International Journal of Assessment and Evaluation in Education
Vol. 3/Dec 2013 (15-30) ISSN 2232-1926

Test of Basic and Integrated Science Process Skills (T-BISPS): How do Form Four Students in Kelantan Fare?

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Abstract

This study aims to gauge the acquisition level of science process skills (SPS) amongst Form 4 students, analysing the data by gender, school location, and two-way interaction between gender and school location. Using a causal comparative design, the authors developed psychometrically-supported 60 multiple-choice-item Test of Basic and Integrated Science Process Skills (T-BISPS) was administered to 245 form four students from two rural and two urban schools in Kelantan. The findings indicated that the students achieved an acquisition level which fell short of the two-thirds benchmark (i.e., 66.67%) for the overall SPS (56.06%), basic SPS (59.29%) and integrated SPS (52.11%), and also for each of the specific science process skills except for communicating (67.35%), classifying (68.73%), and predicting (68.98%) skills. The results from the two-way factorial ANOVA indicated that, while there was no two-way gender and school location interaction effect and main gender effect, only the main school location effect was statistically significant in which urban students markedly outperformed rural students in the overall SPS, basic SPS and integrated SPS. The findings are discussed in relation to other studies and also in terms of possible contributory causes.

Keywords *school science process skills; Malaysian science education; assessment school science*

INTRODUCTION

Education plays a vital role in any country's pursuit of economic growth and national development. Accordingly, in meeting Malaysia's aspiration to become an innovative and developed nation by 2020, science and technology education plays a crucial role. By focusing on the development of individuals who are able to master scientific knowledge and technological competency, the Malaysian science curricula across disciplines and grade levels place a paramount emphasis on the teaching and learning of science process skills (Curriculum Development Division, 2012).

Science process skills are defined as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behavior of a scientist (Padilla, 1990). The mastering of science process skills together with scientific attitudes and knowledge will enable students to think, formulate questions and find out answers systematically by means of critical, creative and analytical thinking (Curriculum Development Division, 2012). A review of the corpus of literature on science process skills (e.g. Padilla, 1990; American Association for the Advancement of Science, 1967; Hassard, 2005; Wellington, 1994) indicates a concord that science process skills are hierarchically structured from the simple (basic) to the complex skills (integrated), and that science process skills are categorized into basic science process skills (BSPS) and integrated science process skills (ISPS).

In the context of Malaysian science syllabuses, the Curriculum Development Division of the Malaysian Ministry of Education has listed 12 science process skills to be inculcated across the education levels, from primary, lower secondary, to upper secondary levels. The 12 science process skills stipulated are: (1) observing, (2) classifying, (3) measuring and using numbers, (4) inferring, (5) predicting, (6) communicating, (7) using space-time relations, (8) interpreting data, (9) controlling of variables, (10) defining operationally, (11) hypothesizing, and (12) experimenting. While the first seven skills are classified as basic science process skills, the latter five skills are grouped as integrated science process skills. The Malaysian science curriculum aims to produce active learners by engaging process skills in which students are given ample opportunities to observe, ask questions, formulate and test hypotheses, analyze, interpret data, report and evaluate findings (Curriculum Development Division, 2012). Malaysian students are expected to be familiarized with thes language of science process skills right from the start as they experience science learning (Curriculum Development Division, 2011).

PROBLEM STATEMENT

The intended science content in the curriculum may be described in terms of science concepts, processes, and attitudes that students are expected to acquire (Robitaille et al., 1993). While Malaysian students are generally good at regurgitating facts that have been fed into them, this fact-regurgitating ability is less valuable in today's ever-changing economy. Instead, students need to be able to reason, to extrapolate, and to creatively apply their knowledge in novel and unfamiliar settings. For this reason, students need to be taught the skills that enable them to think critically by using information creatively. Hence, mastering science process skills is deemed crucial because the skills are required in the process of finding solutions to a problem as well as making decisions in a systematic manner (Curriculum Development Centre, 2012). The Malaysian science curricula are therefore designed to emphasize thoughtful learning by applying science process skills across the science disciplines as envisioned in the Integrated Curriculum for Secondary Schools.

While the Malaysian students' performances in science and mathematics are improving over the years as evident in the results of the standardized national examinations, the performances in international assessments such as Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS), nevertheless, seem to suggest otherwise (Martin, Mullis, Foy, & Stanco, 2012; Ministry of Education Malaysia, 2012). PISA and TIMSS that serve to directly compare the quality of educational outcomes across different countries and systems, assess a variety of cognitive skills such as application and reasoning, which are very similar to the science process skills as these involve pertinent problem solving skills (Gagne, Yekovich & Yekovich, 1993; Hassard, 2005) and higher-order thinking skills (Germann & Aram, 1996; Lee et al., 2002; Rezba et al., 2007). These outcomes indicate that it is no longer adequate for a student to leave school with just having content knowledge. In other words, the emphasis in human capital development is no longer just on the importance of knowledge, but rather on developing higher-order thinking skills (Ministry of Education Malaysia, 2012), which are best linked to science process skills (Burns, Okey, & Wise, 1985; Curriculum Development Division, 2012; Germann, 1994; Hassard, 2005; Lay, Khoo & Lee, 2009; Padilla, Okey, & Dillashaw, 1983).

Currently, the acquisition of science process skills of each student is gauged through the school-based Practical Work Assessment, popularly known in its Malay acronym, PEKA (*Penilaian Kerja Amali*). While teachers expect students to demonstrate the acquisition of science process skills in the assessment of PEKA, the problem of using hands-on procedures to assess skill acquisition by groups of students can be a burdensome task (Dillashaw & Okey, 1980). Filmer and Foh (1997) reported that due to large class size, teachers were less confident in assessing practical work and did not have sufficient time to assess accurately. Besides, there are other problematic aspects in the implementation of PEKA such as time constraint, too many students to be assessed simultaneously, and poor laboratory facilities (Abdul Rahim & Saliza, 2008; Alias, 2001; Faiza, 2003; Yeow, 2002). To circumvent these problems, Dillashaw and Okey (1980, p. 602) suggested a paper-and-pencil group testing format for measuring process skills competency which they argued "can be administered efficiently and objectively".

Additionally, the Government of Malaysia aspires to achieve equity in education (Ministry of Education, 2012) especially in closing the achievement gap between urban and rural students, and between genders where it has been reported that the gender gap is widening. Hence, it is important to measure and gauge students' acquisition level of science process skills, particularly among students who are at the penultimate year of upper secondary schooling across gender and school locality.

The purpose of this research, therefore is to measure the science process skills acquisition amongst Form 4 students (16-17 years of age) in Kelantan using the Test of Basic and Integrated Science Process Skills (T-BISPS) developed by Mohd Al-Junaidi and Ong (2012). T-BISPS is a Malaysian-based instrument with sufficient and acceptable level of content validity, reliability, difficulty and discrimination indices.

RESEARCH OBJECTIVES

This study aims to gauge the acquisition level of science process skills amongst Form 4 students in terms of overall science process skills, basic science process skills, integrated science process skills, and each of the specific 12 science process skills. Pertaining to the overall science process skills, the analysis involves examining the differences by gender, school location, and two-way gender and school location interaction.

Research Questions

On the basis of the research objectives, the following research questions were formulated:

1. What are the levels of science process skills acquisition amongst the Form 4 students in terms of overall, basic, and integrated science process skills?
2. What are the levels of science process skills amongst the Form 4 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, Hypothesizing, and Experimenting?
3. Are there any main effects for gender and school location in terms of overall science process skills?
4. Is there a two-way interaction between gender and school location in terms of overall science process skills?

Science Process Skills: Literature Revisited

In the history of science education development, the launch of the Soviet Union's satellite Sputnik I in 1957 led to a significant shift in the US educational system in which inquiry methods have become more visible and popular. According to Hassard (2005: p. 169) "One of the directions that science education took after Sputnik was to pay attention to the process of science and emphasize inquiry in the development of science teaching materials". In response to increasing criticism against the US science education, a content-oriented science curriculum has been shifted to a more process-based curriculum whereby much attention has been paid to the teaching of the process and skills in scientific exploration (Friedl & Koontz, 2005; Hassard, 2005). Process-based curricular are best associated with inquiry methods in science (Temiz, Tasar & Tan, 2006) and thinking skills (Padilla, 1990). Given the importance of process and skills as being applied by scientists in their efforts to generate scientific theory, concept and law when solving the problem (Friedl & Koontz, 2005), the major initiatives undertaken by the US educational system was Science – A Process Approach (Hassard, 2005), a process-based curricular initiative in which basic processes were introduced in grades K-3 while integrated science process skills were introduced and developed in grades 4-6 (Ong & Ruthven, 2005).

Meanwhile, the Malaysian science curriculum also places paramount focus on inquiry methods and thinking skills. According to Curriculum Development Division (2012), science process skills and thinking skills are utilized in inquiry and problem solving processes. The broad use of the term 'science process skills' is sometimes equated with a multitude of concepts including scientific thinking, scientific methods and critical thinking (Padilla, 1990), as well as scientific skills and problem solving skills (Hassard, 2005). Although differences of views still exist, there appears to be some agreement that science process skills are referring to a set of broadly transferable abilities appropriate to many science disciplines and reflective of the behaviour of scientists (Padilla, 1990). It is a mental process that promotes critical, creative, analytical and systematic thinking which enable students to find solutions to a problem or to make decisions in a systematic manner (Curriculum Development Division, 2012).

The mastery of science process skills is deemed to be crucial, because these science process skills represent rational and logical thinking skills in science (Burns, Okey, & Wise, 1985). For example, observation, a basic SPS, is related to the thinking skills of attributing, comparing and contrasting, and relating, whilst hypothesizing, yet another integrated SPS, is related to the thinking skills of attributing, relating, comparing and contrasting, generating ideas, making hypotheses, predicting and synthesizing (Curriculum Development Division, 2012). As such, these skills need to be realized by teachers that it is important in the learning of science as they provide a scaffold to other cognitive skills such as logical thinking, reasoning and problem solving skills (Rauf, Rasul, Mansor, Othman, & Lyndon, 2013). A corpus of research findings (e.g., Lay et al., 2009; Germann, 1994; Padilla et al., 1983; Tobin & Capie, 1982) has shown that formal reasoning abilities are the best predictors for students' acquisition of science process skills. For instance, Tobin and Capie (1982) have concluded in their studies that students with higher formal reasoning abilities showed better performance in science process skills when 30% of the variance in science process skills was attributed to students' formal reasoning abilities. Lay et al. (2009) also revealed that logical thinking abilities accounted for 20% of the variance in secondary students' integrated science process skills.

Assessing students' acquisition of science process skills therefore is an important aspect in the teaching and learning of science (Burns, Okey & Wise, 1985; Dillashaw & Okey, 1980; Kazeni, 2005; Harlen, 2006). However, a review of the instruments developed for measuring science process skills amongst students at secondary school level indicates that these instruments were deficient in terms of their coverage of the complete domain of 12 science process skills. The process skills coverage of some instruments was limited in that they assessed basic SPS, integrated SPS, or a combination of certain process skills. For instance, Tannenbaum (1971) developed the Test of Science Processes, which measures the observing, comparing, classifying, quantifying, measuring, experimenting, inferring and predicting skills of students in grades 7, 8 and 9. The Test of Integrated Process Skills (TIPS) was developed by Dillashaw and Okey (1980) for middle and secondary school students. Burns, Okey and Wise (1985) developed the Integrated Science Process Skill Test, which is known as TIPS II, for middle and high school students. McKenzie and Padilla (1986) developed a multiple-choice test of graphing skills only, which is appropriate for science students in grades 7-12. Kazeni (2005) developed the Test of Integrated Science Process Skills for grades 10 and 11. The Test of Basic and Integrated Science Process Skills or T-BISPS developed by Mohd Al-Junaidi and Ong (2012) is currently the only valid and reliable instrument available to measure a complete range of 12 science process skills in a Malaysian context, particularly for upper secondary students.

A previous study by Ong et al. (2011) which sought to determine the mastery level of science process skills among Malaysian lower secondary school students in Kapit Division in the state of Sarawak indicated that the students achieved a mastery level which fell short of the two-thirds 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, Ong et al. (2011) found that although there was a gender effect favouring the females, such gender effect 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. No urban comparison was reported simply because the location of the secondary schools in that particular district in Sarawak was classified as either rural or interior by the Malaysian Ministry of Education.

METHODOLOGY

Research Design

Given the research questions that aimed to examine the possible effects of gender and school location on science process skills achievement, the present study employed a causal comparative design. A causal comparative design is appropriate when two or more existing groups are compared retrospectively (Fraenkel, Wallen, & Hyun, 2011; Levy & Ellis, 2011), as in the present study, which compared student acquisition of science process skills in terms of gender and school location. Since the theme of this study is to suggest a causative relationship between the independent variables (i.e., gender and school location) with science process skills achievement (i.e., dependent variable), the causal-comparative design seems appropriate to use as it involves the comparison among existing groups (Gay & Airasian, 2000).

Instrumentation

The Test of Basic and Integrated Science Process Skills (T-BISPS) developed by Mohd Al-Junaidi and Ong (2012) was used in this study. T-BISPS is a multiple-choice test that is created based on Malaysian context through the test development and validation research. The development and validation of T-BISPS has been comprehensively reported in Al-Junaidi and Ong (2012). In essence, the final set of T-BISPS consists of 60 items: 28 items for basic SPS (with the KR-20 reliability of 0.86) and 32 items for integrated SPS (with the KR-20 reliability of 0.89). The mean item difficulty index is 0.60, ranging between 0.37 and 0.75, while the mean item discrimination index is 0.52, ranging between 0.20 and 0.77. The results of the item analysis indicate that T-BISPS with the appropriate psychometric characteristics is an acceptable, valid and reliable test to measure the acquisition of science process skills amongst Form 4 students. Furthermore, it uses both Malay and English languages for the items (i.e., bilingual), and has been validated using local students in its development. As such, the use of T-BISPS was based on its contextual characteristics and sufficient psychometric properties.

Data Collection Procedures

The subjects selected for this study comprised 155 students from two urban schools in Kota Bharu and 90 students from two rural schools in Machang. It was a purposive sampling on the basis of the schools' typicality and locality from the official records kept by the Kelantan State Education Department. It is assumed that all students have been exposed to the teaching and learning of science process skills since their primary schooling right up to secondary schooling. Such assumption is based on the mandated policy explicitly articulated in policy documents such as the Integrated Curriculum for Primary School and the Integrated Curriculum for Secondary School. In each school, the administration of the T-BISPS was done simultaneously for all the classes under the supervision of teachers in school time.

Data Analysis Procedures

Descriptive statistics were computed for overall, basic, integrated, and specific science process skills to gauge the levels of science process skills of the students (in illuminating research questions 1 and 2). Independent samples t-tests were performed on the data set from T-BISPS to compare the main effects for gender (between male and female students) and school location (between urban and rural school) in terms of the overall science process skills (in answering research question 3). A two-way analysis of variance (ANOVA) was computed to test the interaction between gender and school location with regard to the overall science process skills achievement (in illuminating research Question 4).

RESULTS

The preliminary data screening on T-BISPS and each of its 12 sub-scales for normality and other statistical characteristics indicated that the use of parametric methods was appropriate. In this independent t-test, the overall science process skills achievement served as the dependent variables, whereas gender and school location as the independent variables. The results are reported with respect to each specific research question (RQ).

RQ 1: What are the levels of science process skills acquisition amongst the Form 4 students in terms of overall, basic, and integrated science process skills achievement?

Table 1 Descriptive Statistics of the Overall, Basic and Integrated Science Process Skills

Science Process Skills (SPS)	Maximum Score	Mean Score	Mean Percentages	Standard Deviation
Overall SPS	52	33.64	56.06	13.52
Basic SPS	30	19.57	59.29	12.03
Integrated SPS	24	14.07	52.11	19.57

In order to discriminate between students who have mastered with those who have not yet mastered the acquisition of science process skills, 66.7% was used as a cutoff score by means of two-thirds benchmark rule to determine the mastery level. Hence, students must have attained a mean percentage score which is above the two-thirds benchmark (i.e., 66.7%) to be considered as having achieved the mastery level in the overall, basic, and integrated science process skills. Two-thirds benchmark was chosen over other cut-off points to determine a mastery level in Science process skills 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" (Ong et al., 2013, p. 988). Furthermore, the two-thirds benchmark was employed in other studies to determine the benchmark for mastery in science process skills (i.e., Mohd Najib & Abdul Rauf, 2011; Sharifah Nor Ashikin & Rohaida, 2005).

As shown in Table 1, the mean percentages for the overall SPS (56.06%), basic SPS (59.29%) and integrated SPS (52.11%), fell short of the two-thirds benchmark.

RQ2: What are the levels of science process skills acquisition amongst the Form 4 students in each of the 12 science process skills?

Table 2 Descriptive Statistics for each of the 12 science process skills

Science Process Skills	Maximum Score	Mean Score	Mean Percentage	Standard Deviation
Observing	4	1.88	47.04	20.34
Predicting	5	3.45	68.98	19.94
Classifying	5	3.44	68.73	21.28
Measuring and Using Numbers	5	2.12	42.37	21.49
Communicating	5	3.37	67.35	21.23
Making Inferences	5	3.31	66.12	23.54
Using Time and Space Relations	4	2.01	50.20	25.31
Hypothesizing	4	2.41	60.20	30.42
Defining Operationally	5	3.05	60.98	25.97
Identifying Variables	7	4.37	54.59	24.15
Experimenting	5	2.06	41.22	24.50
Interpreting Data	4	2.18	43.67	24.79

Table 2 shows the achievements for each of the 12 specific science process skills. The findings indicate that the students achieved an acquisition level which fell short of the mastery level (i.e., 66.67%) for each of the science process skills except for communicating (67.35%), classifying (68.73%), and predicting (68.98%) skills, which are subsumed under the basic SPS. This suggests that students failed to attain the mastery level for all the integrated SPS.

RQ3: Are there any main effects for gender and school location in terms of overall science process skills?

Table 3 Results from Independent Samples t-test by Gender and School Location for Overall Science Process Skills

Groups	Mean Percentage	Standard Deviation	t	df	p
Male	54.62	12.62	1.063	243	.289
Female	56.65	13.87			
Urban School	57.67	13.67	2.464	243	.014*
Rural School	53.30	12.87			

*Significant at p < .05

Table 3 shows the mean percentages and standard deviations by gender and school location for the overall science process skills in T-BISPS. As shown in Table 3, the main effect for gender in terms of the overall science process skills acquisition was not statistically significant [t (243) = 1.063, p = 0.289 > 0.05]. However, the main effect for school location in terms of the overall science process skills acquisition was statistically significant [t (243) = 2.464, p = 0.014 < 0.05]. According to Cohen (1988), effect size of 0.33 as shown in Table 4 indicates that difference in the mean score between urban and rural school students with regard to the overall science process skills acquisition was medium.

Table 4 Mean and Standard Deviation by School Location for the Overall Science Process Skills

Scale	Urban (n = 155)		Rural (n = 90)		Difference	
	M_1	SD	M_2	SD	$M_1 - M_2$	E.S.[1]
Science Process Skills	34.60	8.20	31.98	7.72	2.62	0.33

ES[1], Effect Size = (female mean score – male mean score) / (pooled SD)

RQ4: Is there a two-way interaction between gender and school location in terms of overall science process skills?

Table 5 Test of 2 x 2 ANOVA (Gender x Location) in terms of the Overall Science Process Skills

Source	SS	Df	MS	F	p
Location*Gender	393.145	1	393.145	2.208	.139

* Significant at α = 0.05

As shown in Table 5, the two-way ANOVA results indicate that the interaction between school location and gender in terms of the overall science process skills acquisition was not statistically significant [F (1, 241) = 2.21, p = 0.139 > 0.05]. Figure 1 shows the profile plot of the non-significant gender and school location interaction, which, interestingly, depicts a seemingly significant gender and school location interaction. We consider this as a "visually deceptive interaction effect" phenomenon which emerged due to probable non-statistical significant differences of mean percentages between the male students from urban schools (54.71%) and rural schools (54.47%), and also between the female students from urban schools (58.91%) and rural schools (52.85%). Table 6 shows the mean percentage and standard deviation by gender and school location for the overall science process skills acquisition.

Table 6 Mean percentage and standard deviation by gender and school location for the overall science process skills (SPS)

Scale	Male				Female			
	Urban (n = 46)		Rural (n = 25)		Urban (n = 109)		Rural (n = 65)	
	M (%)	SD	M (%)	SD	M (%)	SD	M (%)	SD
Overall SPS	54.71	12.31	54.47	13.44	58.91	14.07	52.85	12.73

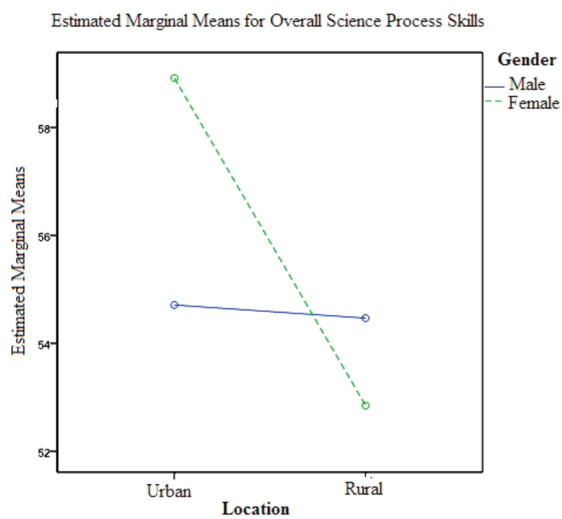

Figure 1 Profile Plots for Gender and School Location Interaction for Overall cience Process Skills

Accordingly, the analyses had to be followed by one-way ANOVA in order to confirm the interaction effect between gender and school location on the overall science process skills. For this analysis, an independent variable which comprised 4 cell codes was established, i.e., code 1 represents urban male students, code 2 represents rural male students, code 3 represents urban female students and code 4 represents rural female students. The results of the one-way ANOVA analysis are given in Table 7.

Table 7 Test of One-way ANOVA for the Overall Science Process Skills

Scale	Difference*	Difference Value	Standard Error	t	df	p
Overall SPS	1	1.62	3.140	0.516	241	0.606
	2	4.20	2.346	1.792	241	0.074

*1= the difference between male and female students in rural schools, 2= the difference between male and female students in urban schools

The results from the one-way ANOVA in Table 7 indicate that the mean difference of 1.62 between the male and female students in rural schools was not statistically significant ($t = 0.516$, $p = 0.606 > 0.05$). Likewise, the mean difference of 4.20 between the male and female students in urban schools was also not statistically significant ($t = 1.792$, $p = 0.074 > 0.05$). These results indeed confirmed that the interaction effect between school location and gender with regard to the overall science process skills was not statistically significant, giving credence to the notion of a visually deceptive interaction effect.

CONCLUSIONS AND DISCUSSION

The achievement of the overall SPS (56.06%), basic SPS (59.29%) and integrated SPS (52.11%) as measured by T-BISPS of Form 4 students fell short of the mastery level (i.e., 66.67%). Similarly, the findings also indicated that the students' achievement fell short of the mastery level for each of the specific science process skills except for communicating (67.35%), classifying (68.73%), and predicting (68.98%). A comparison amongst these outcomes reveals that none of the integrated SPS was attained at the mastery level. It is somewhat perplexing that the majority of basic SPS fell short of the mastery level. This finding was unexpected since the basic SPS are the prerequisites to the integrated SPS (Rauf et al., 2013) which provide the intellectual groundwork in scientific inquiry (Germann & Aram, 1996). We postulate that these results may be explained by the item characteristic of T-BISPS which is content-free. It must be emphasised that while these items are free from testing the recalling or regurgitating of content or subject-matter of science, these items do use a broader range of science-related phenomena in everyday life as the context for the items. As such, the items in T-BISPS are not items that measure science process skills in isolation, as they are situated within a science context which does not require recalling of scientific facts, principles, theories and laws as propounded by Bozkurt and Olgun (2005). Although Harlen (1999) argues that the 'setting' or context of the task does influence the performance of students, Bozkurt and Olgun (2005) counter-argue that evaluating science process skills within the contexts or issues which the students are unfamiliar with, is in fact, important as it provides motivation and raises interest among students who otherwise find the items boring and non-meaningful.

Although we are not able to directly compare this present study with previous studies which have employed similar instruments the comparison could still be made based on the logic of parallel impact of other science-based curricular innovations so long as their distinctive features are clearly identified (Ong & Ruthven, 2005). These results therefore need to be interpreted with caution. By parallel impact comparison, the process skills outcomes in this study are consistent with previous research. In terms of science process skill acquisition level, the finding of this study accords with the earlier research by Ong et al. (2011), who found that the overall SPS (mean percentage = 47.38%), basic SPS (mean percentage = 49.47%) and integrated SPS (mean percentage = 45.30%) achievement of Form 2 students in Kapit, Sarawak fell short of the two-thirds benchmark. Likewise, the finding of this study is rather similar to the finding of Akinbobola and Afolabi (2010) who found that West African senior secondary school students, while failing to attain the two-thirds benchmark in basic SPS (62.80%) and integrated SPS (37.20%), performed better in the former than the latter in the physics practical examinations in Nigeria across the years (1998-2007). Such observation could be attributed to the fact that the integrated SPS are higher level skills (Dillashaw & Okey, 1980; Padilla, 1990; *The American Association for the Advancement of Science*, 1998) which taken together, represents the higher-order thinking skills (Rezba et al., 2007). The basic (simpler) science process skills, by contrast, provide a foundation for learning the integrated (more complex) skills (Padilla, 1990). The finding in which students performed better in basic SPS than integrated SPS provides further credence to the idea that students' ability to acquire integrated SPS is very much dependent on their level of acquisition of basic SPS (Onwu & Mozube, 1992).

The findings of the current study which indicate a weak acquisition of integrated SPS amongst Form 4 students are consistent with that of Hu (2010), Lay et al. (2009), Muna Munirah (2010), Ong and Johairi (2009), Patricia Marlia (2010), and also Zurida and Ismail (2001). However, these results need to be interpreted with caution since these earlier studies used different, non-encompassing, and translated science process skills instruments such as Test of Integrated Process Skills II (Burns, Okey, & Wise, 1985) and Middle Grades Integrated Process Skill Test (Cronin & Padilla, 1986). Based on the pattern in the acquisition level of science process skills, it can be concluded that generally, Form 4 students have not achieved a desirable acquisition level of integrated SPS. The reason for such non-achievement remains unclear, although it is plausible to attribute this non-achievement phenomenon to students' ability in, and grasp of, thinking skills. According to Curriculum Development Division (2012), in order to acquire the science process skills, students have to acquire the thinking skills as well because the mastering of science process skills involves the mastering of the relevant thinking skills. This view supports previous research (e.g., Lay et al., 2009; Padilla, Okey & Dillashaw, 1983; Tobin & Capie, 1982; Zurida & Ismail, 2001) which links integrated SPS and thinking skills. Moreover, Lay et al. (2009), Germann (1994), Padilla et al. (1983), and Tobin and Capie (1982) have found that formal reasoning abilities are the best predictors for students' acquisition of integrated SPS.

The finding in which urban students achieved a markedly higher acquisition level in the overall science process skills provides support to the findings of Sulaiman (2009) who found that urban students performed better than rural students in terms of communicating, classifying, observing and predicting skills. This urban-rural difference may be attributed to the language proficiency level given that science has been taught using English as the medium of instruction until it was reverted to the Malay language in 2013.

RECOMMENDATIONS FOR FUTURE RESEARCH

This study employed the newly developed instrument, T-BISPS which has undergone a rigorous validation process, and hence, psychometrically supported. Previous research findings within the Malaysian context therefore are not amenable for direct comparison simply because of the employment of differential instruments and the use of students of differing grade levels. As such, it would contribute significantly to the research and literature if future studies could utilize the instrument of T-BISPS for measuring science process skills acquisition amongst Form 4 students in various districts and states across Malaysia in order to have a fuller understanding while at the same time, making a fair and reasonable comparison.

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