

Form Four Science Students' Perceptions of the Quality of Learning Experiences Provided by Assessments in STEM Related Subjects

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Abstract

The lagging science and mathematics achievement of Malaysian secondary students in international assessment studies and the decreasing enrollment of science students at secondary school level call for the promotion of Science, Technology, Engineering and Mathematics (STEM) education in our country. One of the preliminary steps that could be taken was to identify the quality of learning experiences provided by assessments in STEM related subjects at the secondary school level. In addressing this concern, this study (which is part of a larger research project) aimed to investigate Form Four Science students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects such as Biology, Chemistry, Physics, Mathematics and Additional Mathematics. A cross-sectional survey research design was used and a sample of 852 Form Four Science students was selected from three categories of secondary schools in Peninsular Malaysia, namely Daily High-Performing (121), Full Boarding High-Performing (168) and Daily Normal (563). The Form Four Science students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects were assessed using a five-point Likert scale questionnaire which was developed based on the STEM Education Quality Framework (2011). The result indicated that the students had positive overall perceptions of the quality of learning experiences provided by assessments in STEM related subjects. In addition, there was no statistically significant difference in the overall perceptions of the quality of learning experiences provided by assessments in STEM related subjects in terms of gender. These results augur well for the promotion of STEM education in our country.

Keywords: Assessment, Quality of learning experiences, STEM related subjects, Science students, Gender

BACKGROUND OF THE STUDY

Science, Technology, Engineering, and Mathematics (STEM) education is an interdisciplinary curriculum that integrates the four disciplines of science, technology, engineering, and mathematics into a cohesive learning approach based on real-world applications. STEM education has the potential to produce and sustain a new workforce of problem solvers, innovators, and inventors who have the knowledge and skills to innovate and compete in the new global marketplace. The strength of the STEM workforce is often viewed as a strong indicator of a 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.). Hence, it is critical to promote STEM education in our country in order to produce and sustain a STEM workforce who can innovate and compete in the new and challenging global marketplace.

In addition, the decreasing enrollment of science students at secondary school level as reported by the Ministry of Science, Technology and Innovation (2012) as well as the lagging science and mathematics achievement and literacy of Malaysian secondary students in international assessment studies call for the the promotion of STEM education in our country.

The 1999, 2003, 2007 and 2011 Trends in the International Mathematics and Science Study (TIMSS) results revealed a worrying trend in the secondary students' science achievement. While the average scale scores for science in TIMSS 1999 (492) and TIMSS 2003 (510) were higher than the international average of 488 and 473 respectively, the average scale scores declined to 471 and 426 in

TIMSS 2007 and TIMSS 2011 respectively, and these average scale scores were lower than the TIMSS 2007 and TIMSS 2011 scale average of 500 (Martin, et al., 2000, 2004, 2008, 2012). Furthermore, in 2009 Malaysia was ranked 52nd in science literacy among 74 participating countries in the Program for International Student Assessment (PISA) conducted by the Organisation of Economic Cooperation and Development (OECD). 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 (OECD, 2010).

Likewise, the lagging mathematics achievement and literacy of Malaysian secondary students in international assessment studies also call for the the promotion of STEM education in our country. In fact, the 1999, 2003, 2007 and 2011 TIMSS results revealed a more worrying trend in the secondary students' mathematics achievement than in the science achievement. The average scale score for mathematics in TIMSS 1999 was 519 which was higher than the international average of 487. Even though the average scale score for mathematics was still higher than the international average of 466 in TIMSS 2003, it declined from 519 in TIMSS 1999 to 508. However, the average scale scores declined further to 474 and 440 in TIMSS 2007 and TIMSS 2011 respectively and these average scale scores were lower than the TIMSS 2007 and TIMSS 2011 scale average of 500 (Mullis, et al., 2000, 2004, 2008, 2012). Moreover, in the PISA 2009 conducted by the OECD, Malaysia was ranked 57th in mathematics literacy among 74 participating countries. 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 (OECD, 2010).

One of the preliminary steps that could be taken was to identify the quality of learning experiences provided by assessments in STEM related subjects at the secondary school level. Assessment is an integral component of the education process (OECD, 2005). Traditionally, the information collected from assessment was used to certify the results of student achievement and streaming students. Within the last decades, however, a strong case has been put forth to widen the purpose of assessment beyond the traditional view (McMillan, 2004). Assessment is integral to teaching and learning process that informs and guides teachers as they make instructional decisions to enhance the quality of students' learning experiences. In other words, assessment should not merely be done to students but also it should be done for students in order to guide and enhance the quality of their learning experiences (National Council of Teachers of Mathematics [NCTM], 2000). Indeed, assessment should support the quality of students' learning experiences of STEM related subjects and provide useful information to both teachers and students.

According to Gronlund (2006), assessment can contribute to more effective instruction and greater student learning when it is properly designed and appropriately used in classroom practice. Research has shown that making assessment an integral part of instruction in classroom practice is associated with improved student learning (NCTM, 2000). Black and Wiliam (1998) conducted a review of about 250 research studies and concluded that in classrooms where teachers include attention to formative assessment in making judgments about teaching and learning, students' learning, including low achievers, is generally enhanced. It is, therefore important to investigate students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects at the secondary school level so that steps can be taken to enhance assessment practices in STEM related subjects and to promote STEM education in our country as well.

Besides, international assessment studies have shown that there are some gender differences in science and mathematics achievement. In the TIMSS 2011 fourth grade science assessment, of the 50 participating countries 23 had no significant gender difference in science achievement but of the 27 remaining countries, 16 had relatively small differences favouring boys, and 3 had relatively small differences favouring girls. Additionally, eight countries had relatively larger differences favouring girls. However, gender differences in science achievement in the TIMSS 2011 eighth grade science assessment were larger, on average, than at the fourth grade, with the difference favouring girls. Interestingly, the gender difference in the TIMSS 2011 eighth grade science assessment varied across countries, with no difference in 17 of the 42 participating countries, a difference favouring boys in 10 countries, and a difference favouring girls in the remaining 15 countries (Martin, et al., 2012).

Likewise, in the TIMSS 2011 fourth grade mathematics assessment, of the 50 participating countries 26 had no significant gender difference in mathematics achievement but of the 24 remaining countries, 20 had small differences favouring boys, and 4 had relatively larger differences favouring

girls. In the TIMSS 2011 eighth grade mathematics assessment, however, gender differences in mathematics achievement were larger, on average, than at fourth grade, with the difference favouring girls. Interestingly, the gender difference in the TIMSS 2011 eighth grade mathematics assessment varied across countries, with no difference in 22 of the 42 participating countries, a difference favouring boys in 7 countries, and a difference favouring girls in the remaining 13 countries (Mullis, et al., 2012).

In the National Assessment of Educational Progress, Freeman (2004) found that there was little significant difference in mathematics scores between boys and girls. Although the scores fluctuated year by year, the average scores of boys in calculus, computer science, and science on Advanced Placement examinations were higher than those of girls.

Objectives of the study

The primary objective of this study was to elicit Form Four Science students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects. The secondary objective was to determine if there was a significant difference in the perceptions of the quality of learning experiences provided by assessments in STEM related subjects between male and female students. Specifically, this study aimed to address the following research questions:

1. What were Form Four Science students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects?
2. Was there a statistically significant difference in the perceptions of the quality of learning experiences provided by assessments in STEM related subjects between Form Four Science male and female students?

METHODOLOGY

Research design and sample

A cross-sectional survey research design was used in this study because it was effective for providing a snapshot of the current Form Four Science students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects in a population (Gay, Miles and Airasian, 2011). The sample of this study consisted of 852 Form Four Science students from three categories of secondary schools in Peninsular Malaysia, namely Daily High-Performing (149), Full Boarding High-Performing (172) and Daily Normal (684). The sample comprised 329 males and 523 females. Table 1 shows the distribution of the sample by school category and gender.

Table 1 Number of students by school category and gender

		Gender		Total
		Male	Female	
School Category	Daily High-Performing	51	70	121
	Full Boarding High-Performing	58	110	168
	Daily Normal	220	343	563
Total		329	523	852

Instrument

The Form Four Science students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects were assessed using a questionnaire which had two sections: Section A and Section B. Section A contained items on the students' demographic data such as gender and school category. Section B contained 10 items on the quality of learning experiences provided by assessments in STEM related subjects in the secondary school curriculum such as Biology, Chemistry, Physics, Mathematics and Additional Mathematics. The 10 items on the quality of learning experiences

provided by assessments in STEM related subjects were developed by the researchers based on the STEM Education Quality Framework (2011).

The framework 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. They are (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.

All the 10 items had a five-point Likert scale response options, namely strongly disagree, disagree, not sure, agree and strongly agree. The students' responses to each item received weighted values from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was piloted with a sample of 170 Form Four students and 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 questionnaire.

Results and Discussion

The results of this study are discussed in the following sections in order to answer the two research questions:

1. Form Fours Science students' perceptions of assessments in STEM related subjects

The means and standard deviations of the 852 Form Four Science students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects for each item and the overall perceptions are shown in Table 2. The means of the Form Four Science students' perceptions for all items in the questionnaire were higher than 3.00, indicating that the students generally had positive perceptions of the quality of learning experiences provided by assessments like examinations or assignments in STEM related subjects. For Item 9, the mean of the students' perceptions was the lowest (3.25), suggesting that the examinations or assignments in STEM related subjects which the students had gone through relatively took the least account of their understanding and skills regarding engineering design. Item 5 has the highest mean of the students' perceptions (3.98), suggesting that the examinations or assignments in STEM related subjects which the students had gone through relatively took the most account of their ability to solve problems.

Finally, the mean of the students' overall perceptions was 3.83, indicating that they generally had positive overall perceptions of the quality of learning experiences provided by assessments in STEM related subjects.

Table 2 Means and standard deviations of Form Four Science students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects

Item	Statement	Mean	Standard Deviation
	The examinations or assignments in STEM related subjects that I had gone through took account of:		
1	my learning experience at school.	3.97	.93
2	my daily experience.	3.78	.94
3	the concepts related to these subjects in an integrated manner.	3.86	.83
4	the connections among these subjects.	3.91	.83
5	my ability to solve problems.	3.98	.82
6	my ability to manage project-type assignments.	3.76	.90
7	the method of thinking more deeply.	3.97	.88
8	the work done in a group.	3.90	.95
9	my understanding and skills regarding engineering design.	3.25	1.13
10	the use of multiple sources of information and technology.	3.83	1.01

Overall perceptions	3.83	.60
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2. Difference in the perceptions of the quality of learning experiences provided by assessments in STEM related subjects in terms of gender

The results of the independent-samples t-tests using IBM SPSS Statistics 22 for each item in and the overall perceptions of the quality of learning experiences provided by assessments in STEM related subjects are shown in Table 3. For Items 1, 2, 3, 4 and 6, the mean scores of the Form Four Science male students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects were lower than those of the Form Four Science female students. However, for Items 5, 7, 8, 9 and 10, the mean scores of the Form Four Science male students' perceptions of the quality of learning experiences provided by assessments in STEM related subjects were higher than those of the Form Four Science female students.

From Table 3, the differences in the mean scores for Item 4 and Item 9 were statistically significant between Form Four Science male and female students at the significance level of .05. These results indicated that there were statistically significant differences in their perceptions of the examinations or assignments in STEM related subjects that took account of the connections among these subjects as well as their understanding and skills regarding engineering design, favouring the females and males for Item 4 and Item 9, respectively.

But, the differences in the mean scores for Items 1, 2, 3, 5, 6, 7, 8 and 10 were not statistically significant between Form Four Science male and female students at the significance level of .05. These results suggested that there were no statistically significant differences in the perceptions of the quality of learning experiences provided by assessments in STEM related subjects as measured by these items between Form Four Science male and female students.

Table 3 Results of the Independent-Samples T-Tests

Item	Male (N = 329)		Female (N = 523)		t	df	Sig. (2-tailed)	
	M	SD	M	SD				
The examinations or assignments in STEM related subjects that I had gone through took account of:								
1	my learning experience at school.	3.95	.93	3.98	.93	-.39	850	.69
2	my daily experience.	3.73	1.02	3.82	.89	-1.38	628.18	.17
3	the concepts related to these subjects in an integrated manner.	3.84	.89	3.88	.79	-.32	637.93	.75
4	the connections among these subjects.	3.84	.87	3.96	.80	-2.16	653.35	.03*
5	my ability to solve problems.	4.00	.84	3.96	.81	.69	850	.49
6	my ability to manage project-type assignments.	3.71	.96	3.79	.87	-1.16	644.32	.25
7	the method of thinking more deeply.	4.02	.87	3.94	.89	1.26	850	.21
8	the work done in a group.	3.92	.98	3.89	.94	.43	850	.67
9	my understanding and skills regarding engineering design.	3.35	1.20	3.18	1.07	2.15	639.27	.03*
10	the use of multiple sources of information and technology.	3.84	1.04	3.82	.99	-.32	850	.75
Overall perceptions		3.82	.63	3.84	.59	-.34	850	.73

* significant at $p < 0.05$

Lastly, the mean score of the Form Four Science male students' overall perceptions of the quality of learning experiences provided by assessments in STEM related subjects was slightly lower than that of the Form Four Science female students. Nevertheless, the difference in the mean scores for the overall perceptions was not statistically significant between Form Four Science male and female students, $t(850) = -.34, p > .05$. This result indicated that there was no statistically significant difference in the overall perceptions of the quality of learning experiences provided by assessments in STEM related subjects in terms of gender.

CONCLUSION

The results of this study showed that the Form Four Science students generally had positive overall perceptions of the quality of learning experiences provided by assessments in STEM related subjects. But, for Item 9 the mean of the Form Four Science students' perceptions was the lowest, revealing that the examinations or assignments in STEM related subjects which the students had gone through relatively took the least account of their understanding and skills regarding engineering design. This phenomenon might be due to the fact that engineering design is not included in most of the STEM related subjects at the secondary school level. This result implies that engineering design should be given greater emphasis in STEM related subjects at the secondary school level so as to promote STEM education in our country.

Further, the results of this study indicated that there was no significant difference in the overall perceptions of the quality of learning experiences provided by assessments in STEM related subjects between Form Four Science male and female students at the significance level of .05. But, there were statistically significant differences in their perceptions of the examinations or assignments in STEM related subjects that took account of the connections among these subjects (Item 4) and their understanding and skills regarding engineering design (Item 9), favouring the females and males for Item 4 and Item 9, respectively. As implied by the latter result, engineering design should be given more emphasis in STEM related subjects particularly for Form Four Science female students so as to address the issue of gender differences in promoting STEM education in our country.

Because this study employed across-sectional survey research design and self-report questionnaire, we acknowledge our limitations in making any generalizations from the results of this study. Nevertheless, the results of this study suggested for this sample of 852 Form Four Science students that they generally had positive overall perceptions of the quality of learning experiences provided by assessments in STEM related subjects which augurs well for the promotion of STEM education in our country.

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