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Lower Secondary Science Teaching and Learning

An Inventory of Apparatus and Materials
Summary Report

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School of Education
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The ideas and opinions expressed in this work are those of the authors and do not necessarily represent the views of the School of Education.

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TABLE OF CONTENTS

PREFACE

This study was part of a larger research project, which was conducted by the School of Education, The University of the West Indies (UWI), St. Augustine in 2002 to investigate the status of lower secondary science in Trinidad and Tobago. It is a survey of the apparatus and materials to support lower secondary practical science in 54 of the 115 schools that existed at the time the research was undertaken. The sample reflects approximately equal percentages of the various school types. The findings have implications for the approaches to science teaching at the lower secondary level, as well as the equitable distribution of resources to support practical laboratory work in all school types in Trinidad and Tobago. It is hoped that the issues that arise out of this preliminary study will influence national and school policies with respect to the financing of science education and the organization of practical work in the lower secondary science curriculum.

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LIST OF APPENDICES

LIST OF TABLES

BACKGROUND TO THE STUDY

Introduction

This study is part of a larger research project, which was undertaken by the School of Education in 2002 to investigate the status of science at the lower secondary level in schools of Trinidad and Tobago. This component of the study arose out of the perception that science students at the lower secondary level were not being exposed to investigative science in any systematic way. While there might be a number of factors that impact on decisions to include or exclude practical work in science at this level, it was necessary to determine first of all whether the necessary resources were in place to support practical work.

In the rationale for teaching and learning of science as articulated in the revised draft science curriculum of the Secondary Education Modernisation Programme (SEMP) science is described as a method of problem solving, which requires that all the necessary resources and skills be used to gather objective evidence, to analyze and synthesize that evidence, then make inferences and draw conclusions (Trinidad & Tobago [T&T]. Ministry of Education, 2002). In addition, two of the goals in the vision statement for the science curriculum are: 1) stimulating curiosity and creativity, and 2) developing competence in the use of the knowledge and methods of science. The underlying assumptions here are that students will participate in the activities of science (hands-on), and that they will embrace science as a way of thinking (minds-on). This suggests that students must be exposed to practical work.

Trinidad and Tobago, like most countries, has invested considerable financial resources in providing and equipping science laboratories to support science teaching in each type of secondary school. (The nature of these schools and their geographical distribution are discussed in the other reports of the research project (see George, 2003; Herbert, Rampersad, & Akinmade, 2003.)) In addition, the costs for the practical component of science courses are recognized by the higher level of funding allocated per student compared with that for other subjects. Again, the assumption here is that practical work would be incorporated into science teaching at all levels.

This study, therefore, sought to obtain an overall picture of the availability and adequacy of resources to support practical work in science at the lower secondary level. In addition, it sought to obtain some information about the challenges or problems faced by lower secondary science teachers in their attempts to use or access resources for practical work. It is against this background that the following research questions were formulated.

Research Questions

1. What is the present situation with respect to the availability and functionality of the recommended capital laboratory equipment for lower secondary science (a) at a general level, and (b) for different school types?

2. What is the present situation with respect to the availability of consumables for lower secondary science (a) at a general level, and (b) for different school types?

3. What is the present situation with respect to (a) the availability of equipment/apparatus for practical work, and (b) the adequacy of the supply of the equipment/apparatus for small-group practical work within a class of 35-40 students?

4. Do (a) the availability of equipment/apparatus for practical work, and (b) the adequacy of equipment/apparatus for small-group practical work vary with school type?

5. What challenges do science teachers face with respect to (a) the repair of broken-down equipment, and (b) sourcing equipment/materials to support practical work?

METHODOLOGY

Data Collection

A questionnaire survey instrument was developed to gather data on the status of schools' inventories of science apparatus and materials. A list of equipment/apparatus and materials was drawn up, using the SEMP materials/equipment listing for lower secondary schools as the major source. The list was circulated for peer review to determine if it reflected what might be essential and minimal. It was then adjusted, based on feedback obtained. This listing was then categorized for convenience into *capital laboratory equipment*, *consumables*, and *general equipment/apparatus for the conduct of practical work*.

While most of the questions in the survey instrument were closed, requiring the respondent to tick the appropriate box, two questions required free responses. One of these questions sought information/explanations for procedures for the repairing and purchasing of equipment/materials. The other question elicited teachers' responses about general problems and concerns with respect to accessing resources to support practical work. In addition, there was a section that sought information on school type, so that the data generated could be examined at a general level across the board and disaggregated according to school type. The instrument was again subjected to peer review and revised once more.

Selection of the Sample

The research targeted the existing 115 government and government-assisted schools with Forms 1 to 3 cohorts. The survey instrument, accompanied by a letter to the principal, was sent to each of the 115 schools. The letter explained the purpose of the survey and requested the cooperation of the principal with this component of the lower secondary science research project.

The Response

The questionnaires were mailed to the identified schools at the beginning of June 2002. The final sample comprised 54 schools. All school types were represented in the final sample as follows—nineteen junior secondary schools, sixteen 5-year government/composite schools, three 5-year government-assisted, nine 7-year government, and sixteen 7-year government-assisted (see Table 1).

Table 1. Frequency of Response to Questionnaires by School Type

School type	Number of schools with Forms 1-3 cohorts	Number of schools responding	% of schools responding
Junior secondary	19	10	52.1
5-yr Government/ Composite	39	16	41.0
5-yr Government-assisted	7	3	42.8
7-yr Government	21	9	42.8
7-yr Government-assisted	29	16	55.2
TOTAL	**115**	**54**	**46.8**

While the response rate was lower than expected, the spread across the various school types showed little variance.

FINDINGS

Introduction

The findings for each research question are discussed separately. The acceptable level for all apparatus/equipment and materials was set at 80%, with the exception of safety equipment, which was set at 100%.

Research Question 1

What is the present situation with respect to the availability and functionality of the recommended capital laboratory equipment for lower secondary science (a) at a general level, and (b) for different school types?

The capital laboratory equipment was grouped in the following subcategories as follows: teaching and learning aids, basic items for preparation and storage, and safety equipment. Safety equipment is addressed first in this section since it was felt that safety should be a priority when conducting practical work in any school.

Safety equipment

Safety equipment included a fire extinguisher, first aid kit, and a fume cupboard. The acceptable level of 100% for any of these items was not achieved at the general level. When the data were examined according to school type, however, it was found that the junior secondary schools were the best equipped with fire extinguishers at a level of 90%. The availability of first aid kits ranged from 77.8% in the 7-year government schools to 40% in the junior secondary schools. With respect to the fume cupboard, availability ranged from 68.8% in the 5-year government/composite schools to 0% in the junior secondary schools.

Functionality of the fume cupboards ranged from 33.3% for 5-year government-assisted schools to 11.1% for 7-year government schools, while for the first aid kits, the range was from 66.7% in 7-year government schools to 25% in the 5-year government/composite schools. Functionality of fire extinguishers ranged from 80% in the junior secondary schools to 33.3% in the 5-year government-assisted schools.

Teaching and learning aids

In general, none of the teaching/learning aids identified (see Appendix A) were available at the acceptable level of 80%. These included the following: aquarium with pump, bathroom scale, colour wheel, models (eye/ear), overhead projector, periodic chart, and the skeleton and parts. The availability level ranged from 13.6% to 69.7%.

When the data were disaggregated according to school type, only the bathroom scale, model of the ear, the model of the eye, and the periodic chart were available to at least 80% of the respondents from the junior secondary schools. The models of the eye/ear were also available to more than 80% of the respondents in the 7-year government schools, but functionality of these items ranged from 44.4% to 66.7%. Additionally, periodic charts were available in 7-year government and 7-year government-assisted schools at the acceptable level. All the other items were either not available at acceptable levels or, if available, were not functional (see Table 2). Functionality of some items, for example, overhead projector, colour wheel, and bathroom scale, was as low as 11.1% in the 7-year government schools.

Table 2. Teaching/Learning Aids Available at Acceptable Levels by School Type

Teaching /Learning aids	**Junior secondary**	**5-year Gov't./Comp.**	**5-year Gov't. Asst.**	**7-year Gov't.**	**7-year Asst.**
Bathroom scale	√				
Model of eye/ear	√			√	
Periodic chart	√			√	√

√ indicates acceptable level of availability

Basic items for preparation and storage

The complete listing of these items can be seen in Appendix A. These included the following: analytical balance (top loading), laboratory oven, reagent bottles, refrigerator, and water still. The acceptable level of 80% was not achieved at the general level.

When the data were disaggregated by school type, the acceptable level of 80% was achieved for analytical balances, reagent bottles, refrigerators, and water stills in the 7-year government-assisted schools. Only reagent bottles were available at the acceptable level in the 7-year government schools. While refrigerators were available to 100% of the respondents in the junior secondary schools, only 30% of the respondents indicated that the refrigerators were functional. However, the refrigerator was the only piece of equipment in this grouping that was functional for at least 80% of the respondents in the 7-year government-assisted schools. None of the other school types indicated this level of functionality for any of the other items (see Table 3).

Table 3. Basic Items for Preparation and Storage Available at Acceptable Levels by School Type

Items	Junior secondary	5-year Gov't./Comp.	5-year Gov't. Asst.	7-year Gov't.	7-year Asst.
Analytical balances					√
Reagent bottles				√	√
Refrigerators	√				√*
Water stills					√

√ indicates acceptable level of availability
***** indicates acceptable level of functionality

Summary

The acceptable level of 100% for equipment in the safety category was not achieved by any school type. Tables 2 and 3 show how the school types are situated with respect to availability at acceptable levels (80%) of some capital equipment. The 5-year government/composite and 5-year government assisted schools are disadvantaged when compared to other school types.

Research Question 2

What is the present situation with respect to the availability of consumables for lower secondary science (a) at a general level, and (b) for different school types?

The consumables were grouped as follows: reagents for routine tests, materials, and other common chemicals.

Reagents for routine tests

Generally, reagents that are considered essential were in good supply (see Appendix D). However, only ammonia solution, Benedict's solution, calcium hydroxide, mineral acids (hydrochloric acid, nitric acid, and sulphuric acid), sodium salts, copper sulphate, iron filings, and magnesium metal ribbon were available at the acceptable level of 80%.

Most of the reagents for routine tests were always available to at least 80% of the respondents of the junior secondary, the 7-year government-assisted, and the 7-year government schools. Only Benedict's solution, hydrochloric acid, sulphuric acid, and iron filings were always available to 80% of the respondents in the 5-year government/composite schools. However, availability of all of the reagents in the 5-year government-assisted schools was at an unacceptable level (see Table 4).

Table 4. Availability of Reagents by School Type

Items	Junior secondary	5-year Gov't./Comp.	5-year Gov't. Asst.	7-year Gov't.	7-year Asst.
Calcium hydroxide	√			√	√
Mineral acids	√	√		√	√
Iron filings	√	√		√	√
Magnesium ribbon	√			√	√
Benedict's solution	√	√		√	√

√ indicates acceptable level of availability

Materials

In general, materials such as filter paper, litmus paper (red and blue), and wooden splints were available at the acceptable level of 80%. The same pattern was observed with respect to filter paper, litmus paper, and wooden splints in all school types, with the exception of the 5-year government-assisted schools. pH paper was available to 68.2% of the respondents overall, but was available at an acceptable level (81.3%) in the 7-year assisted schools. The other materials (string, plasticine, straws, etc.) were available to between 34% and 57.6% of the respondents, in general (see Appendix D). Similarly, supplies of plasticine and straws were available at the acceptable level in the 7-year government schools, while plasticine and string were available in the 7-year assisted schools at the acceptable level of 80%. None of the materials were available at the acceptable level in the 5-year government-assisted schools (see Table 5).

Table 5. Availability of Materials by School Type

Items	Junior secondary	5-year Gov't./Comp.	5-year Gov't. Asst.	7-year Gov't.	7-year Asst.
Filter paper	√	√		√	√
Litmus papers	√	√		√	√
Wooden splints	√	√		√	√
pH paper					√
Plasticine				√	√
String					
Straw				√	

√ indicates acceptable level of availability

Other common chemicals

Generally, the other common chemicals identified (see Appendix D) were not available at the acceptable level. Availability of some of these items, for example, sucrose, sodium

hydrogen carbonate, sodium carbonate, potassium iodide, potassium dichromate, iodine crystals, and ethanol, ranged from 62.1% to 78.8%. However, at least 80% of the respondents in the 7-year government and 7-year government-assisted schools indicated that these chemicals were always available at acceptable levels, with the exception of cobalt (II) chloride (see Appendix E) for the 7-year government schools (55.6%). Ethanol, phenolphthalein, and sodium hydrogen carbonate were always available at acceptable levels in the junior secondary schools. For the 5-year government/composite and 5-year government-assisted schools, none of the chemicals in this category were available to at least 80% of the respondents (see Table 6).

Table 6. Availability of Other Common Chemicals by School Type

Items	Junior secondary	5-year Gov't./Comp.	5-year Gov't. Asst.	7-year Gov't.	7-year Asst.
Sucrose					√
Sodium hyd. carbonate	√			√	√
Sodium carbonate				√	√
Potassium dichromate				√	√
Iodine crystals				√	√
Ethanol	√				√

√ indicates acceptable level of availability

Summary

Generally, the situation with respect to consumables was acceptable across most school types. While the 7-year government and 7-year government-assisted schools had acceptable levels of most items in this category, most of these items were not available at the acceptable level in the 5-year government/composite and 5-year government-assisted schools.

Research Question 3

What is the present situation with respect to (a) the availability of equipment/apparatus for practical work, and (b) the adequacy of the supply of the equipment/apparatus for small-group practical work within a class of 35-40 students?

The term *availability* in the first part of this research question refers to material/apparatus to which teachers had access in order to support science teaching/learning. The assumption was that teachers could deploy available equipment/apparatus as necessary, for example, for whole-group teaching, or at stations for concurrent student activities. The term *adequacy* refers specifically to small-group practical work within a whole-class

setting. Groups were set at between 4 to 5 students, a size thought to be appropriate for maximum student engagement and collaboration.

The equipment/apparatus for practical work was grouped according to the following criteria: the teaching of specific science topics (electricity and magnetism, contraction and expansion of matter, light, sound, mechanics, drying/heating, examination of plant and animal material, volumetric analysis, and basic measurement and manipulation), basic glassware and related equipment, and safety and cleaning equipment (see Appendix F for detailed listing).

Teaching of specific science topics

Electricity and magnetism. Of the items identified as minimal for teaching this topic (see Appendix F), only bar magnets and crocodile clips were available to at least 80% of the respondents, and were in adequate supply at the level of 50% and 45.5% respectively. None of the other equipment, for example, ammeters, voltmeters, battery holders, lamp holders, and connecting wire, were available in adequate supply for the conduct of small-group practical work.

Contraction and expansion of matter. None of the equipment identified for practical work on the contraction and expansion of matter, for example, ball and ring apparatus, and capillary tubing, were available at an acceptable level in any school type. However, with respect to small-group practical work, 13.6% of the respondents had an adequate supply of ball and ring apparatus, and 34.8% had an adequate supply of capillary tubing for the conduct of small-group practical work.

Light. Most of the equipment identified for practical work for teaching this topic (see Appendix F) were not available to at least 80% of the respondents. Only glass blocks were available to at least 80% of the respondents, while 48.5% had an adequate supply for small-group practical work. Availability of rectangular prisms and ray boxes was exceedingly low. These were available to about 35% of the respondents, and less than 20% had an adequate supply for small-group practical work.

Sound. The only item in this subcategory was tuning forks, which were available to about 63.6% of the respondents. However, these were in adequate supply for small-group practical work to less than 30% of the respondents. It should be noted that other apparatus/materials for teaching sound include test tubes, straws, and so on, which are included in other categories.

Mechanics. None of the equipment in this subcategory were available at the acceptable level of 80%, nor in adequate supply for small-group practical work (see Appendix F). Of these items, pendulum bobs were available to 75.8% of the respondents, and in adequate supply for small-group practical work to 47%. Mass sets and pulleys were available to 59.1% and 65.4% of the respondents respectively, but were in adequate supply for small-group practical work to just about 40%. Inclined planes were available to 24% of the respondents and were in adequate supply to 15.2%.

Drying/heating. The items in this subcategory are listed in Appendix F. Tripod stands, wire gauzes, and Bunsen burners were available to at least 80% of the respondents, and in adequate supply for small-group practical work to 65.2%, 47.2%, and 62.1% respectively. Between 25-75% of the respondents indicated that the other items were available, but only 40% indicated that there was an adequate supply for small-group practical work.

Examination of plant and animal material. None of the equipment/materials identified (see Appendix F) were available at the acceptable level. Magnifying lenses were reported as available to the highest percentage of respondents (78.8%), but were only available in adequate supply for small-group practical work to just over half of the respondents (53%).

Volumetric analysis. Items in this subcategory (see Appendix F) included burettes, droppers, and retort stands with clamps. These were available at acceptable levels to at least 80% of the respondents, but in adequate supply for small-group practical work to only 48.5%, 56.1%, and 62.1% respectively.

Basic measurement and manipulation. The basic measurement and manipulation equipment identified as minimal are listed in Appendix F. Only 100ml and 1000ml measuring cylinders, meter rules, spring balances, and stop clocks were available to at least 80% of the respondents. These were in adequate supply for small-group practical work to 54.5%, 54.5%, 63.6%, 50.0%, and 42.4% respectively.

Basic glassware and related equipment

The basic glassware and related equipment identified as minimal are listed in Appendix F. Of these, only beakers (100ml, 250ml), funnels, test tube holders, test tube racks, and test tubes were available to more than 80% of the respondents. These were in adequate supply for small-group practical work to between 53-66 % of the respondents. Y-shaped connectors, gas jars, mortars and pestles, and separating funnels were not available at the acceptable level, but were in adequate supply for small-group work to at least 67% of the respondents.

Safety and cleaning apparatus

Of the safety and cleaning apparatus identified (see Appendix F), only test tube brushes were available to at least 80% of the respondents. However, these were in adequate supply for small-group practical work to 42.4%.

Summary

The emerging pattern is that most of the equipment/apparatus identified are available at unacceptable levels for practical work, and is inadequate for small-group practical work. The data suggest that the available equipment/apparatus and materials may be adequate

for purposes of demonstration, but the reality is that less than half of the respondents have the necessary resources to conduct practical work involving small groups in topics such as light, contraction and expansion of matter, mechanics, and activities involving drying and heating.

Research Question 4

Do (a) the availability of equipment/apparatus for practical work, and (b) the adequacy of equipment/apparatus for small-group practical work vary with school type?

The terms *availability* and *adequacy* in this research question applies as stated in the previous section. The breakdown of the data by school type follows.

Teaching of specific science topics

Electricity and magnetism. Ammeters, bar magnets, battery holders, connecting wires, plotting compasses, and voltmeters were available to at least 80% of the respondents from junior secondary schools. In the 5-year government/composite schools, bar magnets and crocodile clips were the only apparatus available to at least 80%. In the 5-year government-assisted schools none were available to at least 80%. In the 7-year government schools, with the exception of wire cutters and horseshoe magnets, all other apparatus were available to at least 80%. The same was observed in the 7-year government-assisted schools. It would seem that the 5-year government/composite schools and the 5-year government-assisted schools are disadvantaged. None of the equipment listed were in adequate supply for small-group practical work in any school type (see Table 7).

Table 7. Availability of Equipment for Teaching Electricity and Magnetism by School Type

Items	**Junior secondary**	**5-year Gov't./ Comp.**	**5-year Asst.**	**7-year Gov't.**	**7-year Asst.**
Ammeters	√			√	√
Bar magnets	√	√		√	√
Battery holders	√			√	√
Connecting wires	√			√	√
Plotting compasses	√			√	√
Voltmeters	√			√	√
Crocodile clips		√		√	√

√ indicates acceptable level of availability

Contraction and expansion of matter. Only capillary tubing was available at the acceptable level of at least 80% to the respondents in the junior secondary schools and 7-year government-assisted schools. None of the apparatus for teaching about contraction

and expansion of matter were available at acceptable levels in the other school types. In addition, none of the equipment were available in adequate supply for practical classes of 35-40 students in any school type.

Light. Biconvex lenses, concave lenses, glass blocks, and triangular prisms were available to at least 80% of the respondents in the junior secondary schools. Glass blocks and optical pins were available to 100% of the respondents in the 7-year government schools, while biconvex lenses, concave lenses, glass blocks, and optical pins were available to at least 80% of the respondents from the 7-year government-assisted schools. None of the equipment listed were available to at least 80% of the respondents in the 5-year government/composite or the 5-year government-assisted schools. Only optical pins were available in adequate supply for small-group practical work to at least 80% of the respondents from the 7-year government-assisted schools. All the other equipment were not in adequate supply to any school type (see Table 8).

Table 8. Availability of Equipment for Teaching the Topic of Light by School Type

Items	**Junior secondary**	**5-year Gov't./ Comp.**	**5-year Asst.**	**7-year Gov't.**	**7-year Asst.**
Biconcave lenses	√				√
Concave lenses	√				√
Glass blocks	√			√	√
Triangular prisms	√				
Optical pins				√	√*****

√ indicates acceptable level of availability
***** indicates adequate supply for small-group work

Sound. Tuning forks were available to at least 80% of the respondents from the junior secondary and the 7-year government schools. However, tuning forks were not in adequate supply for small-group practical work in any school type.

Mechanics. Pulleys were available in junior secondary schools at the acceptable level. In the 7-year government and 7-year government-assisted schools, assorted mass sets and pendulum bobs were available at acceptable levels. However, none of the equipment were available at acceptable levels in the 5-year government/composite and 5-year government-assisted schools. With the exception of assorted mass sets and pendulum bobs for the 7-year government-assisted schools, none of the other school types had an adequate supply of the equipment listed for small-group work (see Table 9).

Table 9. Availability of Equipment for Teaching Mechanics by School Type

Items	Junior secondary	5-year Gov't/ Comp.	5-year Asst.	7-year Gov't.	7-year Asst.
Pulleys	√				
Mass sets				√	√*
Pendulum bobs				√	√*

√ indicates acceptable level of availability
* indicates adequate supply for small-group work

Drying/heating. Bunsen burners and tripod stands were available to at least 80% of respondents in the junior secondary schools. In the 5-year government/composite schools, Bunsen burners, tripod stands, and wire gauzes were available at an acceptable level. In the 7-year government schools, Bunsen burners, crucibles, pipe clay triangles, tripod stands, and wire gauzes were available at acceptable levels. In the 7-year government-assisted, all equipment, with the exception of gas lighters, were available at acceptable levels. In the 5-year government-assisted schools, none of the equipment were available at the acceptable level. None of the school types had an adequate supply of the items listed for small-group practical work (see Table 10).

Table 10. Availability of Equipment to Support Drying and Heating by School Type

Items	Junior secondary	5-year Gov't/ Comp.	5-year Asst.	7-year Gov't.	7-year Asst.
Bunsen burners	√	√		√	√
Tripod stands	√	√		√	√
Wire gauze		√		√	√
Crucibles					√
Pipe clay triangles				√	√

√ indicates acceptable level of availability

Examination of plant and animal material. Only magnifying lenses were available to at least 80% of respondents in the junior secondary schools. Dissecting scissors, forceps, and magnifying lenses were available in the 7-year government schools. Forceps, magnifying lenses, and monocular microscopes were also available to at least 80% of respondents from the 7-year government-assisted schools. None of the apparatus were available at the acceptable to at least 80% of respondents from 5-year government/composite and 5-year government-assisted schools. None of the school types, however, had an adequate supply of the materials listed for small-group practical work (see Table 11).

Table 11. Availability of Equipment for Examination of Plant and Animal Material by School Type

Items	Junior secondary	5-year Gov't/ Comp.	5-year Asst.	7-year Gov't.	7-year Asst.
Magnifying lenses	√			√	√
Dissecting scissors				√	
Forceps				√	√
Microscopes - monocular					√

√ indicates acceptable level of availability

Volumetric analysis. Burettes, conical flasks (250ml), droppers, retort stands with clamps, and wash bottles were available to at least 80% of the respondents in the junior secondary schools. In the 5-year government/composite schools, burettes and droppers were available, but none of the apparatus were available at the acceptable level in the 5-year government-assisted schools. In the 7-year government schools, burettes, burette clamps, 250ml conical flasks, retort stands with clamps, droppers, 250ml and 1000ml volumetric flasks were available. In the 7-year government-assisted schools, burettes, burette clamps, 250ml conical flasks, droppers, dropping bottles, dropping pipettes, retort stands with clamps, and 25ml volumetric pipettes were available at the acceptable levels. However, with the exception of droppers and retort stands with clamps, which were available in the 7-year government-assisted schools, none of the other school types had an adequate supply of the equipment listed for small-group practical work (see Table 12).

Table 12. Availability of Equipment for Teaching Volumetric Analysis by School Type

Items	Junior secondary	5-year Gov't/Comp.	5-year Asst.	7-year Gov't.	7-year Asst.
Burettes	√	√		√	√
Conical flasks	√			√	√
Droppers	√	√		√	√*
Retort stands w/clamps	√			√	√*
Wash bottles	√				
Burette clamps				√	
Volumetric flasks				√	
Dropping bottles					√
Dropping pipettes					√
Pipettes - 25ml					√

√ indicates acceptable level of availability

***** indicates adequate supply for small-group work

Basic measurement and manipulation. In the junior secondary schools, 50ml and 250ml graduated cylinders, meter rules, spatulas, spring balances, and stop clocks were available at the acceptable level of 80%. In the 5-year government/composite schools, 100ml graduated cylinders and stop clocks were available. In the 7-year government and 7-year government-assisted schools, all equipment, except double beam pan balances, 1000ml measuring cylinders, spirit levels, and water troughs were available at the acceptable level. In the 5-year government-assisted schools, however, none of the equipment were available at the acceptable level of 80%.

With the exception of 10ml graduated cylinders, meter rules, and spring balances in the 7-year government-assisted schools, none of the other school types had an adequate supply of the equipment listed in this subcategory for the conduct of small-group practical work (see Table 13).

Table 13. Availability of Equipment for Basic Measurement and Manipulation by School Type

Items	**Junior secondary**	**5-year Gov't/Comp.**	**5-year Asst.**	**7-year Gov't.**	**7-year Asst.**
10ml grad. cylinders				√	√*****
50ml grad. cylinders	√			√	√
100ml grad. cylinders		√		√	√
250ml grad. cylinders	√			√	√
Meter rules	√			√	√*****
Spatulas	√			√	√
Spring balances	√			√	√*****
Stop clocks	√	√		√	√

√ indicates acceptable level of availability
*indicates adequate supply for small-group work

Basic glassware and related equipment

Beakers (250ml), cork borer sets, funnels, petri dishes, separating funnels, test tube holders and racks, and assorted test tubes were available in the junior secondary schools at acceptable levels. Similarly, in the 5-year government/composite schools, 250ml beakers, petri dishes, test tube holders/racks, and assorted test tubes were available. All the equipment were available at the acceptable level in the 7-year government schools, with the exception of cork borer sets, tongs, watch glasses, assorted corks, and y-shaped connectors. All equipment was available at the acceptable level in the 7-year government-assisted schools, with the exception of 50ml beakers, glass tubing, tongs,

watch glasses, and y-shaped connectors. None of the equipment were available at acceptable levels to the respondents from the 5-year government-assisted schools.

With the exception of stirring rods for the 5-year government-assisted schools, and 100ml beakers, assorted funnels, glass tubing, petri dishes, stirring rods, test tube racks, and assorted test tubes for the 7-year government-assisted schools, none of the available equipment listed were adequate for small-group practical work in other school types (see Table 14).

Table 14. Availability of Basic Glassware and Related Equipment by School Type

Items	**Junior secondary**	**5-year Gov't/Comp.**	**5-year Asst.**	**7-year Gov't.**	**7-year Asst.**
Beakers - 100ml				√	√*****
Beakers - 250ml	√	√		√	√*****
Cork borer sets	√			√	√
Funnels (assorted)	√			√	√*****
Petri dishes	√	√		√	√*****
Separating funnels	√			√	√
Test tube holders	√	√		√	√*****
Test tube racks	√	√		√	√*****
Test tubes (assorted)	√	√		√	√
Stirring rods				√	√
Glass tubing				√*****	

√ indicates acceptable level of availability
***** indicates adequate supply for small-group work

Safety and cleaning apparatus

Test tube brushes were available to at least 80% of the respondents in all school types, with the exception of the 5-year government-assisted schools. Bottle brushes were also available in the 7-year government-assisted schools. Splash goggles were not available to at least 80% in any of the school types. None of the school types had an adequate supply of the safety and cleaning apparatus listed for small-group practical work.

Summary

Availability of equipment/apparatus for the smooth conduct of practical work fluctuated among the various school types, with the 5-year schools (government/composite and government-assisted) somewhat disadvantaged in most areas. Most of the equipment/apparatus were not available at the acceptable level across the school types.

With the exception of the 7-year government-assisted schools (which had an adequate supply of equipment/apparatus for small-group practical work with respect to selected items in the following subcategories: basic measurement and manipulation, glassware and related equipment, mechanics, light and volumetric analysis) and the junior secondary schools (which had an adequate supply of stirring rods), none of the equipment/apparatus were in adequate supply for the conduct of small-group practical work across the school types. Again, the 5-year school types were the most disadvantaged with respect to adequacy of equipment/apparatus for small-group practical work.

Research Question 5

What challenges do science teachers face with respect to (a) the repair of broken-down equipment, and (b) sourcing equipment/materials to support practical work?

Planning for repair

The challenges reported most frequently with respect to equipment repair were:

- unavailability of parts
- lack of financial resources
- unavailability of qualified technicians

When responses were disaggregated according to school type, lack of financial resources was mentioned by all school types, with the exception of the 5-year government-assisted schools. Unavailability of parts and qualified technicians were challenges cited by all school types, with the exception of the two categories of 5-year schools. The focus of the two types of 5-year schools was lack of financial resources to repair equipment.

Sourcing equipment and materials

With respect to purchasing apparatus/equipment, or having access to consumables for practical work, the most frequently cited challenges were:

- limited financial resources
- items not readily available from suppliers
- supplies not received from Ministry of Education

All school types, with the exception of the 5-year government-assisted schools mentioned "limited financial resources" as a constraint. Eleven schools, comprising 5-year government-assisted, 5-year government/composite, and 7-year government-assisted, spoke about supplies not received from the Ministry of Education. The availability of items from suppliers was not mentioned by any of the 5-year government-assisted schools. These schools cited the limited financial resources at their disposal.

Other concerns

In addition to the challenges mentioned above, other concerns that impacted on the ability to adequately provide for practical work were expressed. These were:

- malfunctioning gas lines
- lack of, or inadequate, laboratory facilities
- lack of safety equipment
- absence of laboratory technician

Malfunctioning gas lines was a problem in junior secondary schools. The junior secondary schools, the 5-year government/composite schools, and the 7-year government schools cited lack of, or inadequate, laboratory facilities. The 5-year government/composite schools also mentioned lack of safety equipment and the absence of a laboratory technician. One 5-year government-assisted school mentioned the absence of a laboratory technician.

Summary

Teachers in all school types experienced challenges with respect to sourcing equipment and materials, and the repair of equipment. In addition, the absence of adequate laboratory facilities in the junior secondary schools, the 5-year government/composite schools, and the 7-year government schools constrains any attempt to introduce practical work at this level. Five-year schools have safety issues, and some do not have a laboratory technician/assistant. In addition, the late or non-receipt of financial allocation at these schools hinders attempts to repair or source equipment and materials. Malfunctioning gas lines also limit the types of practical experiences provided for students at this level.

CONCLUSION/DISCUSSION

Introduction

The overall situation with respect to all apparatus and materials is that availability is at unacceptable levels generally. In addition, there is inequitable distribution across the various school types, with 7-year government-assisted and 7-year government schools better equipped than the 5-year government-assisted and 5-year government/composite schools. While apparatus or equipment may be available in the various schools, in many cases they are not functional.

Capital Laboratory Equipment/Apparatus

This category included those standard items usually found in a school laboratory, and which might be considered an initial investment. The assumption was made that there would be yearly or periodic budgetary allocations for the maintenance, repair, or replacement of such equipment. However, it is evident that this is not standard practice. The data suggest that safety is not afforded a high priority, since the acceptable level of 100% for all of the items listed was not attained, either generally or by school type. In addition, the wide range in the levels of availability and functionality of the other capital equipment across the school types gives cause for concern.

Non-functional equipment suggests either lack of funds for repair/replacement, or inability to access funding or trained technicians. The 5-year government/composite and government-assisted schools, as well as the junior secondary schools, are clearly disadvantaged when compared with the other school types. The absence or disrepair of what is considered standard laboratory equipment is likely to impact on the type and quality of practical experiences that teachers can provide for students.

Consumables

These materials have to be replaced periodically as they are used up and, again, the assumption was made that there would be provision for recurrent expenditure in budgetary allocations for science. While the situation with respect to consumables is better than that for capital equipment, with acceptable levels of some of the items identified across the various school types, the position in both 5-year school types, as well as the junior secondary schools, is that availability of most items is at unacceptable levels. Again, there are implications for the quality or kinds of practical work that is possible in these schools.

Equipment/Apparatus for Practical Work

There seems to be available equipment for the purposes of demonstration. While demonstration is useful for the introduction of lessons and for illustration of abstract concepts, it should not be the sole approach to providing practical experiences. This deprives students of direct hands-on experiences, which promote the acquisition of the process skills and enhance the development of science concepts. In addition, hands-on experiences at this level allow students to behave like scientists, and serve to remove some of the mystique and negative attitudes to science that are often encountered at the higher levels in school.

The Teaching of Specific Science Topics

It appears that some topics are privileged with respect to the supporting apparatus/equipment for small-group practical work. For example, while at least 50% of the respondents had an adequate supply of some the equipment for small-group practical work involving electricity and magnetism, examination of plant and animal material, volumetric analysis, and basic measurement and manipulation, the adequacy level was below 40% for the apparatus/equipment for the other topics (light, mechanics, sound, drying and heating, and expansion and contraction of matter). This has implications for how various topics are treated. It should be noted that some of these latter topics deal with concepts traditionally associated with physics. The inference, given the distribution of available apparatus, is that practical work in some topics might be given more emphasis. This is an area that requires further investigation, given that the percentage of science teachers with a physics background at this level is low (see George, 2003).

With the exception of the 7-year government-assisted schools, which had adequate supplies of some materials/apparatus to teach aspects of the range of topics identified in small-group practical work, none of the other school types had an adequate supply. If students are to derive maximum benefit from hands-on and minds-on activities, as suggested in the new curriculum documents (T&T. Ministry of Education, 2002), they need opportunities to engage in small-group practical work. There is a case, therefore, for laboratories to be adequately equipped to support small-group practical work. However, it is evident from this study that the equipment is either non-functional or inadequate to support this kind of activity. In fact, the findings from a subcomponent of this research project reveal that small-group practical work is not a common practice among some lower secondary science teachers (see Herbert et al., 2003). It is likely that teachers are constrained by the lack of resources and inadequate laboratory facilities, or are not knowledgeable about the variety of ways in which practical work may be incorporated into science teaching.

Challenges Faced by Teachers

The challenges faced by most teachers with respect to the repair and sourcing of apparatus/materials can be addressed with proper planning and disbursement of funds, and with adequate policies for management and accountability.

RECOMMENDATIONS

- A comprehensive survey of laboratory facilities and science equipment. This should be mandated for all schools. It would reveal the needs of the various schools, and efforts could then be made to ensure that there is equitable distribution of apparatus and materials that are considered essential. All antiquated and useless equipment should be removed. Such restocking/refurbishing/renovating/expanding would ensure that all schools are adequately equipped for teaching lower secondary science.

- Provision for the maintenance/repair of equipment. A central agency for the repair of school science equipment should be considered. This would ensure that apparatus is functional at all times. This agency could also be responsible for ongoing training for laboratory assistants in maintenance and repair of basic equipment. Links could also be established with the science departments of the Faculty of Science and Agriculture at The University of the West Indies (UWI) and the Association for Science Education in Trinidad and Tobago (ASETT), in order to obtain assistance with training workshops for repair of equipment. It is also recommended that individual schools make links with industry (e.g., British Gas) and other science-related institutions (e.g., NIHERST) for donations of used but serviceable equipment.

- Policy for safety procedures. Safety is a priority and it should be mandatory that school science laboratories be equipped with basic safety equipment and that policies be put in place for maintenance of these. This responsibility could be allocated to the head of the science department. All students should be familiar with the location of this equipment and all science teachers should be trained in the use of the equipment.

- Purchasing equipment. The Ministry of Education should review the procedures for the allocation of funds to schools, and accountability procedures should ensure that funds allocated to science are used for the prescribed purposes. Better procedures need to be established for stocktaking, for example, who is responsible, when should it be done, and so on, so that there is a sense of what is functional, what needs to be repaired, and what new purchases are necessary in time for each new academic year. In addition, the central agency for repairing equipment could also be involved in the development of simple equipment using cheap local materials with a view to reducing costs.

- Training workshops for design of small-group practical work. Teachers should be exposed to workshops on appropriate practical activities that meet curriculum

goals, but which are also fun-filled, relevant to real life, and motivating to students.

- Laboratory support. Teachers may need assistance in the management of small-group practical work at this level. There is a case for the provision of additional laboratory assistants to work with teachers during laboratory sessions.

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APPENDIX A

Availability/Functionality of Capital Laboratory Equipment (%)

Teaching and Learning Aids	**Available**	**Functional**
Aquarium with pump	24.2	10.6
Bathroom scale	36.4	27.3
Colour wheel	13.6	13.6
Model of ear	66.7	45.5
Model of eye	62.1	39.4
Overhead projector	48.5	18.2
Periodic chart	69.7	45.5
Rain gauge	24.2	12.1
Skeleton (human)	66.7	36.4
Skull (carnivore)	33.3	19.7
Skull (herbivore)	30.3	13.6
Soil testing kit	21.2	10.6
Teeth (assorted)	25.8	31.8
Wall clock	47.0	19.2
Basic Items for Preparation and Storage		
Analytical balance (top loading	45.5	33.3
Laboratory oven	33.3	24.2
Reagent bottles (clear) - 250ml	78.8	56.1
Refrigerator	77.3	47.0
Soldering iron	33.3	25.8
Water still	43.9	25.8
Safety Equipment		
Fire extinguisher	72.7	59.2
First aid kit	43.9	36.4
Fume cupboard	48.5	15.2

APPENDIX B

Availability of Capital Laboratory Equipment by School Type (%)

	Junior secondary	5-year Gov't/ Comp.	5-year Asst.	7-year Gov't.	7-year Asst.
Teaching and Learning Aids					
Aquarium with pump	20.0	37.5	33.3	33.3	
Bathroom Scale	90.0	31.3	33.3	11.1	25.0
Colour wheel		6.3	33.3	11.1	25.0
Model of ear	90.0	50.0	33.3	100	68.8
Model of eye	80.0	43.8		88.9	75.0
Overhead projector	50.0	43.8		44.4	56.3
Periodic chart	70.0	56.3		88.9	81.3
Rain gauge	10.0	25.0		11.1	25.0
Skeleton (human)	70.0	68.8		77.8	75.0
Skull (carnivore)	40.0	18.8		33.3	50.0
Skull (herbivore)	50.0	18.8		33.3	37.5
Soil testing kit		18.8	33.3	22.2	25.0
Teeth (assorted)	20.0	18.8		55.6	56.3
Wall clock	70.0	31.3		22.2	62.5
Basic Items for Preparation and Storage					
Analytical balance (top loading)	10.0	25.0	33.3	66.7	81.3
Laboratory oven	40.0	12.5	33.3	44.4	43.8
Reagent bottles (clear) - 250ml	70.0	75.0		100	81.3
Refrigerator	100	75.0		44.4	93.8
Soldering iron		18.8		55.6	62.5
Water still	30.0	18.8		66.7	81.3
Safety Equipment					
Fire extinguisher	90.0	62.5	33.3	77.8	87.5
First aid kit	40.0	37.5		77.8	37.5
Fume cupboard		68.8	33.3	44.4	43.8

APPENDIX C

Functionality of Capital Laboratory Equipment by School Type (%)

	Junior secondary	5-year Gov't/ Comp.	5-year Asst.	7-year Gov't.	7-year Asst.
Teaching and Learning Aids					
Aquarium with pump	10.0		33.3	22.2	
Bathroom scale	60.0	18.8	33.3	11.1	25.0
Colour wheel	10.0	6.3	33.3	11.1	18.8
Model of ear	60.0	37.5		66.7	50.0
Model of eye	50.0	25.0		44.4	56.3
Overhead projector		12.5		11.1	50.0
Periodic chart	40.0	31.3		44.4	68.8
Rain gauge	10.0	6.3			18.8
Skeleton (human)	30.0	25.0		33.3	62.5
Skull (carnivore)	20.0	12.5		11.1	37.5
Skull (herbivore)	10.0	12.5			25.0
Soil testing kit		12.5	33.3		12.5
Teeth (assorted)	20.0	6.3		33.3	37.5
Wall clock	20.0	6.3			43.8
Basic Items for Preparation and Storage					
Analytical balance (top loading)		12.5	33.3	44.4	68.8
Laboratory oven	30.0	12.5	33.3	22.2	37.5
Reagent bottles (clear) - 250ml				55.6	68.8
Refrigerator	30.0	56.3		33.3	81.3
Soldering iron		18.8		44.4	50.0
Water still		12.5		33.3	50.0
Safety Equipment					
Fire extinguisher	80.0	62.5	33.3	55.6	56.3
First aid kit	40.0	25.0		66.7	31.3
Fume cupboard		12.5	33.3	11.1	25.0

APPENDIX D

Availability of Consumables (%)

Reagents for Routine Tests	
Ammonia solution	80.3
Barium chloride	72.7
Benedict's solution	84.8
Calcium carbonate	77.3
Calcium hydroxide	80.3
Copper (II) sulphate	87.9
Copper turnings	66.7
D-Glucose	59.1
Hydrochloric acid	86.4
Iron filings	84.8
Magnesium metal ribbon	80.3
Methyl orange	75.8
Nitric acid	81.8
Potassium permanganate	78.8
Sodium carbonate anhydrous	68.2
Sodium chloride	77.3
Sodium hydroxide	81.8
Starch	71.2
Sulphuric acid	84.8
Universal indicator	72.7
Vinegar	57.6
Zinc powder granular	68.2
Materials	
Chromatography paper	40.9
Filter paper	86.4
Litmus paper (blue)	84.8
Litmus paper (red)	84.8
pH paper (0-14pH)	68.2
Plasticine	43.9
Straws	34.8
String	57.6
Wooden splints	87.9

Other Common Chemicals	
Cobalt (II) chloride	51.5
Ethanol	72.7
Iodine crystals	78.8
Manganese dioxide	65.2
Phenolphthalein	69.7
Potassium dichromate	78.8
Potassium iodide	74.2
Screened methy1 orange	50.0
Silver nitrate	65.2
Sodium carbonate crystals	62.1
Sodium hydrogen carbonate	74.2
Sodium sulphate	60.6
Sucrose	63.6

APPENDIX E

Availability of Consumables by School Type (%)

	Junior secondary	5-year Gov't/ Comp.	5-year Asst.	7-year Gov't.	7-year Asst.
Reagents for Routine Tests					
Ammonia solution	90.0	68.8	33.3	100	100
Barium chloride	60.0	62.5	33.3	100	93.8
Benedict's solution	80.0	81.3	33.3	100	100
Calcium carbonate	90.0	62.5	33.3	100	100
Calcium hydroxide	90.0	62.5	33.3	100	93.8
Copper (II) sulphate	100	75.0	33.3	100	100
Copper turnings	80.0	43.8	33.3	100	87.5
D-Glucose	20.0	56.3	33.3	66.7	100
Hydrochloric acid	100	81.3	33.3	100	100
Iron filings	80.0	87.5	33.3	88.9	100
Magnesium metal ribbon	80.0	68.8	33.3	100	100
Methyl orange	80.0	68.8	33.3	100	93.8
Nitric acid	90.0	75.0	33.3	88.9	100
Potassium permanganate	80.0	75.0		100	100
Sodium carbonate anhydrous	60.0	50.0	33.3	100	93.8
Sodium chloride	90.0	56.3	33.3	88.9	100
Sodium hydroxide	90.0	68.8	33.3	100	93.8
Starch	50.0	62.5	33.3	77.8	100
Sulphuric acid	90.0	81.3		100	100
Universal indicator	90.0	62.5	33.3	88.9	87.5
Vinegar	50.0	31.3	33.3	88.9	87.5
Zinc powder granular	80.0	37.5	33.3	77.8	100
Materials					
Chromatography paper	30.0	31.3	33.3	55.6	56.3
Filter paper	100	81.3	33.3	100	100
Litmus paper (blue)	100	18.8	33.3	100	93.8
Litmus paper (red)	100	81.3	33.3	100	93.8
pH paper (0-14pH)	70.0	68.8	33.3	77.8	81.3
Plasticine	20.0	25.0		77.8	87.5
Straws		12.5	33.3	77.8	62.5
String	40.0	56.3	33.3	66.7	100
Wooden splints	100	87.5	33.3	100	100

Other Common Chemicals					
Cobalt (II) chloride	30.0	43.8	33.3	55.6	75.5
Ethanol	80.0	62.5	33.3	77.8	100
Iodine crystals	60.0	75.0	33.3	100	93.8
Manganese dioxide	70.0	43.8	33.3	88.9	93.8
Phenolphthalein	90.0	37.5	33.3	100	93.8
Potassium dichromate	70.0	68.5	33.3	100	100
Potassium iodide	60.0	56.3	33.3	100	93.8
Screened methy1 orange	40.0	25.0		88.9	87.5
Silver nitrate	50.0	43.8	33.3	88.9	93.8
Sodium carbonate crystals	50.0	43.8	33.3	100	81.3
Sodium hydrogen carbonate	80.0	62.5	33.3	100	93.8
Sodium sulphate	50.0	37.5	33.3	88.9	87.5
Sucrose	40.0	56.3		77.8	93.8

APPENDIX F

Availability/Adequacy of Equipment/Apparatus Used for Practical Work (%)

Teaching of Specific Science Topics	Available	Adequate
Electricity/Magnetism		
Ammeters (0-5amp)	69.7	36.4
Ammeters (0-l) amp	66.7	34.8
Bar magnets	89.4	50.0
Battery holders (size D)	77.3	50.0
Connecting wires	78.8	45.5
Crocodile clips	84.8	45.5
Horseshoe magnets	43.9	15.2
Lamps	66.7	34.8
Lamp holders	72.7	43.9
Multimeters	53.0	36.4
Plotting compasses	69.7	42.4
Solder wire	45.5	33.3
Voltmeters	78.8	48.5
Wire cutters	53.0	24.2
Contraction/Expansion of Matter		
Ball and ring apparatus	63.6	13.6
Capillary tubing	63.6	34.8
Light		
Bi-convex lenses	72.7	40.9
Concave lenses (double)	69.7	43.9
Concave mirrors	62.1	39.4
Glass blocks	81.8	48.5
Optical pins	69.7	56.1
Prisms – equilateral	45.5	21.2
Prisms - triangular	63.6	30.3
Prisms - rectangular	36.4	19.7
Ray boxes (complete)	34.8	13.6
Sound		
Tuning fork sets	63.6	28.8
Mechanics		
Inclined planes	24.2	15.2
Mass sets (assorted)	59.1	40.9
Pendulum bobs	75.8	47.0
Pulleys	65.4	39.4

Drying/Heating		
Bunsen burners	89.4	62.1
Crucibles with covers	75.8	37.9
Evaporating dishes	69.7	40.9
Gas lighters	39.4	16.7
Pipe clay triangles	56.1	37.9
Tripod stands	87.9	65.2
Wire gauzes	81.8	47.2
Examination of Plant and Animal Material		
Bell jars with rubber bungs	37.9	18.2
Dissecting needles	39.4	25.8
Dissecting scissors	48.5	27.3
Forceps	74.2	39.4
Magnifying lenses	78.8	53.0
Microscopes - Monocular	71.2	25.8
Microscopes - Stereo	24.2	13.6
Nets for collecting specimens	16.7	15.2
Prepared microscope slides	57.6	18.2
Volumetric Analysis		
Burettes - 50ml	84.8	48.5
Burette clamps	62.1	78.8
Conical flasks - l00ml	36.4	24.2
Conical flasks - 250ml	77.3	45.5
Droppers	86.4	56.1
Dropping bottles – 60ml	57.6	34.8
Dropping pipettes	53.0	40.9
Retort stands with clamps	86.1	62.1
Volumetric flasks – 100ml	39.4	19.7
Volumetric flasks – 250ml	65.2	42.4
Volumetric flasks - 500ml	63.6	28.8
Volumetric flasks – 1000ml	65.2	24.2
Volumetric pipettes – 20ml	30.0	21.2
Volumetric pipettes - 25ml	68.2	50.0
Wash bottles	83.3	48.5
Measurement/Manipulation		
Double pan beam balances	42.4	25.8
Displacement cans	69.7	34.8
Graduated cylinders – 10ml	72.7	51.5
Graduated cylinders - 25ml	74.2	40.9
Graduated cylinders - 50m1	77.3	54.5
Graduated cylinders – 100ml	80.3	54.5
Graduated cylinders – 250ml	75.8	45.5
Graduated cylinders – 1000ml	80.3	54.5
Meter rules	86.2	63.6
Spatulas	77.3	50.0
Spring balances	80.3	50.0
Spirit levels	22.7	16.7

Stop clocks	84.8	42.4
Vernier calipers	69.7	33.3
Water troughs	37.9	9.1
Basic Glassware and Related Equipment		
Beakers – 50ml	57.6	39.4
Beakers - 100ml	86.4	63.6
Beakers – 250ml	92.4	59.1
Cork borer sets	74.2	36.4
Corks (assorted)	69.7	43.9
Funnels (assorted)	84.8	53.0
Gas jars	66.7	33.3
Glass tubing (assorted)	62.1	43.9
Mortars and pestles	71.2	27.3
Petri dishes	86.4	65.2
Separating funnels	74.2	31.8
Stirring rods	71.2	50.0
Test tube holders	92.4	54.5
Test tube racks	92.4	65.2
Test tubes - 24mm x l50mm	86.4	65.2
Test tubes – 16mm x 150mm	89.4	66.7
Tongs (assorted)	63.6	34.8
Watch glasses - 50m1	59.1	39.4
Watch glasses - 100ml	45.5	34.8
Y-shaped connectors	31.8	18.2
Safety/Cleaning Apparatus		
Bottle brushes (assorted)	60.6	42.4
Splash goggles	42.4	28.8
Test tube brushes	89.4	42.4

APPENDIX G

Availability of Equipment/Apparatus Used for Practical Work by School Type (%)

Teaching of Specific Science Topics	Junior secondary	5-year Gov't/ Comp.	5-year Asst.	7-year Gov't.	7-year Asst.
Electricity/Magnetism					
Ammeters (0-5amp)	80.0	50.0	33.3	88.9	93.8
Ammeters (0-l amp)	70.0	37.5	66.7	88.9	87.5
Bar magnets	90.0	93.8	33.3	100	93.8
Battery holders (size D)	90.0	56.3	66.7	100	87.5
Connecting wires	80.0	62.5	66.7	100	87.5
Crocodile clips	70.0	87.5	66.7	100	87.5
Horseshoe magnets	40.0	50.0	33.3	44.4	31.3
Lamps	7.0	37.5	33.3	100	87.5
Lamp holders	60.0	56.3	66.7	100	87.5
Multimeters	10.0	31.3	33.3	88.9	81.3
Plotting compasses	80.0	56.3	66.7	88.9	68.8
Solder wire	10.0	37.5	33.3	77.8	62.5
Voltmeters	90.0	62.5	66.7	100	81.3
Wire cutters	20.0	50.0	33.3	66.7	56.3
Contraction/Expansion of Matter					
Ball and ring apparatus	70.0	56.3	33.3	77.8	68.8
Capillary tubing	80.0	43.8	33.3	77.8	87.5
Light					
Bi-convex lenses	80.0	62.5	33.3	77.8	87.8
Concave lenses (double)	90.0	62.5		66.7	87.5
Concave mirrors	70.0	50.0	33.3	77.8	62.5
Glass blocks	90.0	62.5	33.3	100	93.8
Optical pins	40.0	62.5	33.3	100	87.5
Prisms - equilateral	40.0	31.3	33.3	77.8	43.5
Prisms - triangular	80.0	68.8	33.3	66.7	56.3
Prisms - rectangular	30.0	25.0		66.7	37.5
Ray boxes (complete)	20.0	18.8	33.3	55.6	43.8
Sound					
Tuning fork sets	80.0	50.0	33.3	100	56.3
Mechanics					
Inclined planes		18.8	33.3	44.4	25.0
Mass sets (assorted)	20.0	43.8	33.3	88.9	81.3
Pendulum bobs	70.0	62.5	33.3	100	93.8
Pulleys	80.0	56.3	33.3	77.8	62.5

Drying/Heating					
Bunsen burners	80.0	87.5	33.3	100	93.8
Crucibles with covers	60.0	68.8	33.3	100	87.5
Evaporating dishes	70.0	62.5	33.3	66.7	87.5
Gas lighters	30.0	31.3	33.3	66.7	37.5
Pipe clay triangles	10.0	37.5	33.3	88.9	81.3
Tripod stands	90.0	81.3	66.7	100	93.8
Wire gauzes	70.0	81.3	33.3	88.9	87.5
Examination of Plant and Animal material					
Bell jars with rubber bungs	40.0	18.8	33.3	44.4	56.3
Dissecting needles	20.0	25.0		66.7	50.0
Dissecting scissors	30.0	25.0	33.3	88.9	68.8
Forceps	60.0	68.8	33.3	88.9	87.5
Magnifying lenses	90.0	75.0	33.3	88.9	81.3
Microscopes - monocular	60.0	62.5	33.3	77.8	81.3
Microscopes - stereo	30.0		33.3	33.3	25.0
Nets for collecting specimens	10.0	12.5		22.0	25.0
Prepared microscope slides	50.0	37.5	33.3	77.8	75.0
Volumetric Analysis					
Burettes - 50ml	80.0	81.3	66.7	88.9	87.5
Burette clamps	40.0	75.0	33.3	100	81.3
Conical flasks - l00ml	40.0	18.8	33.3	66.7	43.8
Conical flasks - 250ml	90.0	68.8	33.3	88.9	87.5
Droppers	80.0	87.5	66.7	88.8	93.8
Dropping bottles – 60ml	70.0	31.3	33.3	44.4	81.3
Dropping pipettes	30.0	43.8		77.8	81.3
Retort stands with clamps	90.0	75.0	66.7	100	93.8
Volumetric flasks – 100ml	30.0	25.0		66.7	56.3
Volumetric flasks – 250ml	40.0	68.8		88.9	75.0
Volumetric flasks – 500ml	50.0	56.5	33.3	77.8	68.8
Volumetric flasks – 1000ml	50.0	62.5	33.3	88.9	62.5
Volumetric pipettes – 20ml	30.0	18.8		55.6	37.5
Volumetric pipettes – 25ml	40.0	62.5	33.3	77.8	81.3
Wash bottles	80.0	75.0	66.7	77.8	93.8
Measurement/ Manipulation					
Double pan beam balances	20.0	50.0		55.6	56.3
Displacement cans	80.0	68.8	33.3	77.8	75.0
Graduated cylinders – 10ml	30.0	75.0	33.3	100	93.8
Graduated cylinders – 25ml	40.0	75.0	33.3	100	87.5
Graduated cylinders – 50m1	80.0	62.5	66.7	100	93.8
Graduated cylinders – 100ml	50.0	81.3	66.7	100	87.5
Graduated cylinders - 250ml	90.0	62.5	66.7	88.9	81.3
Graduated cylinders – 1000ml	50.0	43.8	33.3	77.8	68.8
Meter rules	90.0	75.0	66.7	100	93.8
Spatulas	80.0	68.8		100	87.5
Spirit levels	10.0	6.3	33.3	66.7	31.3

Spring balances	80.0	75.0	66.7	88.9	87.5
Stop clocks	90.0	81.3	66.7	88.9	93.8
Vernier calipers	50.0	62.5	33.3	88.9	87.5
Water troughs	60.0	18.8		55.6	43.8
Basic Glassware and Related Equipment					
Beakers – 50ml	50.0	37.5	33.3	88.9	68.8
Beakers - 100ml	50.0	75.0	66.7	100	93.8
Beakers – 250ml	80.0	93.8	66.7	100	93.8
Cork borer sets	80.0	62.5	33.3	77.8	87.5
Corks (assorted)	60.0	62.5	33.3	77.8	87.5
Funnels (assorted)	80.0	75.0	33.3	100	93.8
Gas jars	70.0	37.5	33.3	100	87.5
Glass tubing (assorted)	70.0	43.8		88.9	75.0
Mortars and pestles	70.0	62.5		88.9	81.3
Petri dishes	90.0	87.5	33.3	88.9	93.8
Separating funnels	80.0	68.8	33.3	88.9	81.3
Stirring rods	60.0	62.5	33.3	100	93.8
Test tube holders	90.0	93.8	66.7	100	93.8
Test tube racks	90.0	87.5	66.7	100	93.8
Test tubes - 24mm x l50mm	90.0	81.3	33.3	100	93.8
Test tubes - 16mm x 150mm	90.0	81.3	66.7	100	93.8
Tongs (assorted)	60.0	62.5		77.8	75.0
Watch glasses - 50m1	50.0	56.3	33.3	66.7	68.8
Watch glasses - 100ml	60.0	25.0	33.3	55.6	62.5
Y-shaped connectors	10.0	25.0	33.3	55.6	31.5
Safety/Cleaning Apparatus					
Bottle brushes (assorted)	40.0	62.5		66.7	81.3
Splash goggles	40.0	18.8	33.3	44.4	50.0
Test tube brushes	80.0	81.3	33.3	100	93.8

APPENDIX H

Adequacy of Equipment/Apparatus Used for Practical Work by School Type (%)

Teaching of Specific Science Topics	Junior secondary	5-year Gov't/ Comp.	5-year Asst.	7-year Gov't.	7-year Asst.
Electricity/Magnetism					
Ammeters (0-5amp)	40.0	25.0	33.3	44.4	50.0
Ammeters (0-lamp)		25.0	33.3	44.4	62.5
Bar magnets	40.0	37.5	33.3	66.7	68.8
Battery holders (size D)	60.0	37.5	33.3	55.6	75.0
Connecting wires	40.0	31.3	33.3	55.6	68.8
Crocodile clips	30.0	43.8	33.3	44.4	62.5
Horseshoe magnets	10.0	60.3			12.5
Lamps	30.0	25.0		33.3	62.5
Lamp holders	40.0	50.0	33.3	44.4	68.8
Multimeters			33.3	44.4	75.0
Plotting compasses	30.0	37.5		22.2	18.8
Solder wire		18.8		66.7	62.5
Voltmeters	60.0	25.0	33.3	55.6	68.8
Wire cutters		12.5		22.2	43.8
Contraction/Expansion of Matter					
Ball and ring apparatus		12.5		11.1	25.0
Capillary tubing	40.0	31.3		22.2	50.0
Light					
Bi-convex lenses	20.0	37.5		33.3	68.8
Concave lenses (double)	30.0	43.8		33.3	62.5
Concave mirrors	40.0	25.0	33.3	33.3	50.0
Glass blocks	30.0	37.5	33.3	44.4	75.0
Optical pins	20.0	43.8	33.3	77.8	81.3
Prisms - equilateral	10.0	12.5		11.1	3.3
Prisms - triangular	30.0	37.5		11.1	37.5
Prisms - rectangular	20.0	12.5		11.1	31.3
Ray boxes (complete)			33.3	33.3	12.5
Sound					
Tuning fork sets	20.0	31.3		33.3	25.0
Mechanics					
Inclined planes		25.0	33.3	11.1	25.0
Mass sets (assorted)	10.0	43.8	33.3	44.4	81.3
Pendulum bobs	10.0	31.3	33.3	66.7	81.3
Pulleys	40.0	25.0	33.3	33.3	43.8

Drying/Heating					
Bunsen burners	40.0	50.0	33.3	55.6	62.5
Crucibles with covers	10.0	31.3	33.3	55.6	50.0
Evaporating dishes	20.0	31.3	33.3	55.6	50.0
Gas lighters	10.0	6.3		33.3	25.0
Pipe clay triangles	12.5			44.4	62.5
Tripod stands	70.0	56.3	33.3	77.8	75.0
Wire gauzes	40.0	50.0	33.3	44.4	56.3
Examination of Plant and Animal Material					
Bell jars with rubber bungs	20.0			33.3	37.5
Dissecting needles	10.0	12.5		33.3	43.8
Dissecting scissors		12.5	33.3	33.3	56.3
Forceps	20.0	37.5		44.4	50.0
Magnifying lenses	60.0	31.3	33.3	44.4	56.3
Microscopes - monocular	10.0		33.3	33.3	37.5
Microscopes – stereo		12.5	33.3	22.2	18.8
Nets for collecting specimens		18.8	33.3		12.5
Prepared microscope slides	10.0	12.5		22.2	18.8
Volumetric Analysis					
Burettes - 50ml	40.0	50.0	33.3	55.6	75.0
Burette clamps	60.0	50.0	33.3	22.2	62.5
Conical flasks - l00ml	20.0	25.0		33.3	31.3
Conical flasks - 250ml	40.0	37.5	33.3	44.4	68.8
Droppers	40.0	56.3	33.3	44.4	87.5
Dropping bottles – 60ml	10.0	25.0	33.3	33.3	56.3
Dropping pipettes	40.0				
Retort stands with clamps	70.0	56.3	33.3	55.6	81.3
Volumetric flasks – 100ml	10.0	18.8		33.3	25.0
Volumetric flasks – 250ml	10.0	37.5		55.6	62.5
Volumetric flasks – 500ml		25.0	33.3	44.4	37.5
Volumetric flasks – 1000ml		18.8	33.3	55.6	25.0
Volumetric pipettes – 20ml	20.0	18.8		33.3	25.0
Volumetric pipettes - 25ml	20.0	56.3	33.3	33.3	75.0
Wash bottles	30.0	50.0	33.3	44.4	75.0
Measurement/ Manipulation					
Double pan beam balances	10.0	18.8	33.3	44.4	31.3
Displacement cans	30.0	37.5	33.3	33.3	37.5
Graduated cylinders – 10ml	20.0	50.0	33.3	55.6	81.3
Graduated cylinders - 25ml	20.0	50.0	33.3	22.2	56.3
Graduated cylinders – 50ml	60.0	56.3	33.3	44.4	75.0
Graduated cylinders - 100ml	30.0	31.3	33.3	55.6	75.0
Graduated cylinders - 250ml	70.0	18.8	33.3	44.4	62.5
Graduated cylinders - 1000ml	30.0	25.0	33.3	22.2	37.5
Meter rules	70.0	6.3	33.3	66.7	81.3
Spatulas	60.0	31.3		55.6	68.8
Spirit levels	20.0		33.3	44.4	18.8

Spring balances	30.0	37.5	33.3	44.4	81.3
Stop clocks	30.0	25.0	33.3	44.4	68.8
Vernier calipers		18.8	33.3	55.6	50.0
Water troughs		6.3		22.2	12.5
Basic Glassware and Related Equipment					
Beakers – 50ml	20.0	37.5		55.6	62.5
Beakers - 100ml	50.0	56.3	33.3	66.7	87.5
Beakers – 250ml	60.0	56.3	33.3	55.6	75.0
Cork borer sets	30.0	31.3		44.4	43.8
Corks (assorted)	40.0	31.3	33.3	55.6	56.3
Funnels (assorted)	20.0	43.8		77.8	81.3
Gas jars	10.0	12.5	33.3	55.6	62.5
Glass tubing (assorted)	40.0	31.3		55.6	81.3
Mortars and pestles		56.3	33.3	33.3	37.5
Petri dishes	60.0	56.3	33.3	66.7	81.3
Separating funnels	10.0	25.0		55.6	37.5
Stirring rods	40.0	33.3	100	66.7	81.3
Test tube holders	60.0	56.3	33.3	55.6	68.8
Test tube racks	50.0	56.3	33.3	66.7	87.5
Test tubes - 24mm x l50mm	60.0	62.5	33.3	55.6	93.8
Test tubes –16mm x 150mm	60.0	62.5	33.3	66.7	93.8
Tongs (assorted)	20.0	31.3		44.4	37.5
Watch glasses - 50ml	30.0	25.0	33.3	44.4	56.3
Watch Glasses - 100ml	50.0	12.5	33.3	33.3	50.0
Y-shaped connectors		6.3	33.3	33.3	25.0
Safety and Cleaning Equipment					
Bottle brushes (assorted)	10.0	56.3		44.4	75.0
Splash goggles	10.0	25.0	33.3	44.4	31.3
Test tube brushes	20.0	43.8	33.3	33.3	62.5