass marble is put into cylinder. Then, students have to make justifications why the water rose at that level. This involves individual applying the conservation reasoning to perceptible objects and properties namely 'remains the same' – is 'conserved' and thus since the two marbles have the same volume they will displace the same amount of water. Making prediction and giving explicit explanation are keys to successful completeness of this item. Both prediction and explanation are also important process of mathematical problem solving. Thus, we argue that these reasoning skills would contribute to the solution outcome of mathematical problems.

3a)	*To the right are drawings of two cylinders filled to the same level with water. The cylinders are identical in size and shape. Also shown at the right are two marbles, one glass and one steel. The marbles are the same size but the steel one is much heavier than the glass one. When the glass marble is put into Cylinder 1 it sinks to the bottom and the water level rises to the 6th mark.*
	If we put the steel marble into Cylinder 2, the water will rise
	a. *to the same level as it did in Cylinder 1*
	b. *to a higher level than it did in Cylinder 1*
	c. *to a lower level than it did in Cylinder 1*
3b)	*because*
	a. *the steel marble will sink faster.*
	b. *the marbles are made of different materials.*
	c. *the steel marble is heavier than the glass marble.*
	d. *the glass marble creates less pressure.*
	e. *the marbles are the same size.*

Figure 1. *Example of item in SRT*

Scoring rubric for SRT

As described earlier, SRT consisted of 12 questions in pairs and the respondents were required to select one correct answer and provided an explanation for the answer based on the list of alternatives answers provided. Scores will be given a value of 1 only if both the answer to every question is correct. If the answer either or both of the pairs are not correct, then no points will be given. Interpretation of scores is shown in Table 1. The SRT is considered a reliable and valid instrument that measures levels of *concrete–formal* operational the same as Piagetian thinking skills in secondary and college–age students (Lawson, 1978). The range of scores of SRS level is 0-12 which decomposes into three levels as suggested by Lawson.

Table 2. Scoring scheme for level of SRS

SRS Scores	Level of SRS
0 – 4	*Concrete*
5 – 8	*Transitional*
9 – 12	*Formal*

Students' scoring in the range of 0-4 on the test were categorised as *concrete* reasoners while students scoring in the range of 9-12 in the test were categorised as *formal* reasoners. Students' scoring in the range of 5-8 were categorised as *transitional* reasoners.

In Table 2, we defined each of SRS level and provide instances of activity for each of the three levels in relation to Item 18 of MT. Students were categorised as having *concrete* reasoning level if they need reference to familiar actions, objects, and descriptive properties; their reasoning is initiated with observations; needs step-by-step instructions; unconscious of his/her own reasoning patterns. For this item, students may only show the understanding concepts of perimeter and area of a rectangle and a circle in solving the problem.

Students were categorised as having *formal* reasoning level if they can initiated with imagined possibilities; uses symbols to express ideas; plan a lengthy procedure given certain overall goals and resources; conscious and critical of his/her own reasoning patterns. In this case, students may systematically plan to find perimeter of irregular shaded region in Diagram 11. This will involve finding the curve length of a semicircle and a quadrant using the formulae for the area and using the given information of the radius length.

Students were categorised as having a *transitional* reasoning level if they remain confined to concrete thinking or are only capable of partial formal reasoning such as they only understand and applying or reconceptualising the concepts of perimeter and area of a rectangle and area of a circle in a new context.

Table 2. Characteristics of level of SRS

Level of SRS	Interpretation	Example of Type of Reasoning as in Item 18 (MT)
Concrete	Needs reference to familiar actions, objects, and descriptive properties; Reasoning is initiated with observations; Needs step-by-step instructions; unconscious of his/her own reasoning patterns.	Understand concepts of perimeter and area of a rectangle and a circle.
Transitional	Remain confined to concrete thinking or are only capable of partial formal reasoning	Understand, applying or reconceptualising concepts of perimeter, area of a rectangle and area of a circle in a new context.
Formal	Initiated with imagined possibilities; uses symbols to express ideas; plan a lengthy procedure given certain overall goals and resources; conscious and critical of his/her own reasoning patterns	Systematically plan to find perimeter of irregular shaded region in Diagram 11. This will involve finding the curve length of a semicircle and a quadrant using the formulae for the area and using the given information of the radius length.

Test 2 - Mathematics Test (MT)

The MT was designed to measure students' Mathematics Achievement. The test was prepared by a panel of experienced mathematics educators, experienced teachers and mathematics curriculum experts. Bloom

taxonomy was used in developing of the items for the tests as it allowed us in examining key concepts and using these concepts to solve the problems. This permitted us in explaining the use of three levels of reasoning skills. The items for the test were selected from a pool of resources such as textbooks, reference books and examination papers. The test consisted of 40 multiple choice questions that covered mathematical strand in the Malaysian Mathematics Syllabus (Year 8 – Year 11). This test was validated by mathematics education experts and had a high reliability index value of 0.895. The following is Item 18 of the MT. The three levels of SRS as played out within Item 18 are explained in column 3, Table 2. This is to ensure that one or more levels of SRS are activated by the students during solving mathematical problems.

18.	Diagram 11 shows a semicircle with a radius of 3 cm and a quadrant with a radius of 1 cm inside a rectangle.
	Diagram 11
	Calculate the perimeter of the shaded region, in cm. (Use $\pi = \frac{22}{7}$)
	A 16 B 18 C 21 D 27

Figure 2. *An example of MT item*

Scoring rubric for MT

Items in the MT were scored as follows:
1 - correct response.
0 - incorrect response.

Procedures

There were three phases in the study. The first phase was concerned with the development and fine-tuning of mathematics test. The details are explained in the MT task section. During the second phase, we pilot tested both the tests to allow for familiarisation process of the data collection processes, to validate the instruments used in the study and to establish the reliable measurements. The third phase involved the administration of the two tests. Both tests were administered during regular mathematics classes. Researchers and classroom teacher assisted in the administration of the tests. The MT, a one-hour paper and pencil format test, was administered in the first instance. Students were invited to complete the SRT in the following week. They were allowed a maximum of 40 minutes for SRT.

Data analysis

Statistical analysis

Descriptive statistics such as frequency and percentage were used to describe the background information about the respondents who participated in this study. Means and standard deviation were used to describe the level of students' SRS and achievement level. In addition, there were two applications of inferential statistics used in this study, namely the t-test and Pearson correlation test.

Results

Four research questions were of interest to the present study. Data relevant to these research questions are presented below.

Research question 1: What are the levels of SRS among upper secondary school students?

Table 3 shows the overall level of SRS exhibited by the participating Year 11 students. The findings of the study showed that 330 (94%) of the students achieved Level 1 (*concrete*) of SRS, 20 (5.7%) achieved Level 2 (*transitional*) and only 1 (0.3%) of them achieved Level 3 (*formal*). The overall mean level of the SRS was 1.76. This indicates that majority of the participating students exhibited *concrete* reasoning level of SRS.

Table 3. Level of SRS

SRS Level	N	Percentage(%)	SRS Mean Score	Standard Deviation
Concrete	330	94.0	1.50	1.18
Transitional	20	5.70	5.65	0.81
Formal	1	0.30	9.00	-
Total	351	100.00	1.76	1.55

Research question 2: Is there a relationship between the SRS and mathematics achievement?

Table 4 displays the results of the analysis of correlation between the SRS scores and Mathematics Achievement. Overall, the correlation between the SRS and Mathematics Achievement was significant indicating a positive relationship between the two variables [(r = 0.593), $p<0.05$]. The coefficient of correlation (r = 0.593) indicating that there was a moderate positive relationship between the SRS and Mathematics Achievement. This suggests that if a student had a high score in SRT, he/she are expected to achieve high score in MT.

Table 4. Correlation between SRS and mathematics achievement

		SRS	Mathematics Achievement
SRS	Mean	1.76	56.40
	Pearson Correlation	1	.59**
	Sig. (2-tailed)		.000

** sig. at $p<0.01$

Research question 3: How does achievement group affect students' SRS and mathematics achievement?

T-test analysis was performed to compare the mean scores of the overall level of SRS for Achievement Group. Analysis as presented in Table 6 showed there were differences in mean overall SRS between

High and Low-Achievement groups [t (349) = 9.260, p < 0.05]. The mean SRS level for High-Achievement group (mean = 2.99) is better than the Low-Achievement group (mean = 1.28). However, based on the interpretation of the SRS scores as presented in Table 5, the level of SRS for both groups of students are in *concrete* reasoning level. The results also showed there were differences in mean overall MT score between High and Low-Achievement group [t(349) = 16.789, p < 0.05]. The mean MT score for High-Achievement group (mean = 81.02) is better than the Low-Achievement group (mean = 46.86). This indicates that students have different levels of SRS (in terms of their SRS score) and Mathematics Achievement as measured by the MT based on Achievement Group. Specifically the High-Achievement group had better SRS and MT scores than the Low-Achievement group.

Table 5. SRS score and MT score vs achievement group

Dependent Variable		Achievement Group		t-value	p-value
		High	Low		
SRS score	Mean	2.99	1.28	9.260	**
	SD	1.66	1.21		
MT score	Mean	81.02	46.86	16.789	**
	SD	13.42	18.32		

** sig. at p<0.01

Research question 4: How does gender affect students' SRS and mathematics achievement?

The results of t-test analysis as illustrated in Table 6 showed there was no significant difference in the overall level of SRS scores between boys and girls [t(349) = 0.765, p > 0.05]. Inspection of the mean value as a whole, boys (mean = 1.82) and girls (mean = 1.70) had quite a similar mean values.. In addition, analysis also revealed there was no significant difference in the overall MT scores between boys and girls [t(349) = 1.99, p = 0.05]. Both boys and girls had quite a similar mean values, boys (mean = 53.98) and girls (mean = 58.83). These findings indicate that students have similar levels of SRS and Mathematics Achievement based on Gender.

Table 6. SRS score and MT score vs gender

Dependent Variable		Gender		t-value	p-value
		Boys	Girls		
SRS score	Mean	1.82	1.70	0.76	0.44
	SD	1.72	1.36		
MT score	Mean	53.98	58.83	1.99	0.05
	SD	23.49	22.22		

Discussion

The study was designed to generate data relevant to issues about level of SRS and Mathematics Achievement among Malaysian students. The first research question addressed the level of SRS among upper secondary school students. We found participants in this study did not do well in SRT. Contrary to our expectation, there was not even spread in the scores for SRS. Almost all the students (94.0%) were in the *concrete* reasoning level and others were in the *transitional* (5.7%) and *formal* (0.3%) reasoning levels.

The second research question addressed the relationship between SRS and Mathematics Achievement. The results indicate that there was a moderate positive correlation between the SRS and Mathematics Achievement as measured by the MT. Data analysis relevant to Research Question 3 showed that students in the High-Achievement group performed significantly better than their Low-Achievement peers in the

MT and SRS scores. Given the positive correlation betweeen SRS and MT, it can be argued that the higher MT scores of High- Achievement group can be atrributed to their superior SRS. However, the SRS scores for all the students including the High-Achievement group was lower suggesting they were operating at *concrete* level.

Interestingly, the relatively higher SRS scores for the High-Achievement group is still low in terms of the SRS level they have achieved. The mean SRS score for this group was 2.99 which falls well into the *concrete* reasoning level. However, as shown in Table 6, despite relatively low SRT scores for High-Achievement group, the score on MT for this group was significantly high (mean = 81.02) in comparison to the Low-Achievement group. The breakdown of SRS levels along Achievement Group did not generate significant differences. This is somewhat surprising given that the low SRS scores did not, as expected, lead to low MT scores. Thus, it would seem that students in High-Achievement group were using processes in addition to SRS, a claim that needs further investigation. The relationship between SRS and Mathematics Achievement for the Low-Achievement group was as per our expectation. That is, low SRS scores for students in the Low-Achievement group led to low score in MT. Thus, it would seem that for Low-Achievement group, SRS play a significant role in their solution search. These results are consistent with the findings of Chinnappan and Lawson (1996) who reported that general problem-solving strategies such as SRS would have a greater effect on low-achieving students.

Gender related analyses of SRS and Mathematics Achievement is relevant to the fourth research question. The result does not indicate significant differences for both SRS and Mathematics Achievement for Gender. This is in contrast to the findings as reported by MOE (2013) which indicates significant differences among girls and boys; girls are performed better than the boys. Thus further investigation is required to explain the pattern of results reported by MOE and these results of present study.

In our analysis of level of SRS, Mathematics Achievement and Gender related inputs, the investigation did not consider the cultural context of the participating students. The students in this study had three types of linguistic backgrounds- Malay, Mandarin and Tamil. It would be interesting to explore the link between students' linguistic background, reasoning skills and mathematical problem solving outcomes.

Review of literature has shown the existence of a positive link between SRS and achievement across different subject domains in secondary curriculum. For example, Schen (2007) found that students who have higher level of SRS tended to perform better in their study of Biology. Such studies that provide empirical evidence for the relationship between SRS and academic achievements are limited, particularly research linking reasoning with achievement in mathematics. In this study, we generated empirical data between SRS and Mathematics Achievement.

In the present study, we drew on Lawson's work concerning the three levels on the assumption that this level would capture the multitude of students' reasoning activated during novel mathematical problem solving. As mentioned above, although all students were operating at Level 1 of SRS, their performance in MT, particularly for the High-Achievement group, was high. It would seem that students are engaging in substantial reasoning when they complete the MT tasks. But this range of reasoning skill was not fully captured by Lawson's levels. We, therefore suggest that Lawson's level of reasoning need to be further developed in order to sensitize it to the nuances of mathematical thinking.

One could provide an alternative interpretation for the apparent lack of link between the low SRS scores for the High-Achievement group and their high MT score. It is plausible that there could be other processes operating in tandem with SRS during the solution of mathematical problem solving such as students' learning style. Equally, as suggested by Ball and Bass (2003) and Lakatos (1976) reasoning is embedded in deeper mathematical understandings. Thus, students's learning style and mathematical understandings constitute significant areas for future investigations..

Conclusions and implications

The low levels of SRS as exhibited particularly by the students in the Low-Achievement group can be attributed to a number of factors. Firstly, it is possible that students were not given explicit instructions

about reasoning and the role of reasoning in solving complex mathematical problems. Secondly, teachers may not understand the nature of deep reasoning and its role in helping students to solve non-routine mahematical problem solving. Based on the above assumptions, we conclude that teachers' professional programme in Malaysia must provide explicit instruction in reasoning skills.

Regular mathematics classrooms should allocate time to support students to reason without any constraints to produce correct or incorrect answers to predetermined outcomes. The current reform initiated by the Malaysian government in promoting higher order thinking skills is not grounded in a complete undesrtanding of what these skills are and how they are played out in mathematical prolem solving. Further research should be conducted to generate higher level of clarity about the roles of reasoning in mathematics learning.

Low performances in TIMSS and PISA by Malaysis students could be attributed to poor reasoning skills. This study indicates that reasoning skills are important at least for the Low-Achievement group. The results provided added support for the claim that in order to do well in TIMSS and PISA, more effort has to be invested and students need to be scaffolded in development of reasoning skills.

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