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Acquisition of Basic and Integrated Science Process Skills Amongst Form 2 Students in Sarawak

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ABSTRACT

Science educators have strongly recommended that paper-and-pencil group testing format be used to measure process skills competency, which can be administered efficiently and objectively without requiring expensive resources. This paper reports the use of an author-developed psychometrically-supported Malaysian-Based Basic and Integrated Science Process Skills Inventory (MB-BISPSI) to gauge the acquisition of science process skills amongst 1021 Form 2 students (548 girls and 473 boys) from seven (four rural and three interior) secondary schools in Kapit Division, Sarawak, exploring the interaction effects of gender, ethnicity, and school location. The findings indicated that the students achieved a mastery level which fell short of the two-third benchmark for the overall science process skills, basic and integrated science process skills, and also for each of the specific 12 science process skills. Additionally, gender-ethnicity interaction effect was found to be statistically significant; while female students generally achieved a markedly higher mean percentage score in the overall Science Process Skills than did the male students, and such a phenomenon was only observed amongst the Kenyah ethnicity. In terms of location, there was no significant difference in the acquisition of science process skills between rural and interior students. Implications for a more thoughtful inculcation of science process skills are proffered alongside recommendations for future research using a more nationally representative sample to examine the validity of such generalisation.

Keywords: Practical work, basic and integrated science process skills, science education

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INTRODUCTION

The Malaysian Science curricula, across disciplines and grade levels, place great emphasis on the acquisition of Science process skills (Curriculum Development Centre [CDC], 2002). Padilla (1990) defines Science process skills as a set of broadly transferable abilities, appropriate to many scientific disciplines and reflective of the behaviour of a scientist. Science process skills are categorised into basic Science process skills (BSPS) and integrated Science process skills (ISPS) (American Association for the Advancement of Science [AAAS], 1967). Using similar categories, the Curriculum Development Centre (CDC) of the Malaysian Ministry of Education has listed seven and five skills respectively for BSPS and ISPS in all of its Science syllabuses for both the primary and secondary levels. The skills listed under BSPS are: (1) observing, (2) classifying, (3) measuring and using numbers, (4) inferring, (5) predicting, (6) communicating, and (7) using space-time relationship. For ISPS, the skills are: (1) interpreting data, (2) controlling of variables, (3) defining operationally, (4) hypothesising, and (5) experimenting. Malaysian students are expected to be familiar with the language of science process skills right from the start as they experience the practical and theoretical aspects of Science.

The mastery of Science process skills is deemed crucial because these skills represent the rational and logical thinking skills in Science (Burns, Okey & Wise, 1985). For example, observing, a science process skill, is related to the thinking skills of attributing, comparing and contrasting, and relating, whilst hypothesising, yet another science process skill, is related to the thinking skills of attributing, relating, comparing and contrasting, generating ideas, making hypothesis, predicting, and synthesizing (CDC, 2002). Accordingly, the acquisition of Science process skills enables students to operate within an enquiry manner and empowers them to act on information to produce solutions to problems.

PROBLEM STATEMENT

Assessing students' acquisition of Science process skills is an important aspect in the teaching and learning of Science. Although Practical Work Evaluation, or its Malay equivalent, *Penilaian Kerja Amali* (PEKA) was introduced in 1999 across Malaysian schools, research has indicated that Science teachers face many problems while implementing the practical work that ranges from uncertainty or less confident in assessing practical work, insufficient time to assess accurately, to under-resourced large class size (Filmer & Foh, 1997; Noorasyikin Kusai, 2002). It was observed in Ong, Wong, Sopia, Sadiah and Asmayati (2011) that when PEKA was done in groups and the assessment was based on group reports, there were bound to be cases in which some students had a free-ride or hitch-hike, only observing the experiments carried out by their group members. Yet, in another instance, when similar experiments are repeated yearly, students tend to submit copied or modified reports from their seniors for assessment. As such, the assessment from the PEKA may not be a true and accurate reflection of the level of Science process skills acquisition of individual students.

To circumvent these problems, Science educators have strongly recommended that paper-and-pencil group testing format be used to measure process skills competency, which can be administered efficiently and objectively without requiring expensive resources (Dillashaw & Okey, 1980). Additionally, in view of the current scenario, where male students were markedly marginalised in terms of educational achievement (Demie, 2001; Wong, Lam, & Ho, 2002) and also of the Malaysian government's aspiration in closing the achievement gap between urban and rural students, as succinctly documented in the Education Development Master Plan, or *Pelan Induk Pembangunan Pendidikan* (PIPP) (Malaysian Ministry of Education, 2006), it follows that the developed Science process skills instrument could be used to illuminate the differences in the acquisition levels between gender and between location.

RESEARCH OBJECTIVES

This study aimed to determine the differential acquisition of Science process skills amongst From 2 students by gender, location, and by ethnicity, as measured by the Malaysian-Based Basic and Integrated Science Process Skills Inventory (MB-BISPSI). The development and validation of MB-BISPSI was reported in Ong *et al.* (2011).

RESEARCH QUESTIONS

In as much as the purpose of this study was to determine the differential acquisition of Science process skills amongst From 2 students by gender, location, and by ethnicity as measured by MB-BISPSI, this study addressed the following questions:

1. What are the levels of Science process skills acquisition amongst the Form 2 students in terms of overall, basic, and integrated Science process skills achievement?
2. What are the levels of Science process skills amongst the Form 2 students in each of the 12 Science process skills: Observing, Classifying, Measuring and Using Numbers, Inferring, Predicting, Communicating, Using Space-Time Relationship, Interpreting Data, Defining Operationally, Controlling Variables, Hypothesising, and Experimenting?
3. Are there any main effects for gender, location, and ethnicity in terms of overall Science process skills?
4. Are there any two-way interaction and three-way interaction amongst gender, location and ethnicity in terms of overall Science process skills?

SCIENCE PROCESS SKILLS: LITERATURE REVISITED

Huppert, Lomask, and Lazarowitz (2002) reckon that science process skills are a "major goal of science education, since those skills are not only needed by scientists, but by every citizen in order to become a scientifically literate person" that can function in global society (p. 807). Additionally, these skills, according to Huppert *et al*. (2002), are applicable to all elements of society and as such, people should know how to use them in their daily life. But then, what constitute the Science process skills?

In the Malaysian context, Science process skills are categorised into basic Science process skills (BSPS) and integrated science process skills (ISPS), of which their precise definitions are given in Table 1.

Ismail (2001) investigated Forms 2 and 4 (14 and 16-year-old) students' performance on integrated Science process skills (ISPS) using the translated version of the instrument developed by Burns, Okey, and Wise (1985). This instrument,

TABLE 1
Definition of Basic Science Process Skills and Integrated Science Process Skills

No	Science Process Skill	Explanations
1	Observing	Process of gathering information about an object or phenomenon using all or some of the senses. Instruments could be used to assist the senses. The observation could be quantitative, qualitative or change.
2	Classifying	Observing and identifying similarities and differences between objects or phenomena, and gather them in terms of similar characteristics.
3	Measuring & using numbers	Observing quantitatively using instruments with standardised units. Ability to use numbers is central to the ability to measure.
4	Inferring	Giving explanation to an observation of event or object. Usually, past experiences and previously collected data are used as a basis for the explanation, and it could be correct or otherwise.
5	Predicting	Process of conjecturing a coming event based on observation and previous experience or availability of valid data.
6	Communicating	Presenting idea or information in varied modes such as orally, in written form, using graphs, diagrams, models, tables, and symbols. It also involves ability to listen to other's idea and respond to the idea.
7	Using space-time relationship	Describing changes in parameter with time. Examples of parameters are location, direction, shape, size, volume, temperature, and mass.
8	Interpreting data	Process of giving rational explanation of an object, event or patterns from the gathered information. The gathered information may come in different forms.
9	Defining operationally	Making definition of a concept or variable by stating what it is, and how it could be carried out and measured.
10	Controlling of variables	Identifying the fixed (constant) variables, manipulated variable and responding variable in an investigation. The manipulated variable is changed to observe its relationship with the responding variable. At the same time, the fixed variables are kept constant.
11	Hypothesising	Ability to make general statement that explains a matter or event. This statement must be testable to prove its validity.
12	Experimenting	This is an investigation that tests a hypothesis. The process of experimenting involves all or combination of the other processes.

which comprises 36 items, measures five process skills: (i) identifying variables (12 items), (ii) operationally defining (6 items), (iii) hypothesising (9 items), (iv) experimenting (3 items), and (v) interpreting data and graph (6 items). Comparing the performance on ISPS by level, there was a statistically significant difference between Forms 2 and 4 students in hypothesising, operationally defining, experimenting, and interpreting data and graph. With respect to gender, statistically significant differences were found in hypothesising, identifying variables, and interpreting data and graph. However, the ISPS mean scores for Forms 2 and 4 students (i.e., 32.3% and 34.5%, respectively) and for boys and girls (i.e., 31.5% and 34.5% respectively) were considered low. In order to explain these low ISPS mean scores, Ismail (2001) points to the ubiquitous use of didactic teaching, note copying and ineffective laboratory teaching that does not relate theory with the practical work.

Abu Hassan and Rohana (2003) investigated the level of Science process skills acquisition within the context of Chemistry amongst 300 form four students drawn from seven secondary schools in Johor Baharu by means of cluster random sampling. However, only two basic Science process skills (i.e., predicting and inferencing) and four integrated Science process skills (i.e., hypothesising, identifying variables, interpreting data, and experimenting) were measured using an author-developed structured-item Science process skills test which has a reliability of 0.90. The findings indicated that the students achieved an overall Science process skills mean of 54.26% and specifically, in descending order, 71.45% for hypothesising, 65.50% for interpreting data, 62.50% for predicting, 59.41% for identifying variables, 49.00% for inferencing, and 36.68% for experimenting.

Kiu (2006) conducted a study to determine the level of integrated science process skills amongst 100 second-year Science education undergraduate students who majored in Science, Chemistry, and Physics at Universiti Teknologi Malaysia in Skudai, Johore. The five integrated Science process skills, namely, controlling variables, hypothesising, defining operationally, interpreting data, and experimenting, were assessed using an instrument, with a reliability of 0.85, which was adapted by Samini (1986) from the Test of Integrated Process Skills I (Dillashaw & Okey, 1980) and Test of Integrated Science Process Skills II (Burns *et al*., 1985). The findings indicated that the overall acquisition of the integrated Science process skills were “moderate”, with a mean score of 20.21 (57.68%). Additionally, it was found that there were no significant differences between gender, and between the Malay and Chinese students in terms of overall integrated Science process skills.

In summary, the review of local indigenous studies on Science process skills acquisition indicate that students, be they secondary or undergraduate, have yet to achieve an acceptable level of mastery (i.e., at least 67% in overall mean percentage score) in Science process skills, particularly those which are categorised as integrated science process skills. However, there has been no study conducted which investigates the interactional effects amongst gender, ethnicity, and school location.

METHODOLOGY

Research Design

In view of the purpose of this study, the appropriate methodology used was a causal-comparative research design. In the causal-comparative design, the existing groups of students of various ethnicities in their respective intact ecological locations were used in the quest to ascertain and gauge their acquisition of Science process skills. In other words, the existing differences between gender, location, and ethnicity in terms of their acquisition of Science process skills were determined and the reasoning for the differences found was proffered. This is in line with the principles in the causal-comparative design where "investigators attempt to determine the cause or consequences of differences that *already exist* between or among groups of individuals" (Fraenkel, Wallen, & Hyun, 2012, p. 366).

Sampling

A purposive cluster random sampling was employed in this study, given that the cluster was the "divisions" in the state of Sarawak and these divisions constituted the "intact groups [that were] randomly selected" (Gay, Mills, & Airasian, 2009, p.129), while purposive was incorporated into the cluster random sampling on the basis that the sole criterion for selection within the intact

TABLE 2
Actual Number of Participating Students by Gender, Location, and Ethnicity

Location/ School	Male							Female						
	M	C	Ib	Ka	Ke	O	Total	M	C	Ib	Ka	Ke	O	Total
Rural														
School A	0	0	23	0	8	6	37	0	0	70	1	6	9	86
School B	4	4	87	2	1	2	100	2	3	82	0	3	1	91
School C	0	1	82	1	0	0	84	1	0	109	0	0	0	110
School D	5	9	79	1	0	1	95	4	6	84	2	0	1	97
Total (a)	9	14	271	4	9	9	316	7	9	345	3	9	11	384
Interior														
School E	1	0	25	1	2	1	30	0	0	29	0	5	1	35
School F	1	0	49	0	0	0	50	0	0	50	0	0	1	51
School G	3	5	9	12	17	31	77	4	4	8	14	26	22	78
Total (b)	5	5	83	13	19	32	157	4	4	87	14	31	24	164
TOTAL (a + b)	14	19	354	17	28	41	473	11	13	432	17	40	35	548

M=Malay, C=Chinese, Ib=Iban, Ka=Kayan, Ke=Kenyah,
O=Others (i.e., other minority of indigenous tribes)

groups was Form 2 students. Note that in other states in Malaysia, “districts” were used instead of “divisions”. Table 2 shows the actual number of students by gender, location, and ethnicity who had participated in this study by responding to the Malaysian-Based Basic and Integrated Science Process Skills Inventory (MB-BISPSI).

Instrumentation

The instrument used was the Malaysian-Based Basic and Integrated Science Process Skills Inventory (MB-BISPSI), of which its development was characterised by two phases: Instrument development process (Cohen, Manion, & Morrison, 2007) as Phase One, and item analysis as Phase Two. The processes involved in Phase One were identifying the test objectives; specifying the content; forming test specification table; writing test items; checking items; and pilot testing. In the item analysis, only items that have difficulty indices between 0.25-0.75 and the discrimination indices of more than 0.40 (McBeath, 1992) were retained, while those items that did not meet these criteria were either rejected or modified. The final set of MB-BISPSI, an encompassing Malaysian-based science process skills test, consists of 60 questions. It has a KR-20 reliability of 0.88, difficulty indices ranging between 0.25-0.75 and discrimination indices which are above 0.4. These three test characteristics are within acceptable limits for a reliable test. The full account on the development and validation of MB-BISPSI was reported elsewhere (Ong *et al*., 2011).

Data Collection Procedures

Prior to the commencement of the study, permission was sought from the Educational Planning and Research Division (EPRD) of the MoE, as mandated by the MoE General Circular 112/86 on ‘Ministry of Education Research Coordination’ (*Penyelarasan Penyelidikan Pendidikan Kementerian Pendidikan Malaysia*). Ethically and technically, upon gaining the approval from the EPRD, letters for permission with the attachment of EPRD approval letter, were forwarded to the Perak and Sarawak State Education Departments, given that the pilot study was conducted in Perak, while the main study of which its findings are reported in this paper, was implemented in Sarawak. Subsequently, the principals of the selected secondary schools were approached in person for the schools in Perak, and through a telephone conversation for schools in Sarawak.

In each school, the administration of research instruments was done simultaneously for all the classes under the supervision of teachers in school time. In administering the instruments, the teachers read the same researcher-prepared instructional script. In order to ensure high completion rate, teachers were asked to ensure that all the response sheets were collected at the end of the session.

Data Analysis Procedures

Data gathered from students’ responses to the Malaysian-Based Basic and Integrated Science Process Skills Inventory (BM-

BISPSI) would initially be subjected to data screening for normality which determines their suitability for parametric analyses. In determining the levels of Science process skills acquisition amongst the Form 2 students in the Kapit Division in terms of overall, basic, and integrated Science process skills achievement (Research Question 1), and in each of the specific Science process skills (Research Question 2), descriptive statistics were employed, and these included mean scores, percentages mean score, and standard deviations. A two-third rule or 66.67% (Mohd Najib & Abdul Rauf, 2011; Sharifah Nor Ashikin & Rohaida, 2005) was used as a benchmark to determine if a student achieved the desired acquisition level of Science process skills. It should be noted that, while one may choose a certain cut-off point such as 50% to determine a mastery level in Science process skills, the two-third rule was adopted simply because it helps to prevent making a decision that a person has "mastered" a certain skill with small majority of correct responses over a large minority of incorrect responses.

In determining the main effects for gender, location, and ethnicity, two-way interactions and three-way interaction amongst gender, location and ethnicity in terms of overall Science process skills (Research Questions 3 and 4), three-way 2 x 2 x 6 (Gender x Location x Ethnicity) Analysis of Variance (ANOVA) for the overall Science process skills were computed. Such three-way analysis provides a better understanding of the variation in the acquisition of Science process skills by gender, location and ethnicity, including the possible interactions among them.

RESULTS

This section begins by reporting the results from data screening. It then reports the quantitative findings when MB-BISPSI data were analysed to determine the level of Science process skills acquisition amongst Form 2 students in terms of overall, basic, integrated, and specific Science Process Skills, and subsequently, to determine the main effects for gender, location, and ethnicity, including the possible interactions among them (i.e., gender, location, and ethnicity), for the Overall Science Process Skills.

(a) Data Screening

The detailed preliminary data analyses for normality and other statistical characteristics for the Overall Science Process Skills, each of the specific 12 science process skills, and the composited basic and integrated science process skills are given in Table 3.

As shown in Table 3, all the values of skewness, which ranged between –0.42 and 0.87, fall within the acceptable range of not more than +1.00 or not less than –1.00 (Morgan, Griego, & Gloeckner, 2001), suggesting that none of the distributions was markedly skewed and consequently, none warranted the use of non-parametric statistics. Furthermore, all the dependent variables have acceptable kurtosis values that fall within the acceptable range of not more than +1.00 or not less than –1.00 (ibid.), suggesting they were neither too peaked with long tails nor too flat with too many cases in the tails.

(b) Acquisition of Overall and 12 Specific Science Process Skills

As shown in Table 4, the mean percentage for the overall Science process skills acquired by the Form 2 students in Kapit Division was 47.38%, while the mean percentages for basic and integrated Science process skills were 49.47% and 45.30%, respectively. Using the two-third rule (Mohd Najib & Abdul Rauf, 2011; Sharifah Nor Ashikin & Rohaida, 2005), the mastery levels in the overall, basic, and integrated Science process skills amongst Form 2 students in Kapit Division were below 66.67%, suggesting a weak acquisition of Science process skills.

As shown in Table 5, the mean percentages for the twelve science process skills range from 37.29% to 63.72%. While students achieved the mastery levels of, in descending order, 63.72% in observing, 57.86% in classifying, 53.34% in predicting, 50.03% in defining operationally, 48.93% in interpreting data, 47.85% in hypothesising,

TABLE 3
Test for Normality

Science Process Skills	Skewness	Kurtosis
Observing	-0.42	-0.36
Classifying	-0.23	-0.67
Measuring and Using Numbers	0.38	-0.56
Inferring	0.11	-0.81
Predicting	-0.06	-0.54
Communicating	0.14	-0.49
Using Space-Time Relationship	0.18	-0.50
Interpreting Data	0.03	-0.95
Defining Operationally	-0.03	-0.70
Controlling Variables	0.87	0.29
Hypothesising	0.09	-0.77
Experimenting	0.15	-0.76
Overall Science Process Skills	0.39	-0.41
Basic Science Process Skills	0.02	-0.36
Integrated Science Process Skills	0.50	-0.46

TABLE 4
Descriptive Statistics of Overall, Basic and Integrated Science Process Skills

Science Process Skills	Maximum Score	Mean Score	Mean Percentage	SD
Overall Science Process Skills	60	28.38	47.38	15.69
Basic Science Process Skills	30	14.84	49.47	15.65
Integrated Science Process Skills	30	13.59	45.30	19.18

46.31% in experimenting, 44.50% in inferring, 43.82% in communicating, 41.31% in using space-time relationship, 37.29% in measuring and using numbers, and 35.93% in controlling variables, these mastery levels, nevertheless, fell short of the two-third target (i.e., 66.67%).

(c) Overall Science Process Skills by Gender, Location and Ethnicity

Table 6 shows the three-way between-subjects ANOVA for the Overall Science Process Skills. As shown in Table 6, the main effects of gender ($F_{(1,997)} = 6.57$, $p = .011 < .05$) and of ethnicity ($F_{(5,997)} = 7.17$, $p < .0005$) were statistically significant and accounted for 0.7% and 3.5% respectively of the total variance in the Overall Science Process Skills. Meanwhile, the main effect of location was not statistically significant ($F_{(1,997)} = 0.38$, $p = .536$), suggesting that there was no markedly difference in the acquisition of Overall Science Process Skills between the rural and interior students.

In terms of gender and possible maximum overall score of 60, female students (mean = 29.08, SD = 9.55) achieved a substantially higher in terms of Overall Science Process Skills than did male students (mean = 27.68, SD = 9.21), although the effect size of 0.15, calculated using (female mean score – male mean score) / (pooled SD of 9.42), according to Cohen's (1988) interpretation, shows that the effect was small.

Analysing by ethnicity for the Overall Science Process Skills within the possible maximum score of 60, Table 7 presents the means and standard deviations while Table 8 shows the results of post hoc test by ethnicity for the Overall Science Process Skills. As shown in Table 8, statistical significant differences were found only between the Chinese and the Iban, the

TABLE 5
Descriptive Statistics for Specific Twelve Science Process Skills

Science Process Skills	Max Score	Mean Score	Mean Percent	SD
Observing	5	3.19	63.72	23.38
Classifying	4	2.32	57.86	27.56
Measuring and Using Numbers	4	1.49	37.29	26.88
Inferring	3	1.33	44.50	30.24
Predicting	5	2.67	53.34	25.12
Communicating	5	2.19	43.82	23.81
Using Space-Time Relationship	4	1.65	41.31	25.21
Interpreting Data	5	2.45	48.93	28.88
Defining Operationally	5	2.50	50.03	25.89
Controlling Variables	7	2.52	35.93	24.43
Hypothesising	7	3.35	47.85	24.77
Experimenting	6	2.78	46.31	26.39

Chinese and the Kayan, and the Chinese and Others (e.g., other minority indigenous tribes), with the mean score differences of 8.36 ($p < .001$), 7.54 ($p= .014 < .05$), and 6.55 ($p =.012 < .05$), respectively.

However, some caution is needed in interpreting these main effects (i.e., main effects for gender, and ethnicity) given that the interaction effect for gender and ethnicity was significant [($F_{(5,997)} = 2.24$, $p = .048 < .05$)] and accounted for 1.1% of the total variance in the Overall Science Process Sills. Table 9 gives the descriptive statistics by gender and ethnicity for the Overall Science Process Skills.

Visual inspection of the profile plots in Fig.1 shows that, while the female students generally achieved a higher acquisition of the Overall Science Process Skills than did the male students, the mean score for each of the ethnicities amongst females was not uniformly higher than the corresponding ethnicities amongst males. Such interpretation, based on a visual

TABLE 6
2 x 2 x 6 (Gender x Location x Ethnicity) Between-Subjects Analysis of Variance for Overall Science Process Skills

Source	df	SS	MS	F	p	η^2
Gender	1	560.43	560.43	6.57	.011 *	.007
Location	1	32.69	32.69	.38	.536	.000
Ethnicity	5	3061.52	612.30	7.17	.000 *	.035
Gender x Location	1	127.89	127.89	1.50	.221	.002
Gender x Ethnicity	5	957.39	191.48	2.24	.048 *	.011
Location x Ethnicity	5	610.09	122.02	1.43	.211	.007
Gender x Location x Ethnic	5	256.73	51.35	.60	.699	.003
Error	997	85112.89	85.37			
Total	1021	915826.00				
Corrected Total	1020	90418.65				

* Significant at p < .05

TABLE 7
Means and Standard Deviations by Ethnicity for Overall Science Process Skills

	Overall Science Process Skills	
Ethnicity	Mean	SD
Malay	30.72	9.00
Chinese	36.13	9.72
Iban	27.76	9.16
Kayan	28.59	10.20
Kenyah	30.37	10.09
Others	29.58	9.43
Total	28.43	9.42

TABLE 8
Results of Post Hoc Test for Ethnicity

Pairwise Comparisons				
Ethnic (I) – Ethnic (J)	Mean Difference (I-J)	p+		E.S.[1]
Malay - Chinese	-5.41	.430		
Malay - Iban	2.96	1.000		
Malay - Kayan	2.13	1.000		
Malay - Kenyah	0.35	1.000		
Malay - Others	1.14	1.000		
Chinese - Iban	8.36	.000	**	0.89
Chinese - Kayan	7.54	.014	*	
Chinese – Kenyah	5.76	.056		0.61
Chinese – Others	6.55	.012	*	0.70
Iban – Kayan	-0.83	1.000		
Iban – Kenyah	-2.61	.389		
Iban – Others	-1.82	1.000		
Kayan – Kenyah	-1.78	1.000		
Kayan - Others	-0.99	1.000		
Kenyah - Others	0.79	1.000		

* Significant at $p < .05$ ** Significant at $p < .001$
+ Adjusted for multiple comparisons: Bonferroni
[1] E.S., Effect Size = (Absolute Mean Difference)/(pooled SD of 9.42)

TABLE 9
Means and Standard Deviations by Gender and Ethnicity for Overall Science Process Skills

Gender	Ethnicity	N	Mean	SD
Male	Malay	14	29.93	7.12
	Chinese	19	36.32	11.31
	Iban	354	27.20	8.69
	Kayan	17	27.06	10.19
	Kenyah	28	26.43	10.46
	Others	41	28.17	10.25
	Total	473	27.68	9.21
Female	Malay	11	31.73	11.25
	Chinese	13	35.85	7.21
	Iban	432	28.22	9.51
	Kayan	17	30.12	10.30
	Kenyah	40	33.13	8.96
	Others	35	31.23	8.23
	Total	548	29.08	9.55

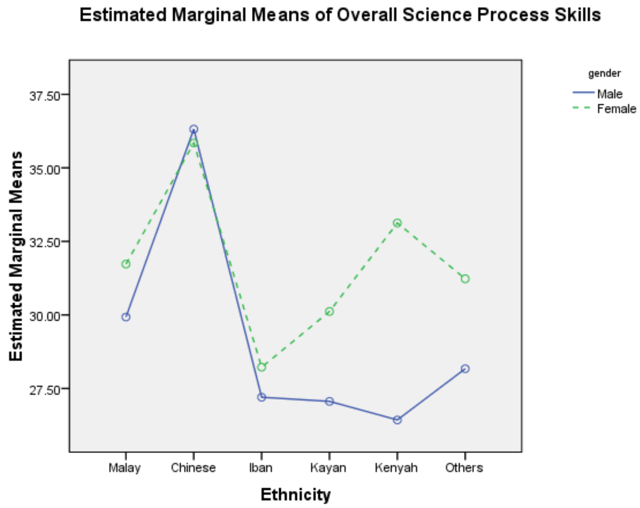

Fig.1: Profile plots of gender and ethnicity interaction for Overall Science Process Skills

inspection of the profile plots, nevertheless, needs to be checked with inferential statistics.

Accordingly, to pursue and test this statistically, a new independent variable consisting of twelve new cell codes was computed. This was then followed by a one-way ANOVA and post-hoc tests. Given the non-significant of Levene's Test (F=1.59, p=.10 < .05), which shows that the assumption of equal variances is not violated, the Bonferroni Post-Hoc Tests were used in which the results indicated that, while the mean differences between female and male students at each level of ethnicity was not significant (e.g., Malay = 1.80, p = .63; Chinese = -.47, p = .88; Iban = 1.02, p = .12; Kayan = 3.06, p = .34; and Others = 3.06, p = .15), only the difference between female and male students of Kenyah ethnicity was statistically significant (Kenyah = 6.70, p = .003).

CONCLUSION AND DISCUSSION

Using the two-third rule, the Form 2 students in Kapit Division failed to achieve the two-third benchmark in the Overall Science Process Skills, Basic Science Process Skills, Integrated Science Process Skills, and in each of the specific 12 Science process skills; namely, the skills of (1) observing; (2) classifying; (3) measuring and using numbers; (4) inferring; (5) predicting; (6) communicating; (7) using space-time relationship; (8) interpreting data; (9) defining operationally; (10) controlling variables; (11) hypothesising; and (12) experimenting.

Meanwhile, the findings from the quantitative analyses using the three-way ANOVA for the Overall Science Process Skills (OSPS) indicated that statistically significant differences were found in main effects for gender and for ethnicity, and in the two-way interactional effect between gender and ethnicity. Specifically, female students achieved better than male students, and that Chinese students achieved better than Iban, Kayan, and Other students. Nevertheless, the interactional effect between gender and ethnicity indicated that while female students achieved markedly higher than male students, and such a phenomenon was only observed amongst the Kenyah ethnicity.

In terms of acquisition of the Overall Science Process Skills, the outcomes of this study indicated that the Science process skills achievement of Form 2 students in Kapit Division fell short of the two-third rule. Equally, they did not meet the benchmark for basic and integrated science process skills, as well as each of the specific 12 science process skills. These findings corroborated the findings of Ismail (2001) who found that Form 2 and 4 students in Simunjan, Sarawak, achieved mean percentages of 32.3% and 34.5% respectively in the integrated Science process skills as measured by the translated version of TIPS-II (Burns, Okey, & Wise, 1985).

Additionally, the outcome of this study in which the Form 2 students achieved a level that fell short of the two-third benchmark lends support to the findings of Kiu (2006), as well as Abu Hassan and Rohana (2003), albeit at different educational levels. In the former, second year Science-based undergraduate students at Universiti Teknologi Malaysia achieved a mean percentage of 57.7% in terms of the integrated Science process skills, as measured by the combined use of TIPS I (Dillashaw & Okey, 1980) and TIPS II (Okey, Wise, & Burns, 1985), while in the latter, Form 4 students in Johor Baharu acquired a mean percentage of 54.3% in the Science Process Skills Achievement Test, a structured test that measures two basic science process skills (i.e., predicting and inferencing) and four integrated science process skills (i.e., hypothesising, identifying variables, interpreting data, and experimenting).

The findings from this study and other similar studies on students' acquisition of science process skills (e.g., Abu Hassan & Rohana, 2003; Ismail, 2001; Kiu, 2006), taken together, suggests that in general, Malaysian secondary students have not sufficiently acquired the science process skills as aspired by the Malaysian Ministry of Education. Therefore, it is imperative for the Ministry of Education to seriously look into this phenomenon of fell-short-of-the-two-third-benchmark in the acquisition of Science process skills amongst Malaysian secondary school students, strategising Science teaching which inculcates the mastery of basic and integrated Science process skills. Additionally, the different ways in which science process skills could be tested in terms of the feasibility in administration and scoring for prompt teacher feedback, instead of relying solely on Practical Work Assessment (PEKA) which teachers face problems in its actual implementation (Filmer & Foh, 1997; Noorasyikin Kusai, 2002), should also be duly considered and swiftly implemented.

Knowing students' acquisition level in each of the Science process skills, appropriate interventions and Science investigative work could then be thoughtfully planned and judiciously executed in our quest to instil these Science process skills amongst the students who constitute the future generation of Malaysia to meet the demand of the 21st century.

RECOMMENDATIONS FOR FUTURE RESEARCH

The findings of this study are derived from lower secondary students in one district (or division) of a Malaysian state. As such, further studies investigating a similar acquisition of science process skills as measured by MB-BISPSI using a more nationally representative sample are recommended in order to examine the validity of such generalisation.

Further study is also needed to determine if similar results can be found at all grade levels across primary education, lower secondary education, upper secondary education, two-year sixth form education, undergraduate and postgraduate education. Equally, it would be beneficial to determine the progression in the mastery of science process skills by examining if students continue to show gains in successive years of secondary and tertiary education.

Additional research is needed to determine which science teaching methods (i.e., inquiry science, investigative science, cooperative learning, constructivist science teaching) have greatest effect on the acquisition of science process skills in general, and each of the 12 science process skills in particular. Equally, given that the impact of various possible combinations of science teaching methods remains unclear, further study to isolate the relative impact, be it positive or otherwise, of these possible combinations would be illuminating and beneficial.

This study gauged the acquisition of science process skills amongst Malaysian secondary students through their responses on MB-BISPSI. It would contribute significantly to the research and literature if the future research could aim at uncovering by means of student interviews as well as school-based practical work, the understanding of, and mastery in, each of the 12 Science process skills by using suitable hypothetical and/or actual experimentation contexts. Besides, the various Science learning environments that could have led the female students to achieve a significantly higher level of Science process skills than the male students should be observed, documented, and analysed so that appropriate pedagogical support could then be provided.

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