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An Analysis of High School Students' Performance on Five Integrated Science Process Skills

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ABSTRACT *This study determined Jamaican high school students' level of performance on five integrated science process skills and if there were statistically significant differences in their performance linked to their gender, grade level, school location, school type, student type and socio-economic background (SEB). The 305 subjects comprised 133 males, 172 females, 146 ninth graders, 159 10th graders, 150 traditional and 155 comprehensive high school students, 164 students from the Reform of Secondary Education (ROSE) project and 141 non-ROSE students, 166 urban and 139 rural students and 110 students from a high SEB and 195 from a low SEB. Data were collected with the authors' constructed integrated science process skills test the results indicated that the subjects' mean score was low and unsatisfactory; their performance in decreasing order was: interpreting data, recording data, generalising, formulating hypotheses and identifying variables; there were statistically significant differences in their performance based on their grade level, school type, student type, and SEB in favour of the 10th graders, traditional high school students, ROSE students and students from a high SEB. There was a positive, statistically significant and fairly strong relationship between their performance and school type, but weak relationships among their student type, grade level and SEB and performance.*

Introduction

While practical work in science is a key component of science education in many countries, it was not until the debut of programmes such as 'Science—A Process Approach' (SAPA), developed by the American Association for the Advancement of Science between 1963 and 1974, that the teaching of science process skills was specifically focused on in elementary and high school science curricula (Bredderman, 1983). Classroom studies on scientific reasoning have centred on the basic and integrated science process skills and over the past three decades, many researchers have focused their attention on these skills (e.g. Molitor & George, 1976; Germann & Aram, 1996; Rainford, 1997). The basic science process skills (BSPS) provide the intellectual groundwork in scientific enquiry, such as the ability to order and describe natural objects and events. Examples of the BSPS are observing, classifying, measuring and predicting. The BSPS are the prerequisites to the integrated process skills. The ability to use BSPS is attributed to the ability to perform empirical-inductive reasoning or Piagetian concrete operational reasoning (Germann & Aram, 1996). The integrated science process skills (ISPS) are the terminal skills for solving problems or doing science experiments.

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Examples of ISPS are identifying and defining variables, collecting and transforming data, constructing tables of data and graphs, describing relationships between variables, interpreting data, manipulating materials, formulating hypotheses, designing investigations, drawing conclusions and generalising. The ability to carry out ISPS is attributed to hypothetico-deductive reasoning (Piaget's formal operational reasoning; Germann & Aram, 1996).

Since the 1960s, science process skills have been emphasised in the process-based integrated science curriculum and textbooks for grade 7–9 students in the Anglophone-Caribbean (Soyibo, 1998). To improve access to, equity in and quality of education for all Jamaican grade 7–9 students, the Reform of Secondary Education (ROSE) project was introduced in 1993 in some pilot schools. By the end of 1999, all Jamaican post-primary schools were expected to be on the project (Soyibo & Figueroa, 1998). Grade 7–9 ROSE and non-ROSE students use: (a) integrated science curricula that are identical in content and philosophy; and (b) the same integrated science textbooks. However, in practice, the former are given the opportunity to do practical activities more than the latter. The ROSE science curriculum, with emphases on BSPS and ISPS, is considered to be more student-centred than the integrated science curriculum offered to non-ROSE students. ROSE science teachers undergo a 2 week course tailored to equip them to utilise the project's methodologies and curriculum materials. Their lessons are also supervised by five teacher educators who provide them with feedback. Consequently, ROSE students are expected to do better than their non-ROSE counterparts on any tests on any aspect of the grade 7–9 science curriculum (Soyibo & Figueroa, 1998).

With the introduction of the ROSE science curriculum in Jamaica, it is expected that 18 BSPS and ISPS will be taught in grades 7–9 through the use of laboratory approaches involving hands-on, minds-on activities. The BSPS and ISPS listed in the Jamaican Ministry of Education Youth and Cultures (MOEYC, 1993a) *Revised Draft: teachers' guide, grades 7–9* are: observing, classifying, measuring, recording data, using numbers, inferring, communicating, creating models, replicating, interpreting data, making decisions, manipulating materials, formulating hypotheses, predicting, identifying variables, generalising, recognising space-time operations, and recognising number relations. The specific areas of the science curriculum where students are expected to acquire these skills are not specified in the teachers' guide (MOEYC, 1993a) and in the students' *Science Instructional Materials, Grades 7–9* (MOEYC, 1993b). But the students are expected to acquire the skills when they are taught the contents of the six themes in the curriculum and perform a variety of practical tasks. The six themes are: exploring the environment, investigating matter, living things, healthy living, energy and forces and the universe and the Earth's resources. In addition, each of the 18 basic/integrated process skills is defined and sample activities students are expected to carry out on each skill are stated in the teachers' guide. For example, interpreting data is defined as 'analyzing data that have been obtained and organized by determined apparent patterns or relationships' and the suggested sample activities on the skill are 'studying a graph, chart, or table of data collected about melting ice cubes and noting that smaller ice cubes melt faster than larger ones'. The definitions and activities were adapted from Carin and Sund (1991). The emphasis on activity-based and process-oriented science teaching in Jamaican ROSE high schools seems logical because some studies have shown that the use of activity-based approaches in science teaching, in contrast to the use of the didactic approach, significantly improved students' science process skills achievement more than their science knowledge achievement (Reynolds, 1991).

Despite the emphasis on students' acquisition of BSPS and ISPS in the non-ROSE and ROSE grade 7–9 science curricula (Soyibo & Figueroa, 1998), a review of the literature reveals that only a few studies have been carried out on students' acquisition of science process skills in Jamaican ROSE and non-ROSE high schools. Soyibo (1992) reported that Jamaican seventh graders' performance on four BSPS (observing, classifying, manipulating and inferring) and two ISPS (interpreting and predicting) was barely 'average', while Rainford (1997) reported that Jamaican seventh graders' performance on three BSPS (observing, classifying and inferring) was poor and that their performance hardly increased from the pre-test to post-test, although they were taught the ROSE grade 7 science curriculum content.

Internationally, many studies have been conducted on students' acquisition of BSPS and ISPS. Mattheis *et al.* (1992) found that a strong correlation existed between reasoning skills and ISPS among two large samples of North Carolina and Japanese junior high school students and that the reasoning and process skills improved as the students progressed from seventh to ninth grade. Germann and Aram's (1996) evaluation of American students' ability to perform the ISPS of analysing, recording data, providing evidence and drawing conclusions, revealed that only 61% of their subjects were able to perform and record the data successfully. While some researchers (Germann & Aram, 1996) have criticised the use of multiple choice tests that were commonly used to assess students' performance on science process skills (Molitor & George, 1976; Soyibo, 1992), only a few researchers Baxter *et al.* 1992; Rainford, 1997) have developed practical laboratory tests to assess these skills.

There is evidence to suggest that despite the premium placed on the teaching of BSPS and ISPS in grades 7–9 in Jamaica since the 1960s, and despite the re-emphasis on the teaching of these skills in Jamaican ROSE grade 7–9 science curriculum, there is a dearth of studies published on Jamaican high school students' performance on ISPS. Several past studies have reported inconclusive findings on the links among many independent variables such as gender, grade level, school location, school type, student type and socio-economic background (SEB) and differences in high school students' performance on specific science subjects. For example, regarding gender differences in science achievement, many studies have reported that males generally outperformed females in science and mathematics (Third International Science and Mathematics Study [TIMSS], 1997), while some reported no gender differences in students' science performance (Greenfield, 1996; Rainford, 1997). Pertaining to school type, some local studies reported that Jamaican students in traditional high schools significantly outperformed their peers in all age and comprehensive high schools in integrated science (Rainford, 1997; Soyibo & Johnson, 1998) and that with reference to student type, Jamaican seventh and eighth graders, following the ROSE science curriculum, significantly outscored their non-ROSE peers in science (Soyibo & Johnson, 1998).

With respect to students' science process skills performance, only a few studies have reported that differences in students' BSPS performance were linked to their school location in favour of urban schools (Soyibo, 1992), school type in favour of students in traditional high schools (Rainford, 1997) and SEB in favour of students from a high SEB (Gallagher, 1994). One justification for this study was that we could not access any published or unpublished studies that had investigated the links among the six independent variables reviewed above and differences in high school students' ISPS performance. However, we suspected that the six variables were likely to be linked to differences in the subjects' ISPS performance. We, therefore, put this conjecture to the test.

Purpose

This study determined if: (a) some Jamaican high school students' level of performance on a test of integrated science process skills (TISPS) was satisfactory or not; and (b) there were any statistically significant differences in the students' performance on the TISPS linked to differences in their gender, grade level, school location, school type, student type, and SEB and their overall TISPS score.

Research Questions

(1) Was the level of performance of some Jamaican ninth and 10th graders on a TISPS satisfactory or not?
(2) Were there any significant differences in the students' performance on the TISPS linked to their gender, grade level, school location, school type, student type, and SEB?
(3) Were there any significant relationships among the students' gender, grade level, school location, school type, student type, and SEB and their overall performance on the TISPS?

Research Design

The research design employed was a survey involving a quantitative component that entailed an *ex post facto* dimension.

Sample

The main study sample comprised 305 students (133 boys, 172 girls; 146 ninth graders, 159 10th graders; 166 urban and 139 rural students; 150 traditional and 155 comprehensive high school students; 164 ROSE, 141 non-ROSE students; 110 from a high SEB and 195 from a low SEB) randomly selected from four comprehensive and four traditional high schools in Jamaica. The pilot sample consisted of a class of 40 grade 9 students in a traditional high school. In Jamaica, 95% of the students who are admitted to the long-established 'traditional' high schools (formerly called 'grammar schools') pass the common entrance examinations (CEE) at age 10 or 11 years, while 5% are admitted on the school principals' discretion, whereas only some of the students who are admitted to the comprehensive high schools (founded in the 1970s as junior secondary schools) pass the CEE, while the majority gain admission by 'age promotion from feeder schools' once they are 12 years old (UNESCO, 1983). In short, many Jamaican traditional high school students are generally intellectually superior to their comprehensive high school counterparts.

Instrumentation and Procedure

In line with the conceptual framework and three assessment dimensions suggested by Solano-Flores and Shavelson (1997), the performance assessment developed for the TISPS belonged to the comparative investigation task type where two or more objects are compared on some attributes. The TISPS measured five skills and 12 subcategories of skills: recording data (three subcategories: completing/constructing: (a) graphs; and (b) tables; collecting and transforming data into graphs and tables); interpreting data (two subcategories: extracting information from: (a) graphs; and (b) tables); generalising (three subcategories: drawing general conclusions from data; interpolating/extrapolating between or beyond data points; identifying data that support a conclusion); identifying variables (three subcategories: identifying the manipulated/causal variable; identifying the measured/responding variable; identifying the controlled variable); and formulating hypotheses (one subcategory: predicting the relationship between the causal and the responding variables). For the main study, the TISPS comprised eight written performance items (maximum score = 41) and two hands-on performance tasks (maximum score = 35) giving on total score of 76. The written performance items measured specific subcategories of the five skills, while the two hands-on performance tasks tested all five skills. One hour each was allocated to each of the three subsets of the TISPS: Written performance test, Splash, and Is it hot or not? (The last two were the hands-on tasks.) Examples of the test items are shown in Appendices A and B. The TISPS Cronbach alpha was 0·74, while the inter-rater reliability coefficients of the pilot scripts scored by one of the authors and an independent marker ranged between 0·89 and 0·91. These suggest that the TISPS's reliability was satisfactory and that one of the authors was highly consistent in scoring the pilot and main study's students' answers. The mean and standard deviation of the pilot sample were 51·34 and 9·05, respectively.

Prior to the pilot study, to ensure that the TISPS items had satisfactory content and construct validity, one university senior lecturer in science education, one teacher's college lecturer, and one experienced ROSE science teacher all of whom were familiar with the Jamaican ROSE and non-ROSE grade 7–9 science curricula were given copies of the TISPS test blue print, 14 written performance test items, two hands-on performance items, and guidelines for its content and construct validation. The validators' comments were used in selecting the pilot test items. Mattheis *et al.*'s (1992) finding that a strong correlation existed between North Carolina and Japanese junior high school students' reasoning skills and ISPS and Soyibo's (1992) finding that Jamaican seventh graders who performed well on two ISPS also performed well on four BSPS provide indirect evidence in support of the construct validity of this study's instrument. Two hands-on tests each lasting 1 hour and a 1-hour written performance test were used because: (a) the time required to administer the two hands-on performance tasks; individually and the cost of providing equipment were limiting factors; (b) the written performance tasks provided the advantage of group administration; and (c) we felt that if the TISPS had been presented as a 3-hour hands-on test, many of the subjects were likely to find the exercise rather stressful. Indeed, one of the authors noted that all the subjects considered the duration of the TISPS to be too long and many of the main study subjects lost their concentration in the last hour of the hands-on task partly because they were not used to doing individual tasks. This was probably because the lecture–demonstration method is most commonly used in teaching science in most Jamaican grade 7–9 classes (Soyibo, 1998), and partly because group work, involving two to five students per group, is recommended for student practical work in ROSE grade 7–9 science classes (MOEYC, 1993a). The subjects' ability to use equipment was not tested in this study. Hence, the hands-on tasks that the subjects performed were modelled on Solano-Flores and Shavelson's (1997) six-stage low-level inquiry procedure. Clear instructions and teacher demonstrations were provided on how they were to manipulate the equipment. Details of the instrumentation are available from the authors.

TABLE I. Means, percentages and standard deviations (SD) on five integrated science process skills

Integrated science process skill ($n = 305$ in each case)	Mean	%	SD
Recording data	13·70	52·80	7·00
Interpreting data	8·88	74·00	1·71
Generalising	7·44	49·60	3·67
Identifying variables	4·57	28·60	4·36
Formulating hypotheses	1·97	32·80	2·06
Overall test	36·56	49·40	15·65

Results and Discussion

The first objective of this study was to determine if the level of performance of selected Jamaican ninth and 10th graders on a TISPS was satisfactory or not. Table I indicates that the subjects' performance in decreasing order was as follows: interpreting data, recording data, generalising, formulating hypotheses, and identifying variables. The table also suggests that because the subjects' mean score on the entire TISPS (36·56 or 49·40%) was less than a score of 2·50 on a five-point scale, their overall level of performance in this study was considered as 'low/poor' and, hence, 'unsatisfactory'. Some of the possible reasons for the subjects' 'unsatisfactory' performance are now discussed. Many of the subjects might not have been familiar with the types of task investigated and the assessment used in this study. Germann *et al.* (1996) asserted that good students' performance on ISPS was dependent on their experience with and domain-specific practice activities on the skills in prior tasks. On the other hand, Ruiz-Primo and Shavelson (1996) reported that students' scores depended on the particular tasks investigated and on the particular method used to assess their performance. Indeed, during many clinical supervisions as a teacher educator, one of the authors observed that in the sampled schools and other ROSE schools, teachers infrequently engaged their students in hands-on science activities. This observation was consistent with Soyibo's (1998) finding that the lecture–demonstration method was predominant in most Jamaican grade 7–9 science classrooms. Many of the subjects might have lacked the communication skills to express themselves explicitly in writing as evidenced in their TISPS scripts—a reason advanced for students' poor performance on science process skills (Germann *et al.*, 1996; Rainford, 1997) and for many Jamaican students' poor science performance at all levels of education (Science Education Committee, 1999). Individual interview of the subjects, which could have been used to probe their answers and determine their in-depth understanding, suggested by Germann *et al.* (1996), was not used in this study because it would have drastically limited the sample size.

The subjects performed relatively better on the skill of recording data probably because most of the items requiring this skill gave prescriptive directions on what the subjects should measure and how to record (first level of the developmental progression of the skill). But a close look at the subjects' test scripts revealed that only a few of them were able to construct tables and graphs and record data in more complex tables on their own. They were also better able to complete and construct tables than graphs. The construction of graphs demands the ability to recognise relations between relations or formal operations in Piagetian terms of which many students are incapable (Shayer & Adey, 1981). The subjects performed fairly well on interpreting data that demanded

TABLE II. Means and standard deviations (SD) by grade level, gender, school location, school type, student type, and socio-economic background (SEB) on the Test of Integrated Science process skills (TISPS)

Variables	*n*	Mean	SD
Grade level			
9	146	33·55	15·28
10	159	39·35	15·49
Gender			
Males	133	36·54	15·46
Females	172	36·60	15·82
School location			
Rural	139	36·19	13·17
Urban	166	36·89	17·46
School type			
Traditional high	150	46·48	11·30
Comprehensive high	155	26·99	13·10
Student type			
ROSE	164	38·29	13·20
Non-ROSE	141	34·57	17·90
SEB			
High	110	42·21	14·29
Low	195	33·39	15·50

$n = 305$ for each variable. ROSE, Reform of Secondary Education Project.

extracting information from graphs and tables, but they were less successful on the skill of generalising which entailed making conclusions, interpolating/extrapolating between/beyond data points and identifying supporting evidence. This might be due to the fact that the lecture method, that dominated science teaching in most Jamaican science classrooms (Science Education Soyibo, 1998; Committee, 1999), did not facilitate the subjects' potential to develop generalising skills and other ISPS. The subjects' poor performance on the skills of identifying variables and formulating hypotheses might be due to the likelihood that they had not been taught the two skills and that their levels of cognitive development were inadequate to enable them to handle the skills. In sum, we are of the view that the teacher-centred mode of teaching science in the sampled schools, which did not allow the subjects to practise and internalise the skills over a fairly long period, was likely to be one main reason for the subjects' overall poor performance on the skills.

The second purpose of this study was to determine if there were any statistically significant differences in the students' performance on the TISPS linked to their gender, grade level, school location, school type, student type, and SEB. Their means and standard deviations were computed (Table II).

Table II indicates that the mean of the: (a) 10th graders was much higher than that of the ninth graders; (b) females was only slightly higher than that of males; (c) urban students was slightly higher than that of rural students; (d) traditional high school students was substantially higher than that of comprehensive high school students; (e) ROSE students was higher than that of non-ROSE students; and (f) students from a high SEB was much higher than that of students from a low SEB. Further analyses revealed that although the ROSE students' mean was slightly higher than that of their non-ROSE

TABLE III. Means and standard deviations (SD) of ROSE and non-ROSE students on the subsets of the TISPS

Integrated science process skill	ROSE		Non-ROSE	
	Mean	SD	Mean	SD
Recording data	15·01	5·17	12·20	7·93
Interpreting data	8·91	1·61	8·83	1·81
Generalising	7·60	3·32	7·26	4·04
Identifying variables	4·70	4·00	4·42	4·75
Formulating hypotheses	2·07	2·01	1·86	2·13
Overall test	38·29	13·21	34·57	17·90

ROSE ($n = 164$), non-ROSE ($n = 141$).
Rose, Reform of Secondary Education Project; TISPS, Test of Integrated science process skills.

peers on the five skills (Table III), it was only in respect of 'recording data skill' that the mean of the former was statistically significantly higher than that of the latter ($t = 3·60$, $p < 0·05$). To confirm if there were statistically significant differences in the subjects' overall means on the TISPS linked to differences in the six independent variables, a six-way analysis of variance (ANOVA) was computed (Table IV).

Table IV shows that there were statistically significant differences in the subjects' scores linked to their: (a) grade level; (b) school type; (c) student type; and (d) SEB, while there were no statistically significant differences in their performance linked to their gender and school location. Table III data suggest that the significant differences were in favour of the 10th graders, traditional high school students, ROSE students and students from a high SEB.

That the 10th graders significantly outscored the ninth graders was expected partly because: (a) they might be more proficient in the use of the English language and in reading (Shaw, 1997); (b) of their greater amount of prior knowledge, experience in science education and higher level of cognitive development; and (c) it was mandatory for the 10th graders to do science practical tasks to satisfy the requirements for the award

TABLE IV. Summary of analyses of variance on students' TISPS performance by grade level, gender, school location, school type, student type and socio-economic background (SEB)

Source of variation	MS	F
Grade level	2381·13	29·547**
Gender	223·66	2·775
School location	60·47	0·750
School type	25924·57	321·695**
Student type	921·03	11·429*
SEB	1771·96	21·988**

*$p < 0.001$; **$p < 0.000$.
TISPS, Test of Integrated Science Process Skills.

of the secondary education certificate in grade 11. Tenth graders were likely to have practised more of the ISPS similar to those tested in this study than the ninth graders. The finding that the subjects in the traditional high schools significantly outscored their comprehensive high school counterparts receives indirect support from Rainford (1997) regarding Jamaican seventh graders' performance on three BSPS listed earlier. The traditional high schools' subjects did significantly better than their comprehensive schools' counterparts partly because many of them were probably academically superior to the latter, based on their mode of admission to their schools discussed earlier and partly because they probably also enjoyed better teaching facilities and the services of teachers of better quality (Soyibo & Johnson, 1998; Science Education Committee, 1999). We expected the ROSE students to outscore their non-ROSE counterparts on each of the five skills because ROSE students were using the ROSE science curriculum that was designed to facilitate the development of science process skills in them, and the ROSE teachers had been trained in the methodology that would enable them to assist their students to acquire the process skills using a hands-on process approach, while the non-ROSE teachers had no training in such an approach. However, the actual difference in the ROSE and non-ROSE students' overall mean score on the five skills was, indeed, minute, suggesting that, although the ROSE teachers were trained in the new methodologies for teaching science, they might not be fully utilising them or were not yet proficient at using the skills (Soyibo & Johnson, 1998). The finding that the subjects from a high SEB significantly outperformed their peers from a low SEB was expected and receives some indirect support from Gallagher (1994) regarding middle school students' performance on BSPS and the findings of many previous studies on the link between students' SEB and science performance (Blosser, 1994). The findings that there were no statistically significant differences in the subjects' performance linked to their gender and school location are interesting as they suggest that Jamaican ninth and 10th graders could learn the five ISPS tested regardless of their gender and school location. The finding that there was no significant gender difference in their performance receives indirect support from Rainford (1997) in respect of Jamaican seventh graders' performance on three BSPS, while the finding in respect of school location was unexpected and is indirectly inconsistent with Soyibo's (1992) finding that rural Jamaican seventh graders' significantly outscored their urban peers on four BSPS and two ISPS. We could not explain the likely reasons for this last finding based on this study's data.

The study's third objective was to establish if there were any significant relationships among the subjects' overall performance on the TISPS and their grade level, gender, school location, school type, student type and SEB. Pearson's product-moment correlation coefficients suggest that there was a positive, statistically significant and fairly strong relationship between the subjects' mean score and school type ($r = 0{\cdot}62$, $p < 0{\cdot}001$), but weak relationships among their means and their: (a) student type ($r = 0{\cdot}12$, $p < 0{\cdot}01$); (b) grade level ($r = 0{\cdot}19$, $p < 0{\cdot}001$); and (c) SEB ($r = 0{\cdot}27$, $p < 0{\cdot}001$), while there were no relationships among their TISPS performance and their school location ($r = 0{\cdot}02$) and gender ($r = 0{\cdot}00$). These findings confirm the results of the data on which the ANOVA was based (Table II).

The finding that there was a positive, statistically significant and 'fairly strong' relationship between the subjects' school type and performance confirms the data in Tables II and IV discussed earlier and suggests that this variable accounted for the highest variation in the subjects' overall performance. The findings that there were no relationships among the subjects' gender and school location and their performance are also consistent with the data in Tables II and IV. The weak relationships among the subjects' student type, grade level and SEB and their performance suggest that there were other factors besides these three variables that contributed to the variations in the subjects' performance which were not investigated in this study. Such variables should be identified and explored in future studies on this topic. They include possible differences in the students' cognitive abilities, learning styles, teachers' qualifications, teaching experience and teaching styles.

Conclusions and Implications

First, this study is novel and significant because we were unaware of any published or unpublished studies that had explored this study's six independent variables with the five ISPS either in Jamaica or elsewhere. For this reason, we were unable to find any previous studies with which this study's findings could be directly compared.

The didactic mode of teaching science in most Jamaican schools was implicated as the main probable cause of the subjects' poor performance in this study (Soyibo, 1998; Science Education Committee, 1999). The five ISPS tested in this study and related ones should be formally taught to the subjects from grade 7 including students' domain-specific practice activities, with multiple related examples. Furthermore, immediate feedback should be provided to the subjects, while they should be assessed using both written and performance/practical tasks. These approaches are likely to improve the subjects' knowledge of and performance on many ISPS, irrespective of their differences on the six independent variables explored in this study.

That the ROSE students significantly outscored their non-ROSE counterparts implies that the ROSE science curriculum and ROSE teacher training programme seemed to have had some salutary effects on the ROSE students' ISPS performance. To improve ROSE and non-ROSE students' understanding and performance on the ISPS tested in this study, Jamaican grade 7–9 science teachers should give their students the opportunities to perform worthwhile ISPS-demanding tasks.

The traditional high school subjects significantly outscored their comprehensive high school peers. To ensure that students in these two types of schools perform equally well on the five ISPS tested and related skills, the Jamaican Ministry of Education should ensure the even and equitable distribution of educational resources across school types in terms of teacher quality, science teaching facilities and the assignment of students to schools.

As expected, the 10th graders substantially and significantly outscored the ninth graders, while the subjects from a high SEB significantly outperformed those from a low SEB. Hence, to improve the ninth graders' performance on the ISPS tested and related ones, their teachers must ensure that the students perform some worthwhile hands-on, minds-on ISPS activities suitable to their intellectual development. To encourage students from a low SEB to perform as well as those from a high SEB on the ISPS, Jamaican grade 7–9 science teachers must employ student-centred instructional strategies that are likely to enhance both categories of students' self-esteem, attitudes and motivation to learn science.

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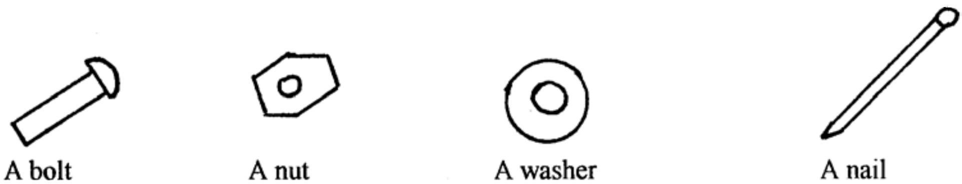
Appendix A

Specimen Test of Integrated Science Process Skills Written Performance Items

Recording Data

1. Look at the objects on the table in front of you. Sort them into four groups: bolts, nuts, washers and nails



There are two parts to this task. Complete this table to show how many objects you found for each group.

(i) Groups of objects and number in each group

Bolts	Nuts	Washers	Nails

(ii) Use the numbers in the table to draw a bar chart on the graph sheet given to you. Remember to label the axes.

Note: Item 1(i) tested the recording data subcategory 1·2 'Completing or constructing tables', while item 1(ii) tested the subcategories 1·1 'Completing or constructing graphs' and 1·3 'Collecting and transforming data into tables and graphs'.

Interpreting Data

2. The table below shows four kinds of fruits that people eat at different times of the year in a village in Jamaica

Fruit	January–March	April–June	July–October	September–December
Oranges	xx		xxx	xxxx
Mangoes			xxxxxx	
Pawpaw	xx		xxx	xx
Pineapples	xx	xx	xxx	xxx

(i) Which fruit is the most common from July to October in the village?
(ii) Which fruit can you find all the year round in the village?
(iii) In which period of the year can you expect to find all kinds of fruits in the village?

Note: Items 2(i) (iii) tested the interpreting data subcategory (b) 'Extracting information from tables'.

Generalising

3. Every week, John measured the height of his plant. He wanted to determine how fast it was growing. These were the heights he recorded for the first 4 weeks

After 1 week 15 cm 2 weeks 30 cm 3 weeks 40 cm 4 weeks 45 cm

(i) Use this information to draw a line graph to show how the height of the plant changed with time on the graph sheet given to you. Remember to label the axes.
(ii) From your graph, what would be the height of the plant after 5 weeks?

Note: Item 3(i) tested the recording data subcategory, 'Completing or constructing graphs' while item 3(ii) tested the generalising subcategory, 'Interpolating/extrapolating between or beyond data points'.

Appendix B

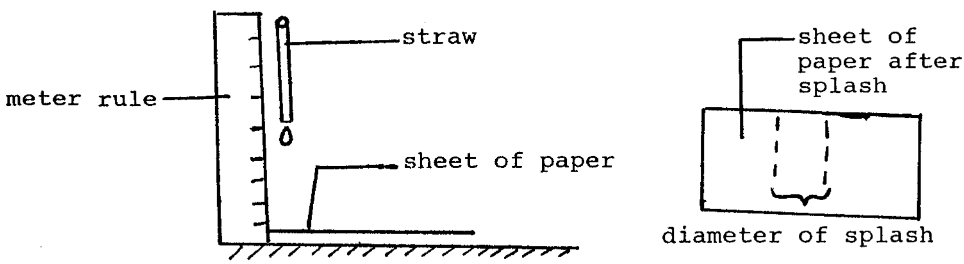
Specimen Test of Integrated Science Process Skills Hands-on Task 'Splash'

1. In this activity, you will investigate the diameter of a splash produced by a drop of water and the effect of varying the height from which the drop is released. You will need:

   1 metre rule 1 ruler (12 cm) 1 straw a sheet of paper
   a plastic cup with water a piece of paper towel

   The teacher will demonstrate to you how you should use a straw as a dropper pipette. Practise how to use your straw as a dropper pipette. When you feel comfortable with this, begin the activity.

   Procedure



   (a) Set up your apparatus as in the diagram above.
   (i) In the space provided, write a hypothesis or your best guess on what you think will happen as you release the drop of water from different heights before you release the drop.
   (b) Use your dropper to deliver one drop of water on to the sheet of paper. Record the height of the splash.
   (c) Repeat step (b), and each time, vary the height from which the drop is released.
   (d) Make a suitable table to display your results. Draw your table here as d(i)

2 (a) Plot a graph to show the relationship between the height of each drop and the diameter of the splash on the graph sheet provided.
   (b) Suppose this investigation was repeated many times and similar results were obtained, write a possible conclusion from this investigation.
   (c) In this investigation, you changed one factor (variable) and measured the response of another factor (variable).
   (i) Which factor (variable) was changed in this experiment?
   (ii) Which factor (variable) responded or was measured in this experiment?

Note: Item 1 (a)(i), tested the subjects' skill of hypothesising; item 1(d)(i) and 2(a), tested their skill of recording data in tabular and graphical forms, respectively; item 2(b), tested their skill of interpreting data and generalising; and item 2(c) tested their skill of identifying variables.