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Secondary School Assessment Practices in Science, Technology, Engineering and Mathematics (STEM) Related Subjects

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The purpose of this study was to elicit secondary students' perceptions of school assessment practices in Science, Technology, Engineering and Mathematics (STEM) related subjects. Examples of STEM related subjects in the secondary school curriculum are Biology, Chemistry, Physics, Science, Health Science, Integrated Living Skills, Mathematics and Additional Mathematics. The researchers employed a cross-sectional survey research design and the sample comprised 221 Form Four students from 3 public secondary schools in the northern zone, 2 public secondary schools in the central zone and 2 public secondary schools in the southern zone of Peninsular Malaysia. Analysis of 170 complete questionnaires from the sample indicated that the students showed positive overall perceptions of school assessment practices in STEM related subjects. The results also indicated that there were no significant differences in overall perceptions of school assessment practices in STEM related subjects in terms of gender and school zone.

Key words: STEM education, STEM related subjects, Secondary students, School assessment practices

In the new global economy, Malaysia needs a new workforce of problem solvers, innovators, and inventors who have the knowledge and skills to innovate and compete in the global marketplace. A key to developing these knowledge and skills is enhancing Science, Technology, Engineering, and

Mathematics (STEM) education in our country. STEM education is an interdisciplinary area of study that bridges the four disciplines of science, technology, engineering, and mathematics. STEM literate students have the ability to identify, apply and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and to innovate to solve them. In fact, STEM education forms the core technological underpinnings of an advanced society. In any country the strength of the STEM workforce is viewed as a strong indicator of the nation's ability to generate ideas towards the creation of innovative products and services as well as to sustain itself (National Governors Association, n.d.).

However, the Malaysian government is facing several major challenges in achieving the goal of strengthening STEM education in our country. The first challenge is the decreasing enrollment of science students at secondary education level. In *Science and Technology Human Capital Roadmap: Towards 2020,* the Ministry of Science, Technology and Innovation (2012, p. 6) reported that:

> The current enrolment ratio of 20 to 80 for Science and Arts students is extremely low compared to the targeted ratio of 60:40. The low ratio indicates that the supply of human resources has never been inclined towards science and technology even though the programme has been introduced since 1967. The reasons of the declining interest among young people for science studies are blamed largely to the school‘s system or curriculum in teaching science, unattractive career path and lack of incentives. Currently, there are 29 Research Scientists and Engineers (RSE) for every 10,000 workforce in Malaysia. The ratio is considered very low compared to the world competitiveness ranking which is discouraging for a nation that aspires to be a developed nation.

The second challenge is the lagging science achievement and literacy of Malaysian secondary students in international assessment studies. Specifically, the Trends in the International Mathematics and Science Study (TIMSS) conducted in 1999, 2003, 2007 and 2011 revealed a worrying trend in the secondary students' science achievement. The average scale score for science in TIMSS 1999 was 492 (which was higher than the international average of 488), in TIMSS 2003 it was 510 (which was higher than the international average of 473), but in TIMSS 2007 and TIMSS 2011 the average scale scores declined to 471 and 426, respectively (which were lower than the TIMSS 2007 and TIMSS 2011 scale average of 500, respectively) (Martin, et al., 2000, 2004, 2008, 2012). Further, in the Program for International Student Assessment (PISA) conducted by the Organisation of Economic Cooperation and Development (OECD) in 2009, Malaysia was ranked 52nd in science literacy among the 74 participating countries. Specifically, the average score of Malaysian students was 422 which was

much lower than the international average of 463 and even much lower than the OECD average of 501 where our closest neighbour, Singapore, was ranked 4th with an average score of 542 (OECD, 2010).

The third challenge is the lagging mathematics achievement and literacy of Malaysian secondary students in international assessment studies. Specifically, the TIMSS conducted in 1999, 2003, 2007 and 2011 revealed a more worrying trend in the secondary students' mathematics achievement than in the science achievement. In TIMSS 1999 the average scale score for mathematics was 519 (which was higher than the international average of 487) and in TIMSS 2003 it declined to 508 (although it was still higher than the international average of 466). However, in TIMSS 2007 and TIMSS 2011 the average scale scores declined further to 474 and 440, respectively (which were lower than the TIMSS 2007 and TIMSS 2011 scale average of 500, respectively) (Mullis, et al., 2000, 2004, 2008, 2012). Moreover, in the PISA conducted by the OECD in 2009, Malaysia was ranked 57th in mathematics literacy among the 74 participating countries. Specifically, the average score of Malaysian students was 404 which was much lower than the international average of 458 and even much lower than the OECD average of 496 where our closest neighbour, Singapore, was ranked 2nd with an average score of 562 (OECD, 2010).

The decreasing enrollment of science students at secondary education level and the lagging science and mathematics achievement and literacy of Malaysian secondary students in international assessment studies point to a serious challenge for the government to supply quality workers whose specialized knowledge and skills will enable them to work productively within the STEM industries and careers. Our country’s economic future will therefore depend upon strengthening STEM education and improving the enrollment of students into the STEM fields at the secondary and tertiary levels. This situation calls for serious steps to be taken by all sectors of education to resolve the decreasing interests in STEM subjects and create ways to inspire and motivate students to embark on STEM disciplines. One of the important steps to be taken is to identify the current school practices in the assessment of STEM related subjects especially at the secondary level. Thus, this study sought to investigate the current assessment practices of STEM related subjects in secondary schools as perceived by the students.

Objectives of the Study

The primary objective of this study was to elicit Form Four students' perceptions of school assessment practices in STEM related subjects. The secondary objectives were to determine whether there were significant differences in the perceptions of school assessment practices in STEM related subjects in terms of gender and school zone. More specifically, this study aimed to address the following research questions:

1. What were Form Four students' perceptions of school assessment practices in STEM related subjects?
2. Was there a statistical significant difference in the perceptions of school assessment practices in STEM related subjects between male and female students?
3. Was there a statistical significant difference in the perceptions of school assessment practices in STEM related subjects among schools in the northern, central and southern zones?

Methodology

Research Design and Sample

The researchers employed a cross-sectional survey research design as it was effective for providing a snapshot of the current secondary students' perceptions of school assessment practices in STEM related subjects in a population (Gay, Miles, & Airasian, 2011). The sample comprised 221 Form Four students from 3 public secondary schools in the northern zone, 2 public secondary schools in the central zone and 2 public secondary schools in the southern zone of Peninsular Malaysia. However, 170 students from the sample completely answered the questionnaire. These students comprised 118 females and 52 males. Table 1 shows the distribution of these students in each school zone.

Table 1
Number of Students By School Zone And Gender

		Gender		Total
		Male	Female	
Zone	Northern	20	55	75
	Central	18	34	52
	Southern	14	29	43
Total		52	118	170

Instrument

The questionnaire comprised two sections, namely Section A and Section B. Section A contained items on the students' demographic data. Section B contained 10 items on school assessment practices in STEM related subjects. Examples of STEM related subjects in the secondary school curriculum are Biology, Chemistry, Physics, Science, Health Science, Integrated Living Skills, Mathematics and Additional Mathematics. The 10 items on school assessment practices in STEM related subjects in the questionnaire were developed by the researchers based on the STEM

Education Quality Framework (2011) which was developed by the Dayton (Ohio) Regional STEM Center in collaboration with Dr. James Rowley of the University of Dayton's School of Education and Allied Professions. The framework consists of 10 quality STEM learning experiences: (1) Potential for engaging students of diverse academic backgrounds; (2) Degree of STEM integration; (3) Connections to non-STEM disciplines; (4) Integrity of the academic content; (5) Quality of the cognitive task; (6) Connections to STEM careers; (7) Individual accountability in a collaborative culture; (8) Nature of assessment; (9) Application of the engineering design process; and (10) Quality of technology integration.

The items in Section B consisted of a five-point Likert scale (strongly disagree, disagree, not sure, agree and strongly agree) and the students' responses to each item received weighted values from 1 (strongly disagree) to 5 (strongly agree). The value of the Cronbach's alpha for all the items was .83, indicating a high degree of internal consistency of the items in the instrument.

Results and Discussion

Students' Perceptions of School Assessment Practices in STEM Related Subjects

Table 2 shows the means and standard deviations of the 170 Form Four students' perceptions of school assessment practices in STEM related subjects for each item in the questionnaire and overall perceptions. As seen in Table 2, the means of the Form Four students' perceptions for all items in the questionnaire were above 3.00, suggesting that the students generally showed positive perceptions of school assessment practices in STEM related subjects. The mean of the students' perceptions for Item 9 (3.51) was the lowest, indicating that the school assessment practices in STEM related subjects that the students had gone through took the least account of their understanding and skills regarding engineering design. The highest mean of the students' perceptions was 4.02 (Item 7), suggesting that the school assessment practices in STEM related subjects that the students had gone through took the most account of their method of thinking more deeply. In addition, the mean of the students' overall perceptions was 3.90, indicating that they showed positive overall perceptions of school assessment practices in STEM related subjects.

Table 2
Means and Standard Deviations of Students' Perceptions of School Assessment Practices in Stem Related Subjects

Item	Statement	Mean	SD
	The school assessment practices in STEM related subjects that I had gone through took account of:		
1	my learning experience at school.	4.01	.86
2	my daily experience.	3.94	.79
3	the concepts related to these subjects in an integrated manner.	3.89	.77
4	the connections among these subjects.	3.94	.68
5	my ability to solve problems.	3.94	.72
6	my ability to manage project-type assignments.	3.95	.76
7	the method of thinking more deeply.	4.02	.83
8	the work done in a group.	3.98	.79
9	my understanding and skills regarding engineering design.	3.51	.90
10	the use of multiple sources of information and technology.	3.84	.88
	Overall perceptions	3.90	.50

Difference in the Perceptions of School Assessment Practices in STEM Related Subjects in Terms of Gender

Table 3 shows the results of the independent-samples t-tests using SPSS version 20 for Windows for each item in the questionnaire and overall perceptions of school assessment practices in STEM related subjects. The mean scores of the Form Four male students' perceptions of school assessment practices in STEM related subjects were lower than those of the female students for all items in the questionnaire except for Item 4. But, the differences in the mean scores for Items 2, 3, 4, 6, 7, 8, 9 and 10 were not statistically significant between male and female students at the significance level of .05, suggesting that there were no statistically significant differences in the perceptions of school assessment practices in STEM related subjects as measured by these items between male and female students. Nevertheless, the differences in the mean scores for Items 1 and 5 were statistically significant between male and female students at the significance level of .05, indicating that there were statistically significant differences in their perceptions of the school assessment practices in STEM related subjects that took account of their learning experience at school as well as their ability to solve problems, favouring the female students in both cases.

In addition, the mean score of the Form Four male students' overall perceptions of school assessment practices in STEM related subjects was lower than that of the female students. However, the difference in the mean scores for overall perceptions was not statistically significant between male and female students at the significance level of .05, indicating that there was no statistically significant difference in the overall perceptions of school assessment practices in STEM related subjects in terms of gender.

Table 3
Results of The Independent-Samples t-Tests

Item	Male (N = 52)		Female (N = 118)		*t*	*df*	*p*
	M	*SD*	*M*	*SD*			
my learning experience at school.	3.71	1.07	4.14	.72	-2.66	71.99	.01*
my daily experience.	3.90	.85	3.96	.77	-.41	168	.68
the concepts related to these subjects in an integrated manner.	3.79	.98	3.94	.66	-1.03	72.14	.31
the connections among these subjects.	3.98	.73	3.92	.66	.51	168	.61
my ability to solve problems.	3.73	.84	4.03	.64	-2.32	77.98	.02*
my ability to manage project-type assignments.	3.81	.79	4.01	.73	-1.61	168	.11
the method of thinking more deeply.	3.98	.87	4.04	.81	-.45	168	.66
the work done in a group.	3.81	.91	4.06	.72	-1.77	80.43	.08
my understanding and skills regarding engineering design.	3.50	.90	3.51	.90	-.06	168	.96
the use of multiple sources of information and technology.	3.83	.94	3.85	.85	-.14	168	.89
Overall perceptions	3.80	.57	3.95	.46	-1.72	168	.09

** significant at $p < 0.05$*

Difference in the overall perceptions of school assessment practices in STEM related subjects in terms of school zone

Table 4 shows the results of the one-way between subjects Analysis of Variance (ANOVA) using SPSS version 20 for Windows for the overall perceptions of school assessment practices in STEM related subjects.

For Items 2, 3, 4, 5, 6, 9 and 10, the mean scores of the Form Four students' perceptions of school assessment practices in STEM related subjects were the lowest in the northern zone. For Item 1, the mean scores of the students' perceptions of school assessment practices in STEM related subjects were the lowest in the central zone while for Items 7 and 8, the mean scores of the students' perceptions of school assessment practices in STEM related subjects were the lowest in the southern zone. However, the differences in the mean scores for all the items were not statistically significant among the northern, central and southern zones at the significance level of .05, suggesting that there were no statistically significant differences in the perceptions of school assessment practices in STEM related subjects for all the items among the school zones.

Although, the mean score of the Form Four students' overall perceptions of school assessment practices in STEM related subjects in the northern zone was lower than that of their counterparts in the central and southern zones. the difference in the mean scores for the overall perceptions was not statistically significant among the three school zones at the significance level of .05. Thus, there was no statistically significant difference in the overall perceptions of school assessment practices in STEM related subjects in terms of school zone.

Conclusion

The results of this study showed that the students showed positive overall perceptions of school assessment practices in STEM related subjects. However, the mean of the students' perceptions for Item 9 was the lowest, indicating that the school assessment practices in STEM related subjects that the students had gone through took the least account of their understanding and skills regarding engineering design. This might be due to the fact that engineering design is not included in most of the STEM related subjects at the secondary school level. Hence, engineering design should be given greater emphasis in STEM related subjects at the secondary school level in order to strengthen STEM education in our country.

Table 4
Results of the One-Way Between Subjects ANOVA

Item	Northern (N = 75)		Central (N = 52)		Southern (N = 43)		F	df	p
	M	SD	M	SD	M	SD			
My learning experience at school.	4.08	.71	3.88	1.04	4.05	.87	.83	(2,167)	.44
My daily experience.	3.87	.81	3.96	.84	4.05	.69	.73	(2,167)	.48
The concepts related to these subjects in an integrated manner.	3.85	.69	3.87	.91	4.00	.87	.55	(2,167)	.58
The connections among these subjects.	3.85	.63	4.12	.73	3.88	.66	2.56	(2,167)	.08
My ability to solve problems.	3.87	.76	4.02	.67	3.98	.71	.76	(2,167)	.47
My ability to manage project-type assignments.	3.89	.75	3.96	.84	4.02	.67	.42	(2,167)	.66
The method of thinking more deeply.	4.01	.86	4.06	.73	4.00	.90	.07	(2,167)	.94
The work done in a group.	3.99	.83	4.06	.75	3.88	.76	.57	(2,167)	.57
My understanding and skills regarding engineering design.	3.35	.85	3.63	.93	3.63	.93	2.14	(2,167)	.12
The use of multiple sources of information and technology.	3.80	.92	3.83	.92	3.93	.77	.31	(2,167)	.74
Overall perceptions	3.86	.50	3.94	.49	3.94	.52	..59	(2,167)	.56

The results also indicated that there was no significant difference in the overall perceptions of school assessment practices in STEM related subjects in terms of gender at the significance level of .05. Although there were no statistically significant differences in the perceptions of school assessment practices in STEM related subjects between male and female students for Items 2, 3, 4, 6, 7, 8, 9 and 10 at the significance level of .05,

there were statistically significant differences in their perceptions of the school assessment practices in STEM related subjects that took account of their learning experience at school (Item 1) and their ability to solve problems (Item 5), favouring the female students in both school assessment practices. In particular, the finding on problem-solving ability which favoured female students contradicts the general research findings that there were gender differences in mathematical problem solving favouring male students (Zhu, 2007). This augurs well for the future development of the school assessment practices in STEM related subjects at the secondary school level.

The results also indicated that there was no significant difference in the overall perceptions of school assessment practices in STEM related subjects in terms of school zone at the significance level of .05. In addition, there were no statistically significant differences in the perceptions of school assessment practices in STEM related subjects among the school zones for all the items at the significance level of .05. This finding is expected as all the schools used the assessment practices as recommended in the national secondary school curriculum.

In conclusion, we acknowledge our limitations in making any generalizations from the results of this study which used a cross-sectional survey research design and self-report questionnaire. In addition, only 170 out of the 221 students in the sample completely answered the questionnaires. Nevertheless, the results of this study suggested for this sample of 170 students that the students had positive overall perceptions of school assessment practices in STEM related subjects.

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References

Gay, L. R, & Miles, G. E., & Airasian, P. (2011). *Educational research: Competencies for analysis and applications* (10th ed.). Boston, MA: Pearson Education International.

Martin, M. O., Mullis, I. V. S., Foy, P., Gonzalez, E. J., Gregory, K. D., Smith, T. A., Chrostowski, S. J., Garden, R. A., & O'Connor, K. M. (2000). *TIMSS 1999 International Science Report.* Boston, MA: International Study Center.

Martin, M. O., Mullis, I. V. S., Gonzalez, E. J., & Chrostowski, S. J. (2004).

TIMSS 2003 international science report. Boston, MA: Chestnut Hill,TIMSS & PIRLS International Study Center, Boston College.

Martin, M. O., Mullis, I. V. S., Foy, P. (with Olson, J.F., Erberber, E., Preuschoff, C., & Galia, J.). (2008). *TIMSS 2007 international science report.* Boston: Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Martin, M. O., Mullis, I. V. S., Foy, P., & Stanco, G. M. (2012). *TIMSS 2011 international results in science.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Mullis, I. V. S., Martin, M. O., Gonzalez, E. J., Gregory, K. D., Garden, R. A., O'Connor, K. M., Chrostowski, S. J., & Smith, T. A. (2000). *TIMSS 1999 international mathematics report.* Boston, MA: International Study Center.

Mullis, I. V. S., Martin, M. O., Gonzalez, E. J., & Chrostowski, S. J. (2004). *TIMSS 2003 international mathematics report.* Boston, MA: TIMSS & PIRLS International Study Center, Boston College.

Mullis, I. V. S., Martin, M. O., & Foy, P. (2008). *TIMSS 2007 international mathematics report.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center, 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, Boston College.

National Governors Association. (n.d.*). Innovation America: Building a science, technology, engineering and math agenda.* Retrieved from http://www.nga.org/cms/stem

OECD (2010), *PISA 2009 Results: What students know and can do – student performance in reading, mathematics and science (Volume I). http://dx.doi.org/10.1787/9789264091450-en*

STEM Education Quality Framework. (2011). Retrieved from http://dev.daytonregionalstemcenter.org/?p=74

Zhu, Z. (2007). Gender differences in mathematical problem solving patterns: A review of literature. *International Education Journal, 8* (2), 187-203.

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