TIMSS 2019 Science Grade 8: Where is Malaysia standing?

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Abstract

Most of the future jobs in Malaysia and worldwide will be related to STEM areas. The nation will need more STEM talent to ensure that the national development can continue to prosper. STEM talent should be nurtured since school education but studies show that Malaysian students were not doing well in science, lack of interest and the teaching method is still examination oriented. This paper reveals the analysis of the Trend in Mathematics and Science Studies (TIMSS) for Science Grade 8 from 1999 to 2019 to find the pattern of the Malaysian students' performance in science. Over 20 years, the percentage of advanced benchmark achievers in TIMSS for Malaysian students have dropped from 5% to 3%. The overall score of Malaysia has never surpassed the international average. Over the years, Malaysian students scored questions that measured application better than questions that measured reasoning. While the interest and appreciation of Malaysian students towards science were high over the year, Malaysian students have very low confidence in science, and it has dropped drastically over the years. Science investigation were conducted by Malaysian school teachers but students scored better in science when the frequency of teachers conducting science investigation in science lessons were "once or twice a month" compared to "once a week". Therefore, it is suggested that the science curriculum should be reviewed to ensure that the topics are not too complicated for school students so that it would not kill their confidence in science. At the same time, inquiry-based learning practiced by science teachers should be improved so that the science investigation conducted in science lessons contributed to the understanding and confidence of the students. Researchers should also look into scientific epistemology when the students construct scientific concepts during science investigation.

Keywords: STEM Education, TIMSS

Introduction

With the recent pandemic and economic shocks, millions people were impacted such as losing the job and some were losing their families. In this excruciating situation, the vaccine to prevent COVID-19 and the suitable technology to adapt with the current norm need to be created. According to the report release in October 2020 by World Economic Forum (WEF, 2020), it can be seen that 50% of the demanded skills by the world in 2025 requires problem solving skills in regards on the analytical thinking, innovation, creativity, reasoning and ideation, whereas another 20% requires technology and programming skills.

STEM education plays a fundamental role in advancing technology, medicine, sustainability, agriculture, national security, economy and society (Rifandi & Rahmi, 2019). The data from WEF (2020) on the Malaysia Profile shows that the emerging jobs are related to STEM as shown in Figure 1. STEM education has become so important to ensure Malaysia can prosper in the future. Hence, we must pay attention to the quality of STEM education for the future of Malaysia.

Based on the report produced by WEF, it can be seen that 90% of the top 10 of the emerging jobs in Malaysia are those related to STEM. Numerous studies have shown the significant relationship between STEM education and science process skills among the students (Çetin & Demircan, 2020; Ültay & Ültay, 2020; Uğur et al., 2020; Strong, 2013). The skills include analytical and critical skills attained through conducting experiments, inferring, observing, predicting, collecting and analysing data. The students will encounter challenges during STEM activities that will stimulate and confront their cognitive, improve the critical thinking and ultimately shape them to be analytical, critical, resilience, creative and innovative (Li et al., 2019; Widya et al., 2019; Nawi et al., 2019). Through STEM education, students will learn to embrace, explore and adapt to new technologies, instead of being uncertain or fearful of new technologies. In the era of 4th Industrial Revolution (4IR) that is filled with constant scientific discovery and technological changes, many new jobs will be created in STEM fields. In order to stay competitive as a nation, it is crucial to build a pool of highly competent and STEM-literate future workforce. Hence, there is an urgency to ensure that the STEM talent pipeline is thriving in terms of quantity and quality.

Figure 1. The future jobs for Malaysia based on the companies surveyed (WEF,2020)

STEM Education in Malaysia

To ensure the quantity, since 1967, Malaysia has targeted 60% of secondary school students to enrol in science stream and enhance their knowledge and expertise in science and technology (Phang et al., 2014). However, until now the percentage has not been achieved. In fact, it is more worrying as the existing percentage is declining (Esther & Noraini, 2007, Yong & Fatin, 2015). The decline of student enrolment in science also occurs worldwide including developed countries (Akpinar et al., 2009; Sharma et al., 2013).

There are various factors that contribute to the decline of the student enrolment in science at schools. The students are more interested in non-science subjects because they consider science subject as difficult (Murshed et al., 2020, Khamis et al., 2018, Yong & Phang, 2015). It happened also to students who perform well in the National Lower Form Examination (PMR) because for them, they feel more secure in non-science professions since job opportunities for science graduates are said to be 'limited' (Mohd Salleh et al., 2012; Zanaton et al., 2006). To date, detailed studies are still being conducted by researchers, scientists, and teachers to identify the real factors of percentage failure in the 60:40 science : non-science policy. Actions have been taken by various parties to close the improve students' interest in science, address certain issues which resulted in ad-hoc changes in education policies and targeting at training teachers in using STEM teaching method without changing the curriculum towards integrated STEM.

According to Siddiqui & Khan (2016) and Renniger & Hidi (2002), in general, students who have good achievement are students who have high interest in the subject. However, students are only motivated to obtain good examination results, not the scientific skills that they should gain. This is because the rote learning at schools to prepare the students for examinations aims to familiarize students with the question format rather than understanding (Mhlolo, 2014; Seth et al., 2005). Therefore, students are only able to answer questions that measure lower order thinking skills (LOTS) but not higher order thinking skills (HOTS). Eventually, it will affect the students' 21st century skills, mastery and confidence in a long run (Leak et al., 2018; Seth et al., 2005).

Apart from this, according to Abrahams & Millar (2008), implementing practical work is an important requirement in learning science, especially to improve understanding, achievement and interest. Through practical work, students can improve the nature of inquiry (Sharifah & Rohaida, 2005) and develop constructivist thinking (Kamisah, 2012). Sandoval (2005), Metallidou (2012) and Khamis & Phang (2017) claim that the development of scientific ideas and skills, which are usually developed during practical work, can motivate students to develop their scientific epistemology. Experiencing how the concept is built through practical work in school can help students to perceive and master science concept better. Students who have positive experience in learning science will generate positive attitude and tend to obtain good result (Akpinar et al., 2009) and cultivate the growth of epistemological beliefs (Ding, 2011). However, a study found that students prefer to memorize and receive knowledge passively (Kember et al., 2014), though in learning science students are supposed to interact directly with the phenomenon itself (Aziz & Lin, 2011). Students who learn through traditional teaching approach such as teacher-centred learning tend to depend on only one source, especially on their teacher's presentation (Che Nidzam et al., 2010; Sharma et al., 2013).

In addition, students who do not have the opportunity to learn through constructivist learning are often seen as passive learners because they are not actively engaged in the learning, and do not even act like scientists (Sandoval, 2005). As a result, students are unable to learn on their own and build new knowledge (Ding, 2014). This passive learning style is badly affecting students' acquisition of knowledge and proficient in science (Ding, 2014). Thus, the method of memorizing concepts is not an appropriate and effective learning method to master science subject. This will jeopardize the effort to produce future STEM workforce who possess the 21st century skills.

Method

Therefore, this paper will look into the current achievement of science among Malaysian students. To do this, data from the Trends in International Mathematics and Science Study (TIMSS) will be used to answer some of the issues posed earlier. TIMSS is an international survey on the science and mathematics achievement of students from various participating countries among Grade 4 and Grade 8 students. The survey is conducted every 4 years since 1995. However, Malaysia only started to participate in TIMSS since 1999 and the survey only involved Grade 8 students or Form 2 students (14 years old) from Malaysian secondary schools. The schools involved were chosen by TIMSS based on a list of schools given by the Ministry of Education Malaysia. For example, in 2019, 177 secondary schools and 7,065 students were involved (Mullis et al., 2020).

The science test given includes multiple-choice and close-ended questions in the content domains of Physics, Biology, Chemistry and Earth Science. The cognitive domains covered are Knowing, Applying and Reasoning. The answers are given scores. The total score for each students is benchmarked into four scales which are (Mullis et al., 2020):

1. Low International Benchmark (400) – students show limited understanding of scientific principles and concepts and limited knowledge of science facts.
2. Intermediate International Benchmark (475) - Students show knowledge and understanding of some aspects of science. Students demonstrate some basic knowledge of plants and animals. They demonstrate knowledge about some properties of matter and some facts related to electricity, and can apply elementary knowledge of forces and motion. They show some understanding of Earth's physical characteristics
3. High International Benchmark (550) - Students communicate and apply knowledge of life, physical, and Earth sciences. Students communicate knowledge of characteristics of plants, animals, and their life cycles, and apply knowledge of ecosystems and of humans' and organisms' interactions with their environment. Students demonstrate knowledge of states and properties of matter and of energy transfer in practical contexts, and show some understanding of forces and motion. Students know various facts about the Earth's physical characteristics and show basic understanding of the Earth-Moon-Sun system.
4. Advanced International Benchmark (625) - Students communicate their understanding of life, physical, and Earth sciences and demonstrate some knowledge of the process of scientific inquiry. Students demonstrate knowledge of characteristics and life processes of a variety of organisms. They can communicate understanding of relationships in ecosystems and interactions between organisms and their environment. They communicate understanding of properties and states of matter and physical and chemical changes. Students communicate understanding of Earth's physical characteristics, processes, and history and show knowledge of Earth's revolution and rotation.

Besides science achievement, TIMSS also administered surveys among the students, teachers and principals to study the background of the participants such as home and school contexts in learning science, curriculum implementation, instructional practices and school resources. In this studies, the TIMSS reports in science achievement will be studied from 1999 to 2019 that can be downloaded from the TIMSS' website - https://timssandpirls.bc.edu/.

Results

Table 1 shows the ranking of Malaysia in TIMSS over 20 years. Based on the trend shown, there is a downward trend in terms of the achievement in science for Malaysia as the percentage of students at the advanced benchmark as dropped from the initial 5% to now 3%. This means that only 3% students participated in TIMSS 2019 has reached the Advanced International Benchmark. Comparison of the average score between 1999 and 2019 shows a declining trend too. Malaysia were doing quite well in 1999 and 2003 where the average score and the percentage of students at the Advanced Benchmark were the highest in the history.

Table 1. Malaysia's achievement in TIMSS Science Grade 8 between 1999 and 2019

Year	Ranking / Total countries	Average Score	% of students at Advanced Benchmark
1999	22 / 38	492	5
2003	20 / 50	510	4
2007	21 / 60	471	3
2011	32 / 42	426	1
2015	24 / 39	471	3
2019	29 / 39	460	3

One could argue that maybe the test has become more difficult now compared to 20 years ago. However, Table 2 shows the score of Singapore over the 6 times of assessment. Singapore has always topped the TIMSS ranking and it is one of the ASEAN countries closest to Malaysia. From Table 2, clearly, the trend of Singapore has been an upward trend since 2007 which is an opposite direction compared to Malaysia. 48% of the Singaporean students have achieved the highest benchmark compared to only 3% of Malaysian students. The more depressing fact is that some countries that were ranked below Malaysia in TIMSS

2015 has actually surpassed Malaysia in TIMSS 2019 such as Bahrain, Qatar and Chile.

Table 2. Singapore's achievement in TIMSS Science Grade 8 between 1999 and 2019

Year	Ranking / Total countries	Average Score	% of students at Advanced Benchmark
1999	2 / 38	568	29
2003	1 / 50	578	33
2007	1 / 60	567	32
2011	1 / 42	590	40
2015	1 / 39	597	42
2019	1 / 39	608	48

If it is zoomed into the cognitive domain since 2007, Malaysia has been doing quite well in the highest level of reasoning, achieving the highest average scores compared to other lower level of cognitive domains. However, the trend declined to achieving better in the applying domain recently despite efforts by the Ministry of Education Malaysia in improving the HOTS elements across the curriculum since 2013.

A lot of efforts were done in Malaysia to increase the students' interest towards science such as the National Science Challenge by the Academy of Science Malaysia (ASM), various STEM informal science learning programs by Petrosains, National STEM Movement, and universities. Generally, Malaysia students have high interest towards science as shown in the Table 4 by TIMSS. In fact, the students' interest has increased over time and is higher than the average. Malaysian students also value science. However, Malaysian students have low confidence in science and the level has declined. Malaysia was ranked the bottom 5th in 2003 the average score of confident in science but overall the years, the ranking dropped to the bottom 2nd just above Japan in 2011, 2015 and 2019. The items used in measuring the confidence in science were:

- I usually do well in science.
- Science is harder for me than for many of my classmates.
- I am just not good at science.
- I learn things quickly in science.
- I am good at working out difficult science problems.
- My teacher tells me I am good at science.
- Science is harder for me than any other subject.
- Science makes me confused.

Interestingly, for all three variables measured in term of students' attitude towards science, the higher the achievement of the variables, the higher the average scores. This means that to achieve better in science, interest, confidence and value towards science are important.

Learning science is synonym to inquiry-based learning. In this student-centred approach, generally students will be designing their own experiments, conducting their own experiments and find out answers to the questions coming from them too. Hence in TIMSS, how students learn science and how teachers teach science are also measured. In TIMSS 2003 and 2007, students were asked to report on their learning in their science classrooms whereas from 2011 onwards, this was reported by the teachers. As a general comparison, both teachers and students believe that science investigation has been implemented in learning science. The average scores were mostly above the international average score. About 70% students involved in TIMSS 2003 and 2007 rated that about half or more of the science lessons involved science investigation such as conducting experiments, conducting investigations in small groups and write or explain about their observations. The results were similar to what the teachers reported. In 2011, 53% students had their teachers reported that about half the science lessons or more, science investigations were conducted, the percentage dropped to 30% in 2015 and then 41% in 2019 (see Table 5). Below are the items to measure teachers' practice in science lessons:

- Observe natural phenomena such as the weather or a plant growing and describe what they see
- Watch me demonstrate an experiment or investigation
- Design or plan experiments or investigations
- Conduct experiments or investigations
- Give explanations about something they are studying
- Relate what they are learning in science to their daily lives

Table 3. Malaysia's average scores in TIMSS Science Grade 8 based on cognitive domains between 2007 and 2019

Year	Overall	Knowing	Applying	Reasoning
2007	471	458	**473**	**487**
2011	426	403	424	**439**
2015	471	466	**476**	467
2019	460	442	**473**	459

Overall, the TIMSS achievement of Malaysian students is higher if their teachers conducted science investigation in about half or more of the science lessons, compared to those that using science investigation in less than half of the science lessons. However, this is not the case at the international average as the achievement for both groups show very little difference. Moreover, Singapore showed the opposite trend in 2019 where students whose teachers use less science investigation in the lessons produced higher achievement. In Singapore, it seems like science investigation was not widely used in science lessons yet students achieve the highest score in TIMSS.

According to Table 6, in 2019, 29% Malaysian students reported that experiment were conducted at least once a week in science lessons but in Singapore, only 12% students reported so. Interestingly, both Malaysian and Singapore students who reported that experiments were conducted only once or twice a month scored better. At the international average, those who conduct less experiments in science lessons seem to achieve better in TIMSS. But those who never conducted experiments in science lessons clearly did not do well at all in the TIMSS achievement test.

Table 4. Malaysian students' attitude towards science in TIMSS Science Grade 8 between 2003 and 2019

Year	Overall	% Very Much Like Learning Science	% Very Confident in Science	% Strongly Value Science
2003	510	42% (44%)	38% (48%)	73% (57%)
2007	471	73% (65%)	26% (48%)	69% (66%)
2011	426	42% (35%)	4% (20%)	49 (41%)
2015	471	51% (35%)	6% (22%)	38% (40%)
2019	460	46% (35%)	8% (23%)	45% (36%)

* brackets denote international average score

Table 5. Teachers' report on their emphasis on science investigation in TIMSS 2011 to 2019

Year	Country	About half the lessons or more	Average achievement	Less than half the lessons	Average achievement
2011	Malaysia	53%	433	47%	417
	Singapore	29%	595	71%	588
	International Average	48%	479	52%	474
2015	Malaysia	30%	478	70%	465
	Singapore	8%	617	92%	595
	International Average	27%	490	73%	485
2019	Malaysia	41%	472	59%	451
	Singapore	3%	597	97%	607
	International Average	27%	492	73%	490

Table 6. Frequency of students conduct experiments in science lessons

Year	Country	At least once a week	Once or twice a month	A few times a year	Never
2019	Malaysia	29% (450)	41% (474)	26% (461)	5% (411)
	Singapore	12% (612)	42% (617)	43% (602)	3% (541)
	International Average	28% (478)	37% (502)	24% (501)	11% (451)

* Brackets denote average achievement scores

Discussion

The study from TIMSS over the years show that Malaysian students have always liked science. This is the same as reported by Phang et al. (2014) by reviewing studies of students' interest in science in Malaysia from 2000 to 2010. In fact, in 2019, Malaysia ranked top 6th in the interest score, which is a lot higher compared to Singapore. Hence, interest may not be the factor that determine the students' achievement (Yong & Phang, 2015). However, interestingly, from Table 4, the attitude that stands out is students' confidence in science. Malaysian students do not believe that they are doing well in science and science is a difficult subject. The feeling of difficulty in science is what hinder the students to achieve better (Zanaton et al., 2006). This could be caused by the curriculum, the instruction and the assessment conducted. When the science curriculum is designed to be too advanced for the students, coupled with instruction that does not relate to students' daily life and assessment that only focuses on scores rather than learning, it is not difficult for students to have no confidence in science.

The result also shows that the frequency of science investigation in science lessons and conducting science experiments does not necessarily produce better achievement in science, although studies show that science practical work could enhance students' understanding of scientific concepts and mastery of scientific skills (Abrahams & Millar, 2008). There is a link between students' mental attitude to knowledge and its relationship with practical work learning. Both create a culture that underlies the acquisition of knowledge. According to Bell and Lederman (2003), students who do not have the opportunity to conduct experiments and do not get enough exposure to practice science properly will affect the development of their scientific epistemology. Thus, the difficulties of students in learning science are exacerbated by the feeling of unhappiness in practical work learning.

In addition, when students often have difficulties to link between knowledge learned in theory with practice (Sandoval, 2005), especially if the findings are different with information obtained from teachers, the students would face conflicts, dilemma or difficulties in learning science (Schommer, 1994). As reported by Hirvonen & Virri (2002), practical work implementation is to help students learn the knowledge of science with the discovery similar to earlier scientists, not to make new theoretical findings.

Since most students have worries whether they have suggested wrong answers and made mistakes in science practical work, so they tend to rely on their teacher to conduct practical work rather than to conduct real inquiry and investigation (Khamis et al., 2018). Schommer (1994) stated that students can easily believe the absolute nature of knowledge presented by their teachers. Students with naïve scientific epistemological belief would consider that doing practical work is to prove theories (Ryder & Leach, 2008; Hirvonen & Virri, 2002). Even though a culture of constructivist is not being practiced among students or even teachers (Rahman & Phang, 2017; Ogan-Bekiroglu & Sengul-Turgut, 2011), the development of epistemology is vital to improve students' view about science. Students with sophisticated scientific epistemological belief will be able to see learning science as a process of discovery rather than memorizing science facts to pass examinations.

Conclusions

This paper has highlighted the importance of STEM education in meeting the needs of future jobs and the demands for a country to thrive in the era of 4IR. However, with the current achievement of science among Malaysian students, there are a lot of effort to be put in to improve the students' achievement via elevating the students' confidence towards science and to ensure that real inquiry-based learning is conducted in school's science practical work. Initiatives to boost students' confidence in science will need major work in reviewing the curriculum, instruction methods and assessment approach. The curriculum should be designed to be more integrated to ensure that the scientific concepts can be related to daily life through project-based learning and inquiry-based learning. The assessment approach must gear towards learning rather than grading so students are given the confidence, motivation and tools to improve themselves as they receive feedback from the science assessment done at schools. As the students improve their scientific epistemological belief through inquiry-based science practical work at schools, it is hoped that their confidence in science will improve as well.

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