ACQUISITION OF SCIENCE PROCESS SKILLS AMONGST FORM 3 STUDENTS IN MALAYSIAN SMART AND MAINSTREAM SCHOOLS

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This article reports the relative effect of smart and mainstream schooling on students' acquisition of science process skills which was measured using TIPS-II(M) — the Malay version of Burns, Okey, and Wise's (1985) Test of Integrated Process Skills II. Using students' primary-school science achievement results in the Standardised National Examination (SNE) as covariate, the data collected were analysed using MANCOVA. The results indicated that the overall integrated science process skills achievement of students who had participated in the Smart Schools was statistically significantly higher than the overall performance of students in the Mainstream Schools. However, the follow-up univariate ANCOVA tests indicated that the overall performance was contributed by only four scales, namely Identifying Variables (IdV), Identifying Testable Hypothesis (ITH), Data and Graph Interpretation (DGI), and Experimental Design (ED). While the significant group differences in IdV, ITH, and ED could be interpreted in a straightforward manner, the group difference in DGI was moderated by class level. The article concludes with a discussion of the findings and recommendations for future research.

INTRODUCTION

The Malaysian Smart Schools, defined as "… learning institution[s] that … [have] been systematically reinvented in terms of teaching-learning practices and school management in order to prepare children for the Information Age" (Smart School Project Team [SSPT], 1997a, p.10), have been piloted in 1999 among 87 schools. It is envisaged that by 2010, all Malaysian schools, be they primary or secondary, would have been transformed to Smart Schools (SSPT, 1997b).

In the process of systematic reinvention in terms of teaching-learning practices for Smart Schools, certain 'new' elements such as Information and Communication Technology (ICT), self-paced, self-directed and self-accessed learning are introduced, while retaining many other existing elements such as the emphasis on constructivist teaching and the promotion of science process skills.

In relation to science education, it is anticipated that the advocacy of science process skills in the Malaysian smart and mainstream science syllabuses would promote intellectual development alongside transferable generic skills deemed critical to the preparation of students for the challenges of the 21st Century. Furthermore, as students experience the mastery of these process skills within the specified content of science, it would develop the emotional and affective dimension, giving them the pleasure of experiencing a school science that mirrors real science. 'Real' in the sense that these process skills are the things that scientists do when they study and investigate.

Given the equally strong advocacy on the inculcation of scientific skills in the Smart and Mainstream Schools, it is vital to investigate the comparative impact of these two types of schooling on students' acquisition of science process skills.

LITERATURE REVIEW

Science Process Skills

Padilla (1990) defines science process skills as a set of broadly transferable abilities, appropriate to many science 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). Using similar categories, the Curriculum Development Centre (CDC) of the Malaysian Ministry of Education has listed 7 and 5 skills respectively for BSPS and ISPS in all 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 and time relations. For ISPS, the skills are: (1) evaluating information, (2) controlling of variables, (3) defining operationally, (4) hypothesising, and (5) experimenting. Table 1 shows the precise definitions for the 12 science process skills as stipulated in all the Malaysian science syllabuses. Students are expected to be familiarised with the language of science process skills right from the start as they experience the practical and theoretical aspects of science.

Table 1
Definition of Science Process Skills

No.	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 and time relations	Describing changes in parameter with time. Examples of parameters are location, direction, shape, size, volume, 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.

Source: Translated from CDC (1994). KL: Ministry of Education. (*Module 2: Scientific Skills*)

RELATED STUDIES

The review of the science literature failed to identify any previous study that examines the impact of the Smart Schools Initiative on students' acquisition of science process skills. Given that the development of science process skills is the variable of interest in this study, this section revisits studies that have examined the impact of certain curriculum and pedagogical reforms on students' acquisition of science process skills.

Preece and Brotherton (1997) explored the effects of a 28-week science teaching intervention that emphasised the basic and integrated science process skills on students' achievement in single and double award GCSE examination at the end of Year 11. These process skills were based on *Science - A Process Approach* (AAAS, 1967) and the intervention was given to 43, 56 and 52 students from Years 7, 8 and 9 respectively.

Since earlier phases of research (Brotherton & Preece, 1995, 1996) and other studies such as CASE (Adey & Shayer, 1993) have found gender differences, reports for females and males were given separately. Preece and Brotherton (1997) found significant difference between experimental and control group means only for males when the intervention took place in Year 8, with an effect size of 0.87. This suggests long-term effects of teaching science process skills on student achievement, and a "readiness" of year 8 males for "enculturation into practices involved in teaching and assessment at the GCSE level" (p. 900). Besides, within this cohort of Year 8 male students, there proved to be a statistically significantly greater proportion of eventual double award males in the experimental group than in the control group, signifying an effect of the science process skills intervention in increasing the likelihood of a student taking double award science.

Beaumont-Walters and Soyibo (2001) determined the level of performance on five integrated process skills among Jamaican ninth- and tenth-graders who participated in the Reform of Secondary Education (ROSE) as compared to ninth- and tenth-graders not participating. The five integrated skills assessed were recording data, interpreting data, generalising, identifying variables, and formulating hypotheses. The findings indicated that although the ROSE students' mean was slightly higher than that of their non-ROSE peers on the five skills, only the mean for ROSE students on "recording data skill" was found to be statistically significantly higher. The researchers explained this finding by suggesting that ROSE teachers, although trained in the new methodologies for teaching science, "might not fully utilising them or were not yet proficient at using the skills" (p.141). On correlations with other variables, Pearson's Product Moment correlation coefficients suggest that there were no relationships among students' performance on science process skills with their school location and gender. That

no gender difference on performance in science process skills was found in Beaumont-Walters and Soyibo's (2001) study is in discord with the findings of Brotherton and Preece (1995, 1996).

Jusoh (2001) investigated Form 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 which comprises 36 items, measures 5 process skills: (i) identifying variables (12 items), (ii) operationally defining (6 items), (iii) hypothesising (9 items), (iv) experimenting (3 items), and (v) evaluating data and graph (6 items). Comparing the performance on ISPS by level, there was a statistically significant difference between Form 2 and 4 students in hypothesising, operationally defining, experimenting, and evaluating data and graph. With respect to gender, statistically significant differences were found in hypothesising, identifying variables, and evaluating data and graph. However, the ISPS mean scores for Form 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. To explain these low ISPS mean scores, Jusoh (2001) points to the ubiquitous use of didactic teaching, note copying and ineffective laboratory teaching that does not relate theory with the practical work.

Research studies done in the 70s and 80s tend to support the link between active student involvement and the development of science process skills (Shaw, 1983; Wideen, 1975). Shaw (1983) studied 83 sixth grade students randomly assigned to 4 science classes: 2 classes in experimental group and 2 classes in control group. The experimental group received science instruction with an emphasis on process skills and problem solving while the control group emphasised strictly science content. Two teachers taught the four classes alternating between the control and experimental to reduce teacher effect. A t-test was used to determine significant

differences between the experimental and control groups in integrated problem solving processes. The experimental group had a significantly higher mean score on the process skill test compared to the control group, including significantly higher scores on the process skills of interpreting data, manipulating and controlling variables, and defining operationally. However, there was no significant difference between experimental and control groups in formulating and testing hypotheses.

Wideen (1975) studied the effect of the curriculum Science – A Process Approach (SAPA). In this curriculum, students were involved in process skill development with frequent use of experimentation and student engagement. The study included 531 students from 25 intact classrooms in grades three through six. The experimental group consisted of classes in which the students were taught using SAPA curriculum while the control group, the students were taught using the traditional instructional methods characterised by didactic lecture, class discussion, and teacher demonstration. ANCOVA was used to determine significant differences between groups on 2 science process assessments and an attitude survey. Students in the SAPA curriculum showed significantly higher scores on the process skill test when compared to the control.

Although purportedly being described as active student involvement, these studies (Shaw, 1983; Wideen, 1975) tended to be biased towards the experimental groups in terms of assessment of dependent variables. This is evidenced from the rigorous preparation of giving process-based intervention to the experimental students and thereafter, tested them on the relevant dimension. As such it is not surprising that experimental group performed significantly higher than the control group on performance in science process skills simply because, in Bart's (1978) line of argument, subjects who had previous exposure to the content area of a test

(i.e., strictly process skills lessons or 'disguised' in the name of problem solving) tended to do better than those subjects who did not. Ethically, the students in the control group had been placed in an unfavourable distressing situation due to test anxiety, which according to McDonald (2001), is characterised as being closely, although not exclusively, associated with feelings of unease, apprehension, distress and depression due to an evaluation that one feels unprepared, unsure of one's ability, or feels s/he has not performed to his/her best.

RESEARCH AIMS AND PROBLEM STATEMENTS

Purpose of the Study

This study aimed to compare the effects of science teaching in Smart Schools to that of Mainstream Schools on students' performance in integrated science process skills as a whole and in each of the five specific integrated process skills (e.g., Identifying Variables, Operational Defining, Identifying Testable Hypothesis, Data and Graph Interpretation, and Experimental Design).

RESEARCH QUESTIONS

This study examined the following research questions:

(1)   Are there any main effect for group (i.e., Smart and Mainstream Schools) and interactional effects of group with gender and/or class level (i.e., high, average and low) in regard to the overall integrated science process skills performance as measured by the Malay version of Test of Integrated Process Skills II [TIPS II(M)]?

(2)   Are there any main effect for group (i.e., Smart and Mainstream Schools) and interactional effects of group with gender and/or class level in regard to the integrated science process skill of:

(a)   Identifying Variables (IdV)?

(b)   Operational Defining (OD)?

(c)   Identifying Testable Hypothesis (ITH)?

(d)   Data and Graph Interpretation (DGI)?

(e)   Experimental Design (ED)?

RESEARCH DESIGN AND METHODOLOGY

Research Design

Given the research questions that aimed to establish the comparative impact of the Smart Schools Initiative and the Mainstream Programme on student acquisition of science process skills, a quasi-experimental design was deemed appropriate in a realistic school setting where it was not possible to randomly assign students to the experimental treatment (experiencing science in the Smart Schools Initiative) and to the control treatment (experiencing science in the Mainstream Programme).

Instrumentation

Test of Integrated Process Skills II or TIPS II, developed by Burns, Okey, and Wise (1985), was used in this study. TIPS II was chosen because the test items were context-friendly even for Malaysian secondary students. Additionally, the development of TIPS II had undergone a process that took serious consideration of its validity and reliability as reported in the Journal of Research in Science Teaching (Burns, Okey, & Wise, 1985). Furthermore, its Malay translated version, referred to as TIPS II(M), has been used with Malaysian secondary students in a number of studies (i.e., Jusoh, 2001; Ismail & Jusoh, 1996), making the results of this study amenable for comparison.

Subjects and Procedures

The subjects selected for this study were 186 male and 197 female students from two Smart Schools and 177 male and 204 female students from two Mainstream Schools in Malaysia. It was a purposive sampling on the basis of the schools' typicality and the judgement made in the selection process was, in part, informed through a consultation with two officers from the Malaysian Ministry of Education who played a key role in monitoring the Smart Schools.

Students in the Smart Schools received their 3-year lower secondary science instruction which, on the basis of the observation of 25 science lessons, was very much ICT-based than their counterparts in the Mainstream Schools. In each school, the administration of the TIPS II(M) was done simultaneously for all the classes under the supervision of teachers in school time.

Data Analysis Procedures

A multivariate analysis of covariance (MANCOVA) was performed on the dataset from TIPS II(M) to test whether the centroid (vectors) of means of the combined subscales was the same for each of the three independent variables (i.e., group, gender, and class level). The class levels were assigned based on the streaming done by the participating schools. The streaming was based on students' previous (i.e., Form 2) end-of-year overall assessment. As such, high-, average-, and low-achieving students generally refer to 'A', 'B & C', and 'D & E' graders respectively. A significant omnibus or overall F-test in MANCOVA would be followed by univariate tests for the subscales to test for eventual subscale differences.

FINDINGS AND ANALYSIS

Results

The preliminary data screening on TIPS-II(M) and each of its five subscales for normality and other statistical characteristics indicated that the use of parametric methods was appropriate. In this MANCOVA, the five subscales served as the dependent variables, UPSR Science Achievement as the covariate, and group, gender and class level as the independent variables. A significant omnibus or overall F-test in MANCOVA for any of the independent variables or the interactions between/among them would be followed by univariate ANCOVA tests for the subscales to determine at what skill(s) (i.e., identifying variables, operationally defining, identifying testable hypothesis, data and graph interpretation, and experimental design) this significance occurred. The results are reported with respect to each specific research question (RQ).

RQ1: Overall Performance in Integrated Science Process Skills

Table 2
Multivariate Tests

Effect	Pillai's Trace Value	F	Hypothesis df	Error df	p	Partial Eta Squared
Group (A)	0.104	17.519	5	757	.000*	.104
Gender (B)	0.010	1.588	5	757	.161	.010
Class Level (C)	0.223	19.038	10	1516	.000*	.112
A x B	0.008	1.275	5	757	.273	.008
A x C	0.035	2.700	10	1516	.003*	.017
B x C	0.030	2.303	10	1516	.011*	.015
A x B x C	0.020	1.529	10	1516	.123	.010

* Significant at $p < .05$

As shown in Table 2, the MANCOVA indicates that there were significant main effects for group (p = .000) and class level (p = .000) on the combined subscales in TIPS-II(M). The proportion of variance on the TIPS-II(M) scores that can be accounted for by group, and by class level, are 10.4% and 11.2% respectively. However, there was no significant main effect for gender (p = .161) on the combined subscales in TIPS-II(M). Some caution is needed in interpreting these main effects if there prove to be interactions between factors.

Table 3 shows the means and standard deviations by group, gender and class level for the five subscales in TIPS-II(M). The three-way group, gender, and class level interaction was not significant (p = .123). Accordingly, discussions on the three-way effect on each of the subscales could be ruled out.

While no significant group and gender interaction (p = .273) was found, there were significant two-way effects of group and class level interaction (p = .003) and gender and class level interaction (p= .011), which, correspondingly, accounted for 1.7% and 1.5% of the total variance on the combined subscales in TIPS-II(M).

Table 3
Means and Standard Deviations by Group, Gender and Class Level for Subscales in the TIPS-II(M)

	Smart Schools (n = 386)												Mainstream Schools (n = 388)											
	Male (n = 186)						Female (n = 200)						Male (n = 184)						Female (n = 204)					
	Low (n = 65)		Ave (n = 78)		High (n = 43)		Low (n = 68)		Ave (n = 71)		High (n = 61)		Low (n = 56)		Ave (n = 73)		High (n = 55)		Low (n = 57)		Ave (n = 88)		High -- (n = 59)	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
IdV	4.65	2.31	5.46	2.69	7.84	2.82	4.56	2.09	5.85	2.89	7.80	2.66	3.89	1.71	3.99	1.50	5.80	2.29	3.47	1.69	4.56	1.57	6.95	2.91
OD	2.38	1.16	2.60	1.55	3.37	1.09	2.31	1.27	2.59	1.24	3.10	1.33	1.88	1.19	2.19	1.21	3.18	1.29	1.98	1.27	2.11	1.28	2.80	1.24
ITH	3.66	1.64	4.37	1.63	5.23	1.39	3.51	1.48	4.10	1.57	5.15	1.55	2.43	1.36	3.40	1.37	4.22	1.55	2.33	1.11	3.43	1.28	4.80	1.57
DGI	2.68	1.44	3.50	1.34	4.12	1.48	2.93	1.51	3.80	1.37	4.11	1.18	1.63	1.10	2.83	1.29	4.02	1.03	1.75	1.34	2.81	1.32	3.63	1.43
ED	1.14	0.85	1.58	0.97	2.19	0.79	1.00	0.79	1.82	1.02	1.92	1.02	0.70	0.66	1.23	0.81	1.55	0.79	0.72	0.75	1.25	0.85	1.90	0.88

Key:

IdV = Identifying Variables

OD   = Operationally Defining

ITH = Identifying Testable Hypothesis

DGI = Data & Graph Interpretation

ED   = Experimental Design

Therefore, alongside the significant main group effects, only significant two-way interaction effects involving group would be taken into account in the subsequent discussion on the univariate analyses for each of the five subscales. Univariate ANCOVA was carried out on each subscale using Bonferroni adjusted alpha of .01.

RQ2(a): Performance in Identifying Variables (IdV)

The main group effect for Identifying Variables was significant [$F_{(1, 761)}$ = 32.20, p < .01]. As there was no higher order interaction involving group, this main group effect could then be treated as conclusive and unambiguous. Group membership accounted for 4.1% of variance in scores on the IdV subscale. Table 4 shows the descriptive statistics by group for IdV. Students from the Smart Schools achieved an appreciably higher adjusted mean score on IdV than did students from the Mainstream Schools.

Table 4
Adjusted Means (AM) and Standard Deviations (SD) by Group for IdV

Scale	Smart (n=383)		Mainstream (n=381)		Difference	
	AM_i	SD	AM_j	SD	$AM_i - AM_j$	E.S.[1]
IdV	5.85	2.86	4.91	2.27	0.94*	0.36

[1]ES, Effect Size = (adjusted smart mean – adjusted mainstream mean)/ (pooled SD of 2.64)
* Significant at p< .01

RQ2(b): Performance in Operationally Defining (OD)

The main group effect for Operationally Defining was not significant $[F_{(1, 761)} = 5.32, p > .01]$. Furthermore, there was no higher order interaction involving group. Therefore, this non-significant main group effect could then be treated as conclusive and unambiguous. There was no statistical difference in the adjusted mean scores on OD between Smart and Mainstream students.

RQ2(c): Performance in Identifying Testable Hypothesis (ITH)

The main group effect for Identifying Testable Hypothesis was significant $[F_{(1, 761)} = 45.28, p < .01]$. As there was no higher order interaction involving group, this main group effect could then be treated as conclusive and unambiguous. Group membership accounted for 5.6% of variance in scores on the ITH subscale. Table 5 shows the descriptive statistics by group for ITH. Students from the Smart Schools achieved a higher adjusted mean score on ITH than did students from the Mainstream Schools.

Table 5
Adjusted Means and Standard Deviations by Group for ITH

Scale	Smart (n=383)		Mainstream (n=381)		Difference	
	AM_i	SD	AM_j	SD	$AM_i - AM_j$	E.S.[1]
ITH	4.23	1.67	3.51	1.60	0.72[*]	0.43

[1]ES, Effect Size = (adjusted smart mean – adjusted mainstream mean)/ (pooled SD of 1.69)
[*] Significant at $p < .01$

RQ2(d): Performance in Data and Graph Interpretation (DGI)

The main group effect for Data and Graph Interpretation was significant [$F_{(1,761)}$ = 42.28, p < .01]. Group membership accounted for 5.3% of variance in scores on the DGI subscale. Table 6 shows the descriptive statistics by group and class level for DGI. There was a significant 2-way group x class level interaction effect [$F_{(1,761)}$ = 15.29, p < .01], indicating that the main group effect was moderated by class level. Figure 1 shows the profile plots for this two-way interaction.

Table 6

Adjusted Means and Standard Deviations by Group and Class Level for DGI

Scale	Smart Schools (n=383)						Mainstream Schools (n=381)					
	High (n=100)		Average (n=150)		Low (n=133)		High (n=112)		Average (n=161)		Low (n=108)	
	AM	SD	AM	SD	AM	SD	AM	SD	AM	SD	AM	SD
DGI	3.66	0.14	3.53	0.10	3.03	0.11	3.62	0.12	2.74	0.10	2.00	0.12

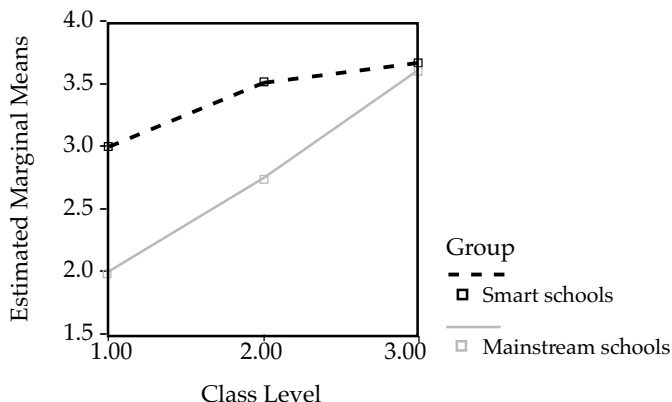Estimated Marginal Means of Data & Graph Interpretation

Figure 1: Data and Graph Interpretation (DGI) Profile Plots for Group and Class Level Interaction

Visual inspection of the profile plots shows that the adjusted mean scores in DGI for each class level in the Smart Schools was not uniformly higher than the corresponding class levels in the Mainstream Schools.

Further statistical testing using Bonferroni Post Hoc Tests (given the non-significant of Levene's test) indicated that there was almost no difference (.04 points, p = 1.00) in DGI achievement between Smart and Mainstream students at high-achieving class level. However, when the class levels were low and average, students in the Smart Schools achieved better (1.03 and 0.79 points respectively) on DGI achievement than those in Mainstream Schools (p < .05). This indicates that the differences in DGI achievement were between students in Smart and Mainstream Schools at low- and average-achieving classes.

RQ2(e): Performance in Experimental Design

There was a significant main group effect between Smart and Mainstream Schools at Experimental Design [$F_{(1,761)}$ = 23.66, p < .01]. As there was no higher order interaction involving group, this main group effect could then be treated as conclusive and unambiguous. Group membership accounted for 3.0% of variance in scores on the ED subscale. Table 7 shows the descriptive statistics by group for ED. Students from the Smart Schools achieved a higher adjusted mean score on ED than did students from the Mainstream Schools.

Table 7
Adjusted Means and Standard Deviations by Group for ED

Scale	Smart (n=383)		Mainstream (n=381)		Difference	
	AM_i	SD	AM_j	SD	$AM_i - AM_j$	E.S.[1]
ED	1.57	1.00	1.25	0.89	0.32*	0.33

[1]ES, Effect Size = (adjusted smart mean – adjusted mainstream mean)/ (pooled SD of 0.96)
* Significant at p< .01

CONCLUSION, DISCUSSION, AND IMPLICATIONS

The overall integrated science process skills achievement as measured by TIPS II(M) of Form 3 students who had participated in the Smart Schools is statistically significantly higher than the overall performance of Form 3 students who had participated in the Mainstream Schools. The follow-up univariate ANCOVA tests indicated that the overall significant group difference in science process skills achievement was contributed by four subscales, namely IdV, ITH, DGI, and ED. While the significant main group differences in IdV, ITH and ED could be interpreted in a straightforward manner, the group difference in DGI was moderated by class level. Here, students in low- and average-achieving classes

in Smart Schools achieved significantly higher than students in low- and average-achieving classes in Mainstream Schools. Based on these findings, it can be concluded that students in the Smart Schools Initiative had improved process skills development. The finding in which there was no significant difference in the process skill of Operationally Defining indicates the need for an emphasis of this skill.

Although the authors are not able to find any previous studies with which these findings could be directly compared, 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. As such, by parallel impact comparison, the process skills outcome in this study is consistent with earlier research on science process skills and activity-based programmes (i.e., Turpin, 2000; Wideen, 1975). The results from Turpin's (2000) study indicated that the overall science process skills development of students involved in the activity-based Integrated Science (IS) programme was significantly higher than students involved in the traditional programme. Equally, Wideen (1975) found a significant difference in the overall science process skills acquisition between students in the SAPA programme and students in the traditional science programme, favouring the former.

The Smart Schools Initiative promotes the use of ICT alongside other smart teaching elements such as constructivist practice, mastery learning, self-accessed, self-paced and self-directed learning. As such, the improved performance in process skills acquisition in this study could not be attributed solely to ICT-based science teaching. Therefore, it would contribute significantly to the research and literature if the future research could determine which smart teaching elements have greatest effect on acquisition of science process skills.

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