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# HOTS: EVIDENCE FROM TIMSS 2011 & ITS IMPLICATION TOWARDS STEM

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**Abstract**

*Science, Technology, Engineering and Mathematics (STEM) education aims to prepare all students with higher order thinking skills to succeed in the 21st century. However, based on The Trends in International Mathematics and Science Study (TIMSS) in 2011, Malaysian students are still weak in higher order thinking skills (HOTS) not only in answering science questions but also in solving science problems. This research was carried out through a microanalysis of TIMSS 2011 in the science assessment. The study found out that Malaysia performed lower than the international average benchmarking in all the cognitive domains except for reasoning in Biology. In fact Singapore and Thailand out performed Malaysia in TIMSS 2011. Malaysia's science education system requires a path of improvement which includes increasing higher order thinking skills mainly in reasoning domain. Reasoning is a crucial thinking skill in the growing interest of Science, Technology, Engineering and Mathematics (STEM) across the globe.*

***Keywords:*** Science, Technology, Engineering & Mathematics (STEM); Trends International Mathematics & Science Study (TIMSS) & Higher Order Thinking Skills (HOTS)

## Introduction

Higher order thinking skills has been discussed increasingly in the science educational literature over the past few decades by researchers' worldwide (Beyer, 1988; Costa, 1985; Glaser, 1984; Pogrow, 1988; Strenberg & Lubart, 1996; Zohar, 1999, 2006; Zohar & Dori, 2003; McLoughlin & Mynard, 2009). Fostering children's higher order thinking skills in school has been an important aim of science education whereby element such as reasoning play a vital role in engaging children in effective inquiry (Barak & Shakhman, 2008; National Science Teachers Association, 2003).

However there is a strong recent concern in researching children's higher order thinking for reasoning in the science classroom because countries across the world such as United States, United Kingdom, Australia, Spain and Israel are facing with science students whom are lacking of higher order thinking skills (Alozie et al., 2010; Osborne, 2010). Contrary to previous researches which have indicated the importance of higher order thinking skills in teaching reasoning skills among science students (Anderson, Lorin & Krathwohl, 2001; O'Brien, 2003; Barack et al, 2008; Papadouris, 2012; Wang et al., 2012; Santamaria, Tse, Moreno-Rios & Garcia-Madruga, 2012), Malaysian science students are also lacking of higher order thinking skill because Malaysian science students were not successful in applying reasoning skill which is an crucial intellectual skill in science (TIMSS, 2011; Hashim, 2006).

Parallel to that, there is a strong recent concern in researching children's reasoning in the science classroom (Alozie et al. 2010; Osborne, 2010). Waldrip, Prain and Sellings (2013) investigated children's reasoning skills in school science in generating and critiquing their own and other children's representations in several selected topic in science and this is in line with the recent TIMSS 2011 results. Reasoning skills is heavily emphasized in science because children are expected to solve multi step science problems, synthesize understandings, evaluate claims and finally justify explanations through their own understanding (Martin et al., 2012).

The decline in Malaysian students' higher order thinking skills are highlighted by the results of TIMSS 2011 whereby Malaysia performed lower than the international average benchmarking in all the cognitive domains except for reasoning in Biology (TIMSS, 2011). TIMSS 2011 assessment also pointed out that Malaysian student could not recognize the basic facts of science and communicate an understanding of complex and abstract concepts in Chemistry, Physics and Earth Science domains because they were unable to master the reasoning skill. Malaysian science students performed very poorly in science items which involve scientific reasoning skill since TIMSS 2007 because they were unable to apply scientific reasoning skill that are necessary for explaining science concept (Abdullah & Shariff, 2008; Kementerian Pelajaran Malaysia, 2000; Martin et al., 2012).

The purpose of this paper is to identify the reason behind Malaysia's alarming performance in TIMSS 2011, especially pertaining to the students' performance in cognitive domain in science subject. It is perceived that Malaysian students are weak in HOTS and does the acquisition of HOTS affect their performance in the cognitive domains?

## Science, Technology, Engineering & Mathematics (STEM)

Currently, Science, Technology, Engineering and Mathematics (STEM) education has emerged as United States' (US) development in science education. STEM education has emerged as one of the most sought after curriculum designs for integrating science, technology, engineering and mathematics into current education (Meyrick, 2011). The advantage of integrating STEM curriculum into all content areas at all grade levels is that it provides students with informal practice creatively solving problems long before they need to decide on a course of study for college (Meyrick, 2011).

The perpetual discussion to increase the number of STEM students' needs more than incentives offered to make it successful. According to Putra (2012), a transformation of the Science and Mathematics curriculum is essential to revive interest in STEM education. In fact the improved teaching pedagogy must also be flexible and be able to evolve with the times. It needs to be more proactive to the fast changing world of science. Putra (2012) adds on that improvements for transformation must address the current method of learning science and teaching by rote, as this is no longer effective in this day and age. However before addressing new transformations, it is vital to observe students' achievement in science and mathematics from time to time with the intention of measuring numerous variables such as teachers' role, students' interest, students' motivation, schools' conduciveness and many more.

Every progressive nation knows that the way to economic success and global prowess starts with a STEM education (Putra, 2012). Since Malaysia is directly comparable to the US on three issues that concern the latest developments or new findings in science, medicine and new technology (MOSTI, 2008), STEM education is also a crucial programme that needs to be given attention by Malaysian education system.

## Data & Methods

The Trends in International Mathematics and Science Study (TIMSS) is a comparative study designed in 1995 by The International Association for Evaluation of Educational Achievement (IEA) (Ghagar, Othman & Mohammadpour, 2011). TIMSS was designed to assess the quality of the teaching and learning of mathematics and science among the fourth and eighth-graders across more than 60 participating countries (Ghagar et al., 2011). Students performing at the Advanced International Benchmark communicated an understanding of complex and abstract concepts in Biology, Chemistry, Physics and Earth Science. Students also combined information from several sources to solve problems and draw conclusions and provided written explanations to communicate scientific knowledge. Malaysia has only involved eighth grade samples since 1999 for each TIMSS (Ghagar et al., 2011). Since Malaysia has allowed eighth grade students to take the TIMSS 2011 assessment, this paper discusses the analysis of higher order thinking skills among eighth grade students for science.

Subsequently this study was an initial effort in exploring the TIMSS data, hence only descriptive statistics and analysis of variance (ANOVA) were employed to analyse three countries which are Singapore, Malaysia and Thailand. International average is used as the benchmark to indicate the minimum score that should have been achieved by other countries. The advantage of ANOVA is that it allows the researchers to include as many conditions as possible in one test (Perry, Brownlow, McMurray & Cozens, 2008). According to Perry et al., (2008), the one factor independent measure design in ANOVA is for situations where the scores in each condition come from different participants and the repeated measures design is for situations where the scores in each condition come from same participants. Since the data analyses emphasises on three different countries, thus this paper employs one way ANOVA where one factor independent measure design is used to determine the cognitive domains that have significantly different means on science achievement. To make pairwise comparisons such as Malaysia and Singapore, it is most easily achieved through the post hoc test. There are advantages and disadvantages of the different post hoc tests. However Perry et al., (2008) recommends the Tukey as it controls the overall Type 1 error rate and is reasonably powerful. Apart from that, this paper also reveals the distribution of TIMSS 2011 items for both content and cognitive domain in contrast of TIMSS 2003 and TIMSS 2007 by using descriptive statistics.

## Findings

In developing the specification for the new items to be developed for TIMSS 2011, consideration was given to the pool of trend items that already existed and were to be used in TIMSS 2011 (trend items are items previously used in TIMSS 2003 or 2007 and retained for use in 2011 as a basis for measuring trends) The science trend items were mapped onto the content and cognitive domains, and new items were written to complement the existing trend item pool all described in Table 1 and Table 2 respectively.

Table 1
*Distribution of TIMSS 2011 Items by Content Domain*

| Content Domain | Number of Trend Items in TIMSS | Trend Score Points | Number of New Items in TIMSS | New Score Points | Total Items | Achieved of Score Points | Target of Score Points |
|---|---|---|---|---|---|---|---|
| **Biology** | 46 (51) | 37% | 33 (36) | 37% | 79 (87) | 37% | 35% |
| **Chemistry** | 25 (27) | 20% | 19 (20) | 21% | 44 (47) | 20% | 20% |
| **Physics** | 33 (36) | 26% | 22 (22) | 23% | 55 (58) | 25% | 25% |
| **Earth Science** | 21 (23) | 17% | 18 (19) | 20% | 39 (42) | 18% | 20% |
| **Total** | 125(137) | | 92 (97) | | 217(234) | | |

*Score points are shown in parentheses.*
*Because results are rounded to the nearest whole number, some totals may appear inconsistent.*

(Source: TIMSS & PIRLS International Study Centre, Lynch School of Education, Boston College, 2011)

Since number of trend items in TIMSS 2011 is trend items previously used in TIMSS 2003 or 2007 and retained for use in 2011 as a basis for measuring trends, there are trends of increase, decrease and no change in the entire content domain for the assessment of TIMSS 2011. Among the entire content domain, Chemistry and Earth Science are the two major content domains that has shown an emphasis in TIMSS 2011 by an increase of 1% and 3% respectively. Meanwhile Biology had no change in previous years of TIMSS assessment for science. However, Physics items declined a total of 3% in TIMSS 2011 as compared to previous years.

Table 2
*Distribution of TIMSS 2011 Items by Cognitive Domain*

| Cognitive Domain | Number of Trend Items in TIMSS | Trend Score Points | Number of New Items in TIMSS | New Score Points | Total Items | Achieved of Score Points | Target of Score Points |
|---|---|---|---|---|---|---|---|
| **Knowing** | 43 (45) | 33% | 30 (31) | 32% | 73 (76) | 32% | 35% |
| **Applying** | 58 (67) | 49% | 34 (36) | 37% | 92(103) | 44% | 35% |
| **Reasoning** | 24 (25) | 18% | 28 (30) | 31% | 52 (55) | 24% | 30% |
| **Total** | 125(137) | | 92 (97) | | 217(234) | | |

*Score points are shown in parentheses.*
*Because results are rounded to the nearest whole number, some totals may appear inconsistent.*

(Source: TIMSS & PIRLS International Study Centre, Lynch School of Education, Boston College, 2011)

Knowing, applying and reasoning are the cognitive domains which assessed the students' knowledge and understanding of science through the process of scientific inquiry in recognizing the importance of scientific inquiry in the teaching and learning process. As compared to previous assessment of TIMSS, there was a huge emphasis placed in reasoning domain in all science content for TIMSS 2011. A total of 13% were increased in reasoning cognitive form previous TIMSS assessment. The priorities of the other two cognitive domains which are knowing and applying were decreased by 1% and 12%.

Table 3
*Distribution of TIMSS 2011 Items by Content Domain and Item Format*

| Content Domain | Multiple-Choice Items | Constructed-Response Items | Total Items |
|---|---|---|---|
| **Biology** | 38 (38) | 41 (49) | 79 (87) |
| **Chemistry** | 22 (22) | 22 (25) | 44 (47) |
| **Physics** | 29 (29) | 26 (29) | 55 (58) |
| **Earth Science** | 21 (21) | 18 (21) | 39 (42) |
| **Total** | 110 (110) | 107 (124) | 217 (234) |
| **% of Score Points** | 47% | 53% | |
| **Target % of Score Points** | 50% | 50% | |

*Score points are shown in parentheses.*
*Because results are rounded to the nearest whole number, some totals may appear inconsistent.*

(Source: TIMSS & PIRLS International Study Centre, Lynch School of Education, Boston College, 2011)

The following Table 3 exhibits display the number of items and score points for each content domain by item format. TIMSS 2011 included multiple-choice items where the student chooses the correct answer from four response options and constructed-response items where the student is required to provide a written response. As described in the Table 3 above, the goal was that at least half of the total number of score points represented by all the questions should come from multiple-choice questions. However, the percentage of score point reveals that the emphasis were given to written response by a total of 6% which also shows that TIMSS 2011 assessment draws upon the full range of thinking skills and behaviours specified in cognitive domains.

Table 4
*Distribution of TIMSS 2011 Items by Cognitive Domain and Item Format*

| Cognitive Domain | Multiple-Choice Items | Constructed-Response Items | Total Items |
|---|---|---|---|
| **Knowing** | 58 (58) | 15 (18) | 73 (76) |
| **Applying** | 40 (40) | 52 (63) | 92 (103) |
| **Reasoning** | 12 (12) | 40 (43) | 52 (55) |
| **Total** | 110 (110) | 107 (124) | 217 (234) |
| **% of Score Points** | 47% | 53% | |
| **Target % of Score Points** | 50% | 50% | |

*Score points are shown in parentheses.*
*Because results are rounded to the nearest whole number, some totals may appear inconsistent.*

(Source: TIMSS & PIRLS International Study Centre, Lynch School of Education, Boston College, 2011)

Meanwhile Table 4 exhibits display the number of items and score points for each cognitive domain by item format for both types of assessments. It appeared that for constructed-response items, the importance of the cognitive domains was levelled from applying, reasoning and finally knowing. Both applying and reasoning has been vital cognitive domains in assessing the students thinking ability in scientific inquiry by a percentage of 49% and 37% respectively.

The following Table 5 exhibits the science assessment between Singapore, Thailand, Malaysia and International average for both the content and cognitive domains.

Table 5
*Comparison of Malaysian Eighth Grade (Form 2) Achievement at the TIMSS 2011 International Benchmarks of Science Achievement among International Average and Neighbouring Countries*

| **Country** | **Content Domain** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Biology** | | **Chemistry** | | **Physics** | | **Earth Science** | |
| | **Cognitive Domain (%)** | | | | | | | |
| | **Apply** | **Reason** | **Know** | **Reason** | **Know** | **Apply** | **Apply** | **Reason** |
| **Malaysia** | 69 | 60 | 73 | 18 | 53 | 16 | 49 | 5 |
| **International** | 83 | 57 | 85 | 35 | 58 | 32 | 63 | 18 |
| **Singapore** | 92 | 75 | 91 | 64 | 73 | 45 | 83 | 22 |
| **Thailand** | 77 | 45 | 67 | 20 | 41 | 22 | 61 | 8 |

(Source: TIMSS & PIRLS International Study Centre, Lynch School of Education, Boston College, 2011)

Each item in the science assessment is associated with one content domain and one cognitive domain, providing for both content-based and cognitive-oriented perspectives on student achievement in science. The four content domains at the eighth grade are Biology, Chemistry, Physics and Earth Science meanwhile the three cognitive domains which are knowing, applying and reasoning.

The data shown in Table 5 is further analysed using Levene's Test to indicate the homogeneity of variances in the content and cognitive domain groups. Table 6 below reveals the approximately equal variances in each of the group.

Table 6
*Test of Homogeneity of Variances*

| **Content Domain** | **Levene Statistic** | **df1** | **df2** | **Significant (*p*-value)** |
|---|---|---|---|---|
| **Earth Science** | 3.476 | 2 | 9 | .076 |
| **Physics** | 3.781 | 2 | 9 | .064 |
| **Chemistry** | 4.615 | 2 | 9 | .042 |
| **Biology** | 2.839 | 2 | 9 | .111 |

If the Levene's test result is not significant ($p>0.05$), the variances are approximately equal (Perry et al., 2008). All the content domain in Table 6 shows that the variances are approximately equal accept for chemistry because it is lesser than 0.05. This is because the variances of chemistry are not homogeneous, thus it indicates the variances are significantly different. The following page reveals the results of ANOVA for content domains through Table 7.

Table 7
*Differences between Content Domains and Cognitive Domains among Singapore, Malaysia, International Average & Thailand in ANOVA analysis*

| **Content Domain** | | df | F | **Significant (*p*-value)** |
|---|---|---|---|---|
| **Earth Science** | Between Groups | 2 | 51.954 | .000 |
| | Within Groups | 9 | | |
| | Total | 11 | | |
| **Physics** | Between Groups | 2 | 28.213 | .000 |
| | Within Groups | 9 | | |
| | Total | 11 | | |
| **Chemistry** | Between Groups | 2 | 32.988 | .000 |
| | Within Groups | 9 | | |
| | Total | 11 | | |
| **Biology** | Between Groups | 2 | 84.313 | .000 |
| | Within Groups | 9 | | |
| | Total | 11 | | |

Each of the cognitive domain (knowing, applying and reasoning) for each of the country (Singapore, Malaysia, International Average and Thailand) are analysed using ANOVA. Based on the Table 7, it can be inferred that there are significant differences between reasoning, knowing and analysing for all the content domains in all the countries. This is because the *p* value for the entire content domain are less than 0.05 ($p<0.05$). However though the results in Table 7 indicates high significant, it does not state where the significance lies. Hence an analysis of achievement for science cognitive domain between TIMSS 2011 and TIMSS 2007 is carried out for Singapore, Malaysia and Thailand. Table 8 points out the ANOVA analysis for achievement of science cognitive domains among the Singapore, Malaysia and Thailand.

Table 8
*Trends in Achievement for Science Cognitive Domains among Singapore, Malaysia and Thailand for TIMSS 2011 & TIMSS 2007 in ANOVA analysis*

| **Cognitive Domain** | | df | F | **Significant (*p*-value)** |
|---|---|---|---|---|
| **Knowing** | Between Groups | 2 | 15.069 | .027 |
| | Within Groups | 3 | | |
| | Total | 5 | | |
| **Applying** | Between Groups | 2 | 22.103 | .016 |
| | Within Groups | 3 | | |
| | Total | 5 | | |
| **Reasoning** | Between Groups | 2 | 21.095 | .017 |
| | Within Groups | 3 | | |
| | Total | 5 | | |

The data analysis in Table 8 above indicates the significant value for TIMSS 2011 and TIMSS 2007 for each of the cognitive domain among Malaysia, Singapore and Thailand. The significant values for each of the cognitive domain is less than 0.05, hence it can be inferred that there are significant differences between Malaysia, Singapore and Thailand for the three cognitive domains measured in both TIMSS 2011 and TIMSS 2007. The findings in Table 8 is further analysed using Tukey (HSD), a post hoc test to identify the spot of significant differences among the three countries through Table 9 in the following page.

Table 9

*Significant difference for Science Cognitive Domains among Singapore, Malaysia and Thailand for TIMSS 2011 & TIMSS 2007 in Tukey (HSD) Post Hoc Test*

| **Cognitive Domain** | **(I) Domain** | **(J) Domain** | **Mean Difference** | **Std. Error** | **Significant (*p*-value)** |
|---|---|---|---|---|---|
| **Knowing** | Malaysia | Singapore | -144.000* | 27.850 | .028 |
| | | Thailand | -27.500 | 27.850 | .632 |
| | Singapore | Malaysia | 144.000* | 27.850 | .028 |
| | | Thailand | 116.500* | 27.850 | .050 |
| | Thailand | Malaysia | 27.500 | 27.850 | .632 |
| | | Singapore | -116.500* | 27.850 | .050 |
| **Applying** | Malaysia | Singapore | -132.500* | 21.897 | .018 |
| | | Thailand | -14.000 | 21.897 | .811 |
| | Singapore | Malaysia | 132.500* | 21.897 | .018 |
| | | Thailand | 118.500* | 21.897 | .025 |
| | Thailand | Malaysia | 14.000 | 21.897 | .811 |
| | | Singapore | -118.500* | 21.897 | .025 |
| **Reasoning** | Malaysia | Singapore | -119.000* | 21.244 | .023 |
| | | Thailand | 1.000 | 21.244 | .999 |
| | Singapore | Malaysia | 119.000* | 21.244 | .023 |
| | | Thailand | 120.000* | 21.244 | .022 |
| | Thailand | Malaysia | -1.000 | 21.244 | .999 |
| | | Singapore | -120.000* | 21.244 | .022 |

**The mean difference is significant at the 0.05 level.*

The asterisks (*) indicate that there are two pairs of countries whose mean differ significantly (at the $p<0.05$ level) from each other. However this paper only discusses the significant difference of Malaysia as compared to Singapore and Thailand. According to these data, there are only significant difference between Malaysia and Singapore because there are no significant difference between Malaysia and Thailand. Knowing domain for both Malaysia and Singapore shows that there are significant differences as the significant value is $p=0.028$. Meanwhile applying domain also indicates significant differences between both these countries because of the significant value which is $p=0.018$. Malaysia and Singapore also differ in reasoning domain with $p=0.023$ as the significant value. In short, all the three cognitive domains show significant dissimilarity between Malaysia and Singapore.

## Discussion

The three main cognitive domains discussed in this study were knowing, applying and reasoning for eighth graders in science content domains. These cognitive domains which are evaluated in content domains of biology, chemistry, physics and earth science are analysed for Singapore, Malaysia and Thailand. Hence, this study found that there are significant difference between Singapore and Malaysia in all the cognitive domains for each content domain. Although data from TIMSS 2011 points out the achievement difference for science cognitive domains between Malaysia and Thailand, statistical analysis reveals that Malaysia's performance were higher in significant difference as compared to Singapore. Parallel to this, Malaysia achieved lower than Singapore for knowing, applying and reasoning domains in biology, chemistry, physics and earth science. Knowing, applying and reasoning which are stressed in TIMSS 2011 assessment are cognitive domains that can be traced back to Revised Bloom's Taxonomy (1956). Revised Bloom's Taxonomy gives progression from remembering to creating (Pohl, 2000) for higher order thinking skills. Table 10 in the following page describes these levels alongside indicative intended learning outcomes.

Table 10
*Revised Bloom's Taxonomy (1956) and Indicative Outcomes*

| Bloom's Statement | Indicative Outcome |
|---|---|
| **Remembering** | Ability to recalling information.<br>*Recognizing, listing, describing, retrieving, naming and finding.* |
| **Understanding** | Ability to explaining ideas or concepts.<br>*Interpreting, summarising, paragraphing, classifying and explaining.* |
| **Applying** | Ability to use information in another familiar situation.<br>*Implementing, carrying out, using and executing.* |
| **Analysing** | Ability to break information into parts to explore understandings and relationships.<br>*Comparing, organizing, deconstructing, interrogating and finding* |
| **Evaluating** | Ability to justify a decision or course of action.<br>*Checking, hypothesising, critiquing, experimenting and judging.* |
| **Creating** | Ability to generate new ideas, products or ways of viewing things.<br>*Designing, constructing, planning, producing and inventing.* |

(Source: Pohl, 2000)

The TIMSS assessment evaluates the knowing domains constructed on questions such as naming, recognizing and interpreting. Meanwhile both applying and reasoning domains are measured by questions on implementing, checking and constructing. Based on the results, it can be inferred that Malaysian students could only recognize some basic facts from the life and physical sciences. In fact, Malaysian students could not communicate an understanding of complex and abstract concepts in chemistry, physics and earth science.

Applying domain form linkage using higher order skills where the student uses meaningful information such as abstractions, formula, equations or algorithms in new application in new situation (King, Goodson & Rohani, 2012). Higher order skills include analysing, evaluating and creating which require mastery of previous levels such as applying routine rules to familiar or novel problems (McDavitt, 1993; King, et al., 2012). Meanwhile higher order thinking skills involves breaking down complex material into parts, detecting relationships, combining new and familiar information creatively within limits set by the context and combining and using all previous levels in evaluating or making judgements (King et al., 2012). The significant difference between Singapore and Malaysia indicates that Malaysia's higher order thinking skills are decreasing since the results of TIMSS 2007. The range of mean difference between Malaysia and Singapore is getting greater since results indicate that Malaysian students could not achieve more than the International average for TIMSS 2011.

One interesting finding from this study was that despite of involving three cognitive domains, there was less emphasis on knowing at eighth grade and somewhat more emphasis on reasoning domain. This is because there was a huge emphasis placed in reasoning domain in all science content for TIMSS 2011 since a total of 13% were increased for evaluating reasoning domain from the previous TIMSS assessments. Reasoning domain is included as one of the major cognitive domain in TIMSS assessment because by using reasoning domain, science students are expected to evaluate and make decisions (TIMSS, 2011). Reasoning shares the attributes of Bloom's higher order skills through analysing, evaluating and creating. However, significant difference between cognitive domains and countries involved pointed out that, Malaysia performed lower than Singapore in all content domains for reasoning domain. In fact Malaysian students were unable to engage in scientific reasoning to solve problems, develop explanations, draw conclusions, make decisions and extend knowledge to new situations. Based on the analysis data, Malaysian eighth graders were not successful to apply higher order thinking skills in reasoning that are valid within the context of available knowledge and other intellectual skills (King et al., 2012). Higher order thinking skills include critical, logical, reflective, metacognitive and creative thinking which are activated when students encounter unfamiliar problem, uncertainties, questions or dilemmas (King et al., 2012).

There is a strong recent concern in researching childrens' reasoning in science classroom (Alozie et al. 2010; Osborne, 2010). In fact Waldrip et al., (2013) investigated children's reasoning and argumentation skills in school science in generating and critiquing their own and other children's representations in several selected topic in science. However, Papadouris (2012) emphasized that the belief that reasoning skills or strategies might be too complex for elementary and middle school is just a scepticism that needs to be avoided hence, there is a need for more research in inform teaching attempts for promoting reasoning skills starting in the upper grades of the elementary school. This is in-line with Piaget's perspective that believes humans' thinking processes change radically, though slowly, from birth to maturity because we constantly strive to make sense of the world. According to Piaget, the ability to solve conservation problem depends on having an understanding of three basic aspects of reasoning which are identity, compensation and reversibility.

Reasoning domain in all components of higher order skills should be introduced at a very basic level in elementary schools and further developed throughout students' science education in secondary school (TIMSS, 2011). However according to Malaysia Education Blueprint 2013-2025, while there are certainly many excellent teachers in the Malaysian education system, a 2011 research study found that only 50% of lessons are being delivered in an effective manner. This means that the lessons did not sufficiently engage students, and followed a more passive, lecture format of content delivery. These lessons focused on achieving surface-level content understanding, instead of higher-order thinking skills. Hence, this statistic is particularly challenging as an estimated 60% of today's teachers will still be teaching in 20 years' time.

## Conclusion

Looking at TIMSS 2011 assessment and other educational views, it is inevitable that Malaysia should take necessary steps to foster higher order thinking skills among science students. According to Nayar (2012), introducing something new could give a fresh air to our science education. The increasing flow in STEM pipeline has become a better way to motivate young minds to continue interests in science (Rhoads, 2004). Since Malaysian science education is aiming at making science more appealing to students and indirectly inviting more students to pursue their studies in science-related areas (Saat, 2012), more emphasize should be given for STEM education in Malaysia. According to Adcock (2012), as STEM education (where the emphasis is E for Engineering) is asserted into classrooms, an inquiry based and a hands-on learning environment which offers the opportunity to design and construct solutions for problems throughout the curriculum was identified. While incorporating engineering design into the classroom, Lee (2012) added that students not only worked cooperatively to develop problem solving and decision making skills but at the same time, students managed to think in a critical and creative manner to demonstrate a true understanding of concepts during science lessons. Engineering design also promotes critical intelligence (Golanbari & Garlikov, 2008; Burghardt, 1999) and intellectual traits (Paul, Niewoehner & Elder, 2006) which are important component for stimulating science especially in the purpose of fostering higher order thinking skills (Duncan, 2003).

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