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.
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 functioning 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.

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.
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 development 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.
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 orchestrate 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 mathematics teachers better understand the role of HOTS in empowering students move from lower levels to higher levels of cognitive functioning in the context of problem tasks that appear in TIMSS. We have 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 empirical means.
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REFERENCES


