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Developing Themes of Guiding Principles to Foster Higher Order Thinking Skills in Teaching and Learning of Mathematics

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Abstract

The trend results of TIMSS and PISA shows that students' achievement is low in the field of mathematics, especially in answering questions that require Higher Order Thinking Skills (HOTS). Thus Malaysian Education Blueprint 2013-2025 suggested transitions in mathematics education from focusing on cognitive algorithm skills to the implementation of HOTS in teaching and learning of mathematics. A holistic framework in the form of comprehensive processes of fostering HOTS in mathematics teaching and learning is needed to guide teachers in implementation suitable activities in the classroom. Therefore, this research is intended to develop a Guiding Principles of Fostering Higher Order Thinking Skills (GP-HOTS) in teaching and learning of mathematics for secondary school students. Specifically, this article discusses the analysis of HOTS inculcation development in teaching and learning in general and in mathematics education to generate items and themes for GP-HOTS. This qualitative analysis document involves two strategies. Firstly, the electronic databases and journals used to find related articles. In addition, the journals related to HOTS are analyzed to identify more relevant journals. Keywords used for search is HOTS, creative thinking, critical thinking, methods/strategies/techniques for teaching in the 21st century, and the methods/strategies/techniques for effective teaching. At the second stage, the method of snowballing is used to identify the items and themes for GP-HOTS. The themes and items for GP-HOTS were then tested for the content validity and reliability by determining the content validity and the alpha Cronbach indices. The results showed that there are seven main themes of how teachers can foster HOTS in teaching and learning of mathematics namely determining the learning outcomes, planning questioning strategies, practicing active learning, developing habits of mind, practicing reflective thinking, implementing optimally assessment for learning and integrating information, communication and technology. The themes and its items have satisfied level of content validity indices for the face and content validities as well as revealed excellent

acceptable level of reliability index. Those themes and its items which contributed to GP-HOTS are important in helping to improve teachers' mathematical knowledge for teaching, hence creating futuristic minded students.

Keywords: Higher Order Thinking Skills, Secondary School, Teaching and Learning of Mathematics

Introduction

Quality of teaching is a major impact on student engagement and achievement in the classroom (Darling-Hammond, 2000; Barber & Mourshed, 2007; Jensen, 2010; Elliot, 2015; Adnot et al., 2016; Ryan, 2016). In particular, teachers' understanding of mathematics, curriculum and higher order thinking skills contribute to the classroom practice, their professional development as well as students' achievement (Loucks-Horsley et al., 1998). However, higher-order thinking skills among mathematics teachers in Malaysia are still at low level and the teaching and learning process involves mathematical algorithm that emphasize procedural skills (Kementerian Pendidikan Malaysia (KPM), 2013; Nooriza & Effandi, 2015). A study by AKEPT 2011 found that 50% of teachers observed failed to deliver their lesson effectively, especially to foster students' higher-order thinking (KPM, 2013). Past researches have proven that the most important problems facing teachers is their unwillingness to implement the agenda, lack of knowledge, pedagogical skills and attitudes towards teach (Rajendran, 2008; Rosnani & Suhailah, 2003; Nooriza & Effandi, 2015) as well as students need to first find out all the facts and concepts of a subject before they can be encouraged to think (Sukiman et al., 2012). Many studies also show that modules are important requirement raised by teachers in implementing elements of HOTS (Yee et al., 2012; Nooriza & Effandi, 2015). However, the module is only temporary medium of teaching because normally the module consists of selected topics, and may be suitable for the targeted group of students. Hence, a framework which enables the process of how to apply HOTS in teaching and learning of mathematics should be designed so that teachers always have the appropriate guidelines to implement activities in the classroom. Thus, this study aims to develop a guiding principle to foster HOTS in teaching and learning of mathematics.

Higher Order Thinking Skills in Mathematics Teaching and Learning

Various definitions of HOTS have been put forward by many researchers (Anderson & Krathwohl, 2001; Wengilnsky, 2002; Brookhart, 2010; Collins, 2014). As for the Malaysian Curriculum Development Division, HOTS is defined as the ability to apply knowledge, skills and values in making of reasoning and reflection for problem solving, decision making, innovative and able to create something (KPM, 2013). Generally, it can be concluded that HOTS is the intellectual process in which students must turn their minds to understand the meaning of a piece of information, recognizing the relationship between ideas, outlines the principles and rules, analyzing and classifying the individual's ability to make assessments and judgments hence combining and designing new ideas. HOTS focus on applying - ability to apply knowledge to produce something new, such as running an experiment and constructing things; analyzing - structuring information into smaller parts, determining how the overall structure or goals related to each other; evaluating - making judgments based on criteria and standards through checking

and critiquing; and creating - consolidating elements to form something; organizing, generating, designing or reproducing elements into a new pattern or structure.

Teachers are supporters of the establishment of high levels community-minded and this requires teachers themselves competently use HOTS. Intellectual engagement in the classroom is teacher's responsibility. When teachers implement the instructional containing pedagogy which helps students to develop HOTS, teachers are actually working directly to improve students' achievement (Boaler & Staples, 2008; Franco et al., 2007). In addition, HOTS development can ease the transition of knowledge and skills to responsible action and their specific functions in society in the future (Zoller, 2001).

Trends in International Mathematics and Science Study [TIMSS] and Programme of International Student Assessment [PISA] are two large-scale international comparative achievement studies that assess students' performances in mathematics. The pattern of results in TIMSS and PISA has revealed a marked decline in Malaysian lower secondary school students' mathematics performance (KPM, 2013). In the analyses of Malaysian students' performance in TIMSS over a number of years, Mullis, Martin, Foy and Arora (2012) found that only 2-10% of the students are capable of interpreting the information and drawing generalization in solving complex problems. These activities collectively demand higher order thinking. Mullis et al.(2012) also showed that 60% of Malaysian students achieved below the average score set for international benchmarking. Collectively, these results suggest that Malaysian students understand the basic mathematical concepts but, in general, are not able to transfer that knowledge to the solution of non-routine problem situations similar to those that appear in TIMSS assessment (KPM, 2013).

Likewise, the results of another international study, PISA 2009 showed that Malaysian students' performances were located in the bottom one third of all the 74 participating countries (KPM, 2013; Walker, 2011). As in the TIMSS study results, PISA's report for mathematics achievement showed that only a small proportion (8%) of Malaysian students exhibited advanced levels of thinking. Thus, trends both in TIMSS and PISA provide evidence of Malaysian students' continuing difficulty in solving mathematical tasks which involve interpretation and synthesis, key aspects of HOTS.

Among the factors that contribute to the weak achievement is because the student is not able to answer correctly the questions that require them to think on a higher level (Mullis et al. (2012)). This finding is further strengthened by the Kestrel Education Consulting (UK) study and the 21 Century schools (USA) studies where they found that higher order thinking skills among teachers and students in Malaysia is very low (KPM, 2012). Further, at the Malaysian Certificate of Education level, the distribution of questions prepared for Paper 1 and Paper 2 for Mathematics subject, the ratio of the level of difficulty which is low, medium and high is only 6: 3: 1 (Marlina, 2013). This clearly showed that the higher order thinking elements still less highlighted in the public examinations assessment in Malaysian education system. Lack of exposure to HOTS questions will led to a poor student achievement in mathematics (Rosyahaida,

2014). Our argument is that in order for HOTS to have a significant impact on students' engagement with mathematics and improve students' performance, mathematics teachers ought to implement and develop a fine-grained analysis of tasks that students encounter in international tests such as TIMSS and PISA, and demonstrate how to support students in the use of *HOTS* in making progress in such tests. This exercise can also be expected to help teachers better understand the nature and role of HOTS in their teaching and learning in scaffolding deeper learning. This could be achieved if the teaching and learning of mathematics activities that fostering HOTS is cultural practiced in mathematics classroom. Hence, Guiding Principles of Fostering Higher Order Thinking Skills (GP-HOTS) in teaching and learning of mathematics for secondary school students are needed to be developed in helping mathematics teachers to design the activities that can enhance students' HOTS.

Methodology

This study is part of a large study that was carried-out in two phases. This article will only discuss the first phase of the study. The first phase is an intensive literature review to analyze the teaching and learning of mathematics that fostering HOTS from three important perspectives; theories and models, policies and best practices. Theories and models that are related to HOTS as well as several Malaysian policy documents were reviewed. For the best practices, it is mainly a qualitative analysis document where two search strategies were used to identify the relevant literature of the studies. This strategy was suggested by Page (2008) and considered as the appropriate and efficient method to identify relevant literatures. At the first stage, relevant electronic databases such as ProQuest, SpringLink, Science Direct, Academic Search Premier, Education Research Complete, and ERIC were used to search for the relevant articles. The keywords used for search were HOTS, mathematics teaching, and secondary education.

Furthermore, individual journals pertaining to HOTS in teaching and learning were searched individually to identify more relevant papers, for example, Educational research, International Journal of Teaching and Learning in Higher Education, Curriculum and Leadership Journal, Journal of Teaching and Learning, Creative Education, Journal of Student Engagement: Education Matters, International Journal of Social Science and Humanity, Higher Education, Journal for research in Mathematics Education, Educational Studies in Mathematics, and Journal of Mathematics Teacher Education. At the second stage, snowballing method was used to identify the relevant articles which were extracted from the bibliography of key articles of this review. The literature search was conducted from August 2016 to May 2017 and limited to only Malays and English-language studies published between 2000 and 2017.

An article was considered for this review if it met three criteria: (a) it focused primarily on fostering HOTS, (b) it examined elements of HOTS in teaching and learning of mathematics or other subjects in general; (c) the research was undertaken in the setting of secondary schools and among mathematics teachers. For the purpose of this article, only peer-reviewed studies published in academic journals were included. Therefore, literature reviews, conceptual papers, conference proceedings, theses and government reports were excluded for this review. Duplicate

publications were removed. The articles were screened for relevance, mainly based on the titles, abstracts and keywords.

Having all themes and items for the Guiding Principles of Fostering Higher Order Thinking Skills in Teaching and Learning of Mathematics through extensive document analysis, the instrument was constructed and then tested for the content validity and reliability. This instrument was constructed based on the information gathered from document analysis and expert inputs. It was designed in such a manner that the form of data received can be weighted and prioritized so that it can be linked to a practical decision guiding principles for fostering HOTS in teaching and learning of mathematics. The instrument is divided into two sections. The first section enquires demographic information with fixed-choice items which allows for numerical comparison relatively easy. Items were about position, designation, name of school, teaching experience gender, highest academic qualification, professional qualification, area of expertise and subject taught. Second section of the instrument consists of five Likert scales items that measure the themes of GP-HOTS. In this study, the Content Validity Index (CVI) was calculated as an empirical measurement analysis to validate the validity of the instrument (Lynn, 1986; Lawshe, 1975; Polit & Beck, 2006). Lynn (1986) suggested the formula and procedures to determine the CVI as illustrated in Table 1.

Table 1
Determining the Face and Content Validity Index

No.	Matter											
1	Scale	Ordinal										
2	Formula	$CVI = \frac{n}{N}$ Divide the ordinal scale into two groups for example for scales 1, 2, 3, 4: 1 and 2: a group for “not agreed”, 3 and 4: a group for “agreed” and vice versa. n – numbers of evaluator agreed N – Sum of evaluator Mean CVI is a mean of all CVI each item.										
3	Range accepted	<table border="1"> <thead> <tr> <th>N</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>2-4</td> <td>1.00</td> </tr> <tr> <td>5</td> <td>> 0.83</td> </tr> <tr> <td>6</td> <td>> 0.86</td> </tr> <tr> <td>7-10</td> <td>> 0.78</td> </tr> </tbody> </table>	N	Value	2-4	1.00	5	> 0.83	6	> 0.86	7-10	> 0.78
N	Value											
2-4	1.00											
5	> 0.83											
6	> 0.86											
7-10	> 0.78											

Upon completion of validity measure the reliability of the guiding principle instrument was established. Cronbach’s Alpha coefficient is widely used to measure the reliability of Likert data that forms the psychometric instrument (Subedi, 2016). The value of Cronbach’s Alpha

coefficient varies from .00 to 1.00 and the alpha value of .65 to .95 is satisfactory, showing that the instrument has appropriate levels of reliability.

Findings and Discussion

This section will discuss the findings based on the teaching and learning of mathematics that fostering HOTS from three important perspectives, namely the theories, policies and best practices.

Theories Perspectives

Three main theories related to teaching and learning of mathematics that fostering HOTS are Skemp's (1979) mathematical understanding, Bruner's and Dienes's multi-modal representation approaches and Piaget's cognitive development (Wong, 2009). Skemp (1979) proposed three types of understanding: (a) instrumental understanding as knowing the rules without reason, dependent on memory, and short term in effect; (b) relational understanding as knowing what to do and why, easily constructed from general principles, and more permanent; and (c) logical understanding as conforming to accepted conventions in mathematics and pertaining to logical proof. Skemp also explained that mathematical concepts of a higher order than those a person already knows cannot be communicated to that person by mere definition. At the secondary levels, a definition with ample examples and non-examples must be used. This will lead the teacher to ask the students to discuss similarities and differences using the thinking skill compare and contrast which show the use of HOTS elements.

The multi-modal approach is an extension of the ideas of Bruner and Dienes (Wong, 2009). Bruner proposed that to acquire mathematical concepts, the learner works through the three modes: enactive, iconic and symbolic. Dienes enunciated the principle of multiple embodiment, which states that several related models must be used to help students abstract the relevant mathematical concepts. Thus, to put these principles into a practical form, mathematics teachers should have designed strategies that consisting of those modes to acquire HOTS, hence developing students to think mathematically as well as understand better and are more motivated.

Piaget in his theory of cognitive development has mentioned that the key to cognitive development is developmental stages. Initially, students develop operational thinking, logical and finally systematic manipulation of symbols (Slavin, 1988). At the formal operational stages, students can think beyond concrete objects, and have developed deductive thinking and combinatorial thinking (Wong, 2009). Piaget also described two cognitive processes when learners attempt to learn new materials; the assimilation and accommodation processes. The assimilation process means that the learner can integrate new experience into existing cognitive structure without much difficulty. On the other hand, accommodation means that the learner has to modify existing schema or create new one in order to learn new things. Therefore, mathematics teachers need to be sensitive to these implications that arise from the different cognitive processes involves when students tackle new task. Both Piaget and Bruner focus on active learning, active inquiry and discovery, inductive reasoning, intrinsic motivation, and

linkage of previously learned concepts and information to new learning. These lead teachers to create situations in which teaching and learning of mathematics should foster HOTS where students think about the thinking process thus equipping students to solve problems not only in academic work but also in real life problems.

Policies Perspectives

Two policy documents were analysed, namely the Malaysian National Education Philosophy (MNEP) and the Malaysia Education Blueprint (PPPM) 2013-2025 which related to enhancing HOTS in teaching and learning for the Malaysian nation. The MNEP written in 1988 and revised in 1996, enshrines the Ministry's and Government's vision of education as a means for the holistic development of all children: intellectually, spiritually, emotionally, and physically (KPM, 2013). The process of education is claimed to be able to develop the potential of an individuals. The holistic development means integrating all potential of individual in such a manner that produces balanced and harmonious citizens. Balanced individuals are those that have a balance in their physical, emotional, spiritually and social development. Physical aspect includes aspects such as maintaining physical agility and good health that enable those individuals to work independently and contribute towards the personal well being as well as for the betterment of family, society and nations. Meanwhile intellectual aspect covers the cognitive knowledge. Cognitive here not only includes the ability to think rationally logically and solving problem. Being knowledgeable and able to think critically and creatively is important, and these are elements of HOTS. Meanwhile the spiritual and emotional aspects cover elements such as belief in God, embrace religious faith, spiritual stability, emotional intelligence, appreciation of moral value and norms of society, good behavior, loyalty and willing to sacrifice for the people and the country.

The Malaysia Education Blueprint 2013-2025 (KPM, 2013), the master plan for education sector development in Malaysia, came about as a result of a comprehensive review of the education system in 2011. The Blueprint affirms the critical role of education in turning Malaysia into a knowledge-based economy, able to compete in the increasingly globalised economy. The Blueprint puts at the forefront seven student aspirations which should be based on Knowledge, Thinking Skills, Leadership Skills, Bilingual Proficiency, Ethics and Spirituality, and National Identity. Specifically, the thinking skills element which related to HOTS is one of the main focus in this study. Students learn how to continue acquiring knowledge throughout their lives, connect different pieces of knowledge, and create new knowledge. Furthermore, they should master a range of important cognitive skills, including critical thinking, reasoning, creative thinking, and innovation. This is an area where the system has historically fallen short, with students being less able than they should be in applying knowledge and thinking critically outside familiar academic contexts (KPM, 2013). Hence, the emphasis in teaching and learning is no longer just on the importance of knowledge, but also on developing HOTS.

Best Practices Perspective

Basically, no articles were found on theme of guiding principle of fostering HOTS in mathematics teaching. However, this review found a total of 15 articles on themes related to fostering HOTS in teaching and learning of mathematics as well as in general subjects, published

between 2010 and 2017 (Table 2). These articles were published in several multidisciplinary journals associated with mathematics education, science education, general education and technology. Two papers were published in 2010 and two articles in 2012 and 2014. Only one paper was published in 2011 and it is the only one related to the habit of minds. The quantity was increased to 4 and 3 in 2015 and 2016 respectively. During the search period for this review article, no paper was published in 2017. However, this figure is expected to grow as the area of study is gaining increasing popularity. Table 1 showed that there are seven main themes of namely determining the learning outcomes, practicing questioning strategies, practicing active learning, developing habits of mind, practicing reflective thinking, conducting optimum assessment for learning and integrating information and communication technology. Most of the articles discussed each of the themes separately and the theme on practicing an active learning was the most that can be found.

Table 2
Articles on Themes Related to Fostering HOTS in Teaching and Learning of Mathematics

Themes		Authors						
		Determining learning Outcomes	practicing questioning strategies	Practicing Active learning	Developing habit of mind	Practicing reflective thinking	Conducting optimum assessment for learning	integrating ICT on technology
1	Nardone and Lee (2010)			X				
2	Limbach and Waugh (2010)	X	X	X		X	X	
3	Yee et al (2011)				X			
4	Liljedahl (2012)			X				
5	King et al (2012)		X	X			X	X
6	Ghasempour et al (2013)			X				
7	Collin (2014)	X	X	X				
8	Kwan and Wong (2014)			X				
9	Chan and Yan (2015)	X	X	X		X	X	
10	Kong (2015)			X				
11	Tunca (2015)			X				
12	Tandiseru (2015)			X				
13	Sanders (2016)			X				
14	Hino (2016)					X		
15	Salihuddin et al (2016)							X

Based on comprehensive document analyses on theory, policies and best practices, there are seven main themes teachers can foster HOTS in teaching and learning of mathematics namely determining the learning outcomes (7 items), practicing questioning strategies (16 items), practicing active learning 16 items), developing habits of mind (7 items), practicing reflective

thinking (6 items), conducting optimum assessment for learning (7 items) and integrating information and communication technology (6 items). Further, the validity and reliability processes were done to ensure all the themes of the guiding principle are appropriate. The face and content validity of the themes were analyzed using the content validity index (CVI). The CVI values for all five experts were presented in Table 3 (face validity) and Table 4 (content validity). Number 1 indicated a favorable rating, while 0 means unfavorable rating. In addition, the experts were also requested to give comments and additional suggestion to improve the themes as well as the items. Using CVI method, the acceptable standard for index of average congruity recommended by Waltz (2005) (cited in Polit & Beck, 2006) is .90 for five evaluators. In this case, $0.91 > 0.90$ for face validity and $0.96 > 0.90$ for content validity, hence suggested that the instrument could be considered evidence of good face and content validity.

Table 3
CVI values for Face Validity

Item	Aspect	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	CVI
1	Format of the instrument are accepted.	1	1	1	1	1	1
2	The instructions are clear.	1	0	1	1	1	0.8
3	Words used are appropriate.	1	0	1	1	1	0.8
4	The font size is appropriate.	1	1	1	1	1	1
5	The words spelling are correct.	1	1	1	1	1	1
6	The grammar used is correct.	1	0	1	1	1	0.8
7	The terms used are appropriate.	1	1	1	1	1	1
mean							0.91

Table 4
CVI values for Content Validity

Theme	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	CVI
Determining the learning outcomes	1	1	1	1	1	1
Planning questioning strategies	1	1	1	1	1	1
Practicing active learning .	1	1	1	1	1	1
Developing habits of mind.	1	1	1	1	1	1
Practicing reflective thinking	1	1	1	1	1	1
Implementing optimally assessment for learning	1	0	1	1	1	0.8
Information and Communication Technology Integration	1	1	1	1	1	1
	mean					0.97

After the validity processes were done, a survey was conducted to establish the reliability of the themes as well as the items on the constructed instrument. A representative sample of the target population was purposely selected for this survey. Thirty five secondary mathematics teachers from different schools from the state of Selangor and Perak were randomly chosen for this purpose. The result of the internal consistency tests for the survey was reported to be 0.97, hence is excellent acceptable level for this research purposes (Creswell, 2014). The above results indicated that the seven themes and its items are suitable in fostering HOTS in mathematics teaching.

Conclusion

The study has successfully developed seven main themes of how teachers can foster HOTS in teaching and learning of mathematics namely determining the learning outcomes, planning questioning strategies, practicing active learning, developing habits of mind, practicing reflective thinking, implementing optimally assessment for learning and integrating information, communication and technology. The themes and its items have satisfied level of content validity indices for the face and content validities as well as revealed excellent acceptable level of reliability index. The GP-HOTS adds the pedagogical knowledge in line with the 21st century learning which emphasizes on thinking skills as well as problem solving skills. This knowledge enhances ideas to all educators especially the mathematics educators to constantly update the latest information on teaching and learning. Specifically these guiding principles emphasize on how teachers can plan activities that are useful for fostering students' HOTS. In addition, teachers are not required to use certain modules but they can refer these guiding principles and diversify their teaching methods in developing students' HOTS. Those developed themes and it items which contributed to GP-HOTS are important in helping to improve teachers' mathematical knowledge for teaching, hence creating futuristic minded students.

As mention earlier, this article only reported findings from the first part of a large study that was carried-out in two phases. Further studies on exploratory factor analysis and confirmatory factor

analysis will be done to explore and verify the possible underlying factor structure of the developed GP-HOTS in mathematics teaching.

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