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ROLE OF HIGHER ORDER THINKING SKILLS IN ENHANCING TIMSS TASKS

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Abstract

Students' performances in TIMSS and PISA have featured strongly in recent discussions and debates about the quality of mathematical learning outcomes both from teachers and policy makers. Findings of TIMSS and PISA showed that most high school students in Malaysia continue to perform at less than satisfactory levels. Particularly, in tasks that are cognitively demanding. However, such findings are based on a broad-brush view of the performance of Malaysian students. In this analysis, there is a lack of information about the kind of tasks which are proving to be problematic to the students. This latter information, we argue is critical for future actions aimed at lifting their TIMSS performances. The Malaysian Ministry of Education had advocated for the integration of Higher Order Thinking Skills [*HOTS*] in mathematics and science. The result of TIMSS has placed greater emphasis on the need to teach *HOTS* effectively. Our argument is that in order for *HOTS* to have a significant impact on students' engagement with and improvement on TIMSS, researchers ought to undertake a fine-grained analysis of student performances in relation to particular tasks and use this information to help teachers understand and integrate *HOTS* in their teaching. In this paper, we present a critical analysis of selected TIMSS Tasks and demonstrate how to better support students in the use of *HOTS* in making progress with such tasks. In so doing we present a methodology that can be utilised by teachers better understand the role of *HOTS* in empowering students move from lower to higher levels of cognitive funtioning in the context of TIMSS and similarly demanding tasks. Our methodology provides an important starting point for the design of future professional development programs for Malaysian mathematics teachers in articulating *HOTS* and implementing them in regular classrooms.

Key words: Higher Order Thinking Skills [*HOTS*], mathematics problem solving, secondary mathematics, TIMSS Tasks, mathematics teacher professional development, level of

INTRODUCTION

Students' mathematics achievement is often associated with the future economic power and competitiveness of a country. Therefore, the desire to understand and identify factors that may have meaningful and consistent relationships with mathematics achievement has been shared among national policy makers and educators around the world. Today, it is widely accepted that that the main purpose of educational systems is to teach students how apply mathematics in a range of contexts. Higher Order Thinking Skills [*HOTS*], such as logical thinking, critical thinking and reasoning skills are the basic skills for daily life, apart from the academic achievements in the schools (Marshall & Horton, 2011). In order to lift performance of students, the nature and development of these skills, specifically in the context of mathematics teaching and learning must be understood by teachers in all sectors of education

(Santos-Trigo & Moreno-Armella, 2013).

The extent to which mathematics teachers understand the role of *HOTS* in learning and applying mathematics is emerging to be an issue. Hinde and Perry (2007) commented that teacher in general tended associates cognitive skills with the school's curriculum, with limited attention to the role of these skills in facilitating student's thinking and learning within particular subject. Further, teachers have limited opportunities to engage in activities with the students that will support the development of high order cognitive abilities (Ewing, Foster & Whittington, 2011, Ministry of Education, 2013). The ability to integrate *HOTS* in mathematics can be hampered by a number of factors including teacher's limited knowledge of *HOTS* (Harpster, 1999).

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 (Ministry of Education, 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 and colleagues 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 (Ministry of Education, 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 (Walker, 2011; Ministry of Education, 2013). 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*.

It is critical that there is a need for future actions aimed at lifting Malaysian students' TIMSS and PISA performances. In a more recent policy decision, in an effort to enhance students' performances in mathematics, the Malaysian Ministry of Education had advocated for the integration of *HOTS* in mathematics and science. Our argument is that in order for *HOTS* to have a significant impact on students' engagement with mathematics and improve students' performance, researchers ought to undertake a fine-grained analysis of tasks that students encounter in international tests such as TIMSS, 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 present paper will illustrate a methodology that can be utilised by teachers to better understand the role of *HOTS* in empowering students move from lower levels to higher levels of cognitive funtioning in the context of TIMSS and similar tasks. Before analyzing the TIMSS tasks, it is necessary to understand the framework for TIMSS mathematics assessment. In this paper, we will focus on mathematics tasks completed by eighth grade students in TIMSS 2011.

RELATIONSHIPS BETWEEN *HOTS* AND TASK VARIABLES

In analyzing the TIMSS tasks, task variables such as mathematical *Content* underpinning the problems and *Representation* of the problems will be described. The link between these two concepts with the role of *HOTS* will be explained so that teachers will be better understand how to empower students with higher levels of cognitive processes during mathematical problem solving.

A major concern of this paper is to elucidate the role of *HOTS* in helping students tackle cognitively demanding problems in international assessment of mathematics such as TIMSS. We have identified two key dimensions of these context problems. Firstly, we have analysed *Content* that is embedded in the problems. Secondly, the construction of potentially useful *Representations* of the problems was identified. In this section, we examine links between the two above dimensions of the task variables and the *HOTS*. Figure 1 provides a schematic representation of these key constructs. As indicated in the figure, all three constructs are informed and informed by each other.

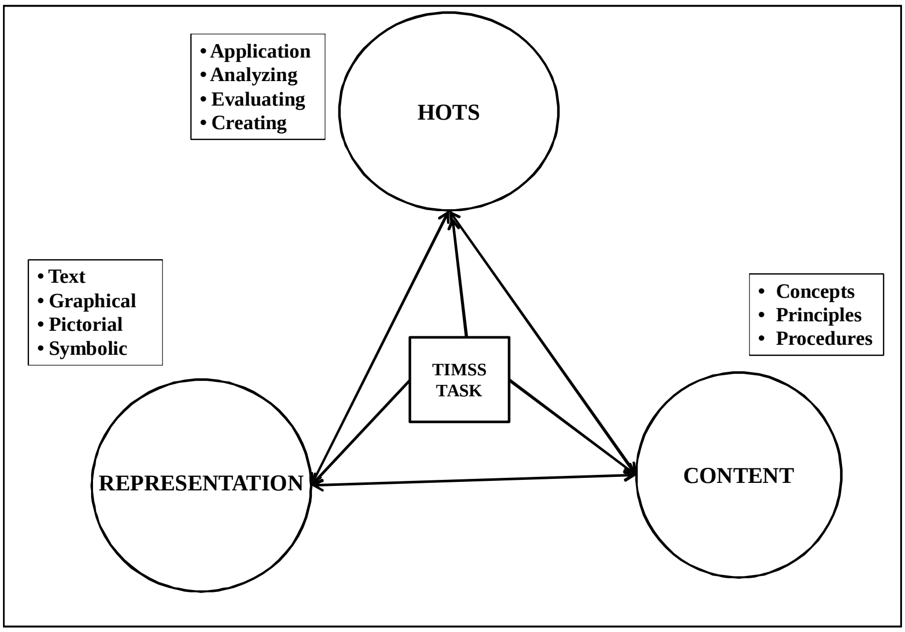


Figure 1: Relationship between *HOTS* and Task Variables

We illustrate the links between *HOTS*, *Content* and *Representation* by considering a problem task (Figure 2). In order to solve this problem, students need to convert the problem statement into a visual representation. This transformation requires students to identify the necessary elements and determine the links between these elements, a process that requires *Analyzing* – one of *HOTS*. Following the decision to translate the texts, students could construct a visual followed by symbolic representation (equation). This latter step of constructing involves *Creating*- another *HOTS*. Through the creation of the visual representation, students could focus on the mathematical content that underpins the problem including rectangular shape, semicircle, perimeter, area and integer. On completing the solution, students could also engage in activity that examine the reasonableness of the values of *x* and *y* – *Evaluating (HOTS)*. The next step could involve the use of a strategy where the students solve the equation by working from the known to.

Given ABCD is a piece of rectangular paper with an area of 28 cm^2, a width of $7x$ cm and a length of y cm. AEB is a semicircle-shaped cut from the paper. The remaining perimeter of the paper is 26 cm. Find the integer values of x and y (Use $\pi = \frac{22}{7}$).

Figure 2: Mathematical Problem Task

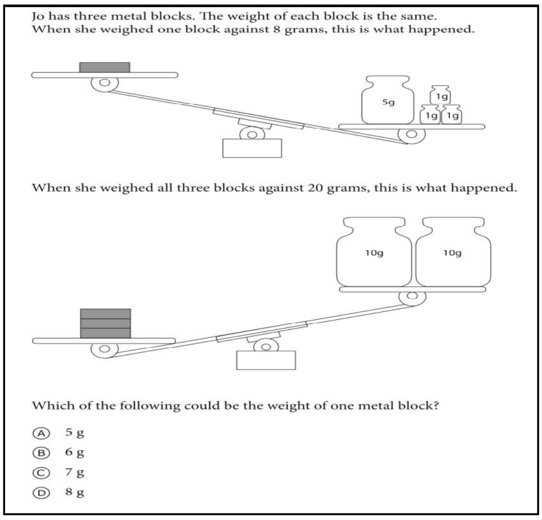
The process of setting up an equation or the generation of other equations involves translation from language to symbols. Collectively, these activities involve *Analyzing* and *Evaluating* such as detecting the appropriateness of a procedure for the given problem, activities that are formed parts of *HOTS*. In summary, mathematical problem solving requires algorithmic and non-algorithmic thinking by accessing relevant *Content* knowledge. This knowledge drives *Representations*, activation of strategies and *HOTS*, all of which work in tandem. In this interplay, it is important to recognise that all the three constructs (*HOTS*, *Content*, *Representation*) are interwoven and interdependent on each other.

ANALYSIS TIMSS TASKS

We now turn to selected TIMSS tasks (Foy, Arora & Stanco, 2013) to demonstrate the role of *HOTS, Concept and Representation* during the developiment of potential solutions.

Example (TIMSS 2011)

As indicated in Figure 3, this task involves the establishment of inequalities (*Content*) and the identification of a strategy which could enable the students to determine the weight of one metal block. By critically *Analyzing* (*HOTS*) this problem, students need to transform the visual comparison of the weights into alternative *Representations* involving inequalities. Thus, the process of setting up these inequalities involves translation from visual to symbolic (inequality). While the *Representation* in the form of inequality is important strategy, the building of this *Representation* involves integration of number of relevant information – *Creating* which is *HOTS*.



Content Domain: Algebra
Topic Area: Equations/ Formulas and Functions
Cognitive Domain: Reasoning

Figure 3: Example 1 of TIMSS 2011 Task

Students had to create two inequalities that are consistent with the two conditions of weight comparisons. Following this, they have to *Evaluate* (*HOTS*) which values for the weight of one metal block that will satisfy the condition of the inequalities. At this point, a guess-and-check strategy may be appropriate in producing a rapid solution. In applying the guess-and-check heuristics, students will iterate the process of substituting 5, 6, 7, and 8 into the inequalities until the available solution is found. The solution also can be found by solving the inequalities algebraically to find the weight of one metal block. Both strategies involve *Applying* (*HOTS*) that focus on the students' ability to apply knowledge and concept to understand the question. In sum, throughout the solution process students have used cognitive processes of varying levels of complexity that are directly related to HOTS – *Applying, Analyzing, Evaluating* and *Creating.*

SIGNIFICANCE OF *HOTS* IN HELPING STUDENTS TACKLING TIMSS PROBLEMS

We have demonstrated that *HOTS* are crucial for students to move from one phase to another phase by activating relevant *Content* and marshalling this information during the construction of rich and powerful *Representation*. However, teachers play a critical role in foregrounding and integrating *HOTS*, *Content* and *Representation* in the above problem contexts. Our analyses in this report shows that the relation between the above three key constructs are complex and that teachers need support in understanding these relationships in the context of non-routine problems.

The conceptual framework provided in Figure 1 explicates the links between *HOTS*, *Content* and *Representation* and provides a useful guide for classroom practice. In order for teachers to orcharstrate these three co-dimensions, they need to undertake the critical analyses of the mathematical tasks in question.

Mathematics teachers also need guidance in lesson planning that articulate a clear understanding of what constitute *HOTS* instruction, and how to implement them in regular classroom. The results of our tasks analyses and *HOTS* provides an important starting point for designing future professional development programs for Malaysian mathematics teachers in adapting *HOTS* into secondary mathematics instruction.

CONCLUSION

In this paper, we have presented a methodology that can be utilised by matematics teachers better understand the role of *HOTS* in empowering students move from lower levels to higher levels of cognitive funtioning in the context of problem tasks that appear in TIMSS. We hve attempted to make explicit the role of *HOTS* in helping students during the solution of TIMSS. In so doing, we have built a conceptual framework which relate the three key constructs: *HOTS, Content* and *Representation*.

Through a critical analysis of selected TIMSS tasks, we have showed how *HOTS* could play a significant role in mathematical understanding and problem solving. This conceptual framework constitutes a significant advancement in connecting literature on *HOTS* and in solution of problems that appear in TIMSS. In order to help teachers develop specific activities to support the students, future studies could examine the validity of this framework by emiprical means.

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REFERENCES

Foy, P., Arora, A. & Stanco, G. M. (2013). Timss 2011 User Guide for the International Database Released Items Mathematics – Eight Grade. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.

Harpster, D. L. (1999*). A study of possible factors that influence the construction of teacher-made problems that assess higher-order thinking skills*. Unpublished Doctoral Dissertation. Montana, USA: Montana State University-Bozeman.

Hinde, E. R. & Perry, N. (2007). Elementary teachers' application of Jean Piaget's theories of cognitive development during social studies curriculum debates in Arizona. *The Elementary School Journal, 108(1),* 63-79.

Marshall, J. C. & Horton, R. M. (2011). The relationship of teacher-facilitated, inquiry-based instruction tostudent higher-order thinking. *School Science and Mathematics, 111(3),* 93-101.

Ministry of Education. (2013). *Malaysia Education Blueprint 2013-2025 (Preschoool to Post-Secondary Education*, Putrajaya, Malaysia: Kementerian Pendidikan Malaysia.

Mullis, I. V. S., Martin, M. O., Ruddock, G. J., O'Sullivan, C. Y. & Preuschoff, C. (2009). *TIMSS 2011 assessment framework*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.

Mullis, I. V. S., Martin, M. O., Foy, P. & Arora, A. (2012). *TIMSS 2011 International results in mathematics*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College. Retrieved 2nd January 2013, from http://timssandpirls.bc.edu/timss2011/downloads/T11_IR_Mathematics_FullBook.pdf.
National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics.Reston.* VA: NCTM.

Santos-Trigo, L. & Moreno-Armella, L. (2013). International perspectives on problem solving research in mathematics education, a special issue. *The Mathematics Enthusiast, 10(1&2),* 3–8.

Walker, M. (2011). *PISA 2009 Plus results performance of 15-years olds in reading, mathematics and science for 10 additional participants*. Melbourne: Australia Council for Educational Research (ACER). Retrieved 30 August 2012, from http://research.acer.edu.au/cgi/viewcontent.cgi?article=1000&context=pisa.