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**Lower Secondary Science Teaching and Learning
A Glimpse into the Science Classroom**

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PREFACE

This study was part of a larger research project, *Lower Secondary Science Teaching and Learning*, 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 an exploratory study of a sample of 31 lower secondary science classrooms, representing the range of school types within the educational system. While one limitation of this work is that it might be difficult to generalize to the larger population because of the small sample size, the data do provide a glimpse into the practices of lower secondary classroom teachers. The initial findings have implications for the training and professional development of science teachers with respect to planning for, and teaching, lower secondary science. It is hoped that the issues that arise out of this preliminary study will provide stimulus for further research on a larger scale.

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LIST OF ACRONYMS AND ABBREVIATIONS

CXC	Caribbean Examinations Council
Dip.Ed.	Diploma in Education
NCSE	National Certificate of Secondary Education
SEMP	Secondary Education Modernisation Programme
UWI	The University of the West Indies
WASA	Water and Sewerage Authority

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CHAPTER 1

Background to the Study

1.1. Introduction

Lower secondary science is one of the compulsory components of the secondary school curriculum in Trinidad and Tobago. The concept “lower secondary science” appears simple and straightforward, but, as illustrated below, what constitutes its philosophy, structure, and modality of implementation varies widely among the major categories of secondary schools in Trinidad and Tobago. The major categories of schools fall within the general framework of government-assisted schools and government schools. The older (traditional) schools are the 5- and 7-year government-assisted schools and the 5- and 7-year government schools. The new sector of the secondary system consists of a variety of school types—junior secondary, senior secondary, senior comprehensive, and senior secondary comprehensive schools. The new sector also includes the recently established secondary schools and secondary centres, which are part of the reform initiative of the Secondary Education Modernisation Programme (SEMP). With the exception of the senior comprehensive schools, lower secondary science is offered in all categories of schools.

Lower secondary science education within Trinidad and Tobago has been influenced by a number of factors. These include official curriculum documents with their underlying philosophies/rationales, the range of textbooks in use, the quality of the physical facilities, the availability of educational resources, and the experiences and qualifications of the science teachers (see George, 2003).

It is possible, then, that there is a range of practices and experiences that can constitute lower secondary science. There is some available survey data on science teaching at the lower secondary level in Trinidad and Tobago with respect to the practices, needs, and beliefs of science teachers (see George, 1995); on the evaluation of the National Certificate of Secondary Education (NCSE) pilot science programme (see George, 1997); and on lower secondary students’ interests, perceptions, and experiences of science (Sjoberg, 2000). There has been a perception, however, that science teaching at this level does not fulfill contemporary goals of science education with respect to the development of process skills, competence in the use of knowledge and methods of science, and critical awareness of the role of science in everyday life.

There has been little formal research into classroom practices at the lower secondary science level. In addition, there has been no official monitoring or evaluation of the enacted lower secondary science curriculum. In the absence of such feedback, there was

no empirical evidence to show how science was being presented in the classroom at this level.

While there has been some local research on the experiences of students during their first three years of schooling (see Jules, 1998), this study, which was conducted during 2002, may be the first of its kind that was designed to focus exclusively on the enactment of science at the lower secondary science level in Trinidad and Tobago. It also attempted to examine some of the issues related to the quality of lower secondary science teaching and learning by looking at teachers' intentions for science teaching/learning.

Quality teaching is usually examined within the framework of effective teaching, and two issues that are often highlighted in the literature on effective teaching are teachers' intentions and teaching strategies.

1.1.1. Teachers' intentions

Teaching within the school setting is by its very nature an intentional act. It is expected that teachers' decisions in the classroom will lead to the attainment of pre-established learning goals related to the subject. The assumption is that teaching behaviours are based on teachers' intentions (Ajzen, cited by Haney, Czerniak & Lumpe, 1996). Reference to teachers' intentions is found in most of the literature on effective teaching (Chiappetta & Koballa, Jr., 2002; Cooper, 1990; Sanchez & Valcarcel, 1999). For example, Cooper (1990, p. 3) posits that "the two critical dimensions of effective teaching are *intent* and *achievement*." He describes the effective teacher as one who is able to bring about intended learning outcomes.

Most teacher education programmes, including the Diploma in Education (Dip.Ed.) science offering at The University of the West Indies (UWI), expose the participants to formal lesson planning based on the rational model espoused by Tyler (1949). This practice is undergirded by the assumption that the best indicator of the teachers' intentions is the lesson plan, which has been defined by Yusuf-Khalil (1997, p. 132) as "a formal or intentional activity in which teachers prepare a written framework for guiding action, as opposed to a 'mental plan.'"

Cooper (1990) states that "planning for many teachers is one of the most interesting parts of teaching, providing them with an opportunity to use their imagination and ingenuity" (p. 30). The limited research coming out of the Caribbean region, however, gives a different perspective. Evans (1983, p. 108) found that Jamaican student teachers viewed lesson planning as a "temporary evil to be tolerated until certification." Also working in Jamaica, Yusuf-Khalil (1997) found that experience and training influence how teachers plan. For example, pre-trained teachers, and those with 0-3 years experience and the Dip.Ed., indicated that lesson plans were necessary. However, 44% of teachers with 4-9 years experience and the Dip.Ed. indicated that lesson plans were not necessary since they had "head knowledge" of their intentions.

Therefore, any attempt to understand what happens within the classroom must, of necessity, investigate the teachers' intentions for their lessons, since their choice of behaviours/strategies is influenced by their intentions.

1.1.2. Strategies for science learning

Contemporary thinking on science education suggests that students should be actively engaged in hands-on and minds-on practical laboratory activities that facilitate the development of manipulative and technical skills, place greater emphasis on metacognition through development of the reflective habit, and focus on the use of science processes and higher-order thinking skills to solve problems (Harcombe, 2001).

The literature on science teaching suggests that effective science teachers know how to design and guide learning experiences, under particular conditions and constraints, to help diverse groups of students develop scientific knowledge and an understanding of the scientific enterprise (Magnusson, Krajcik, & Borko, 1999). These statements are supported by a body of research based primarily on the work of Grossman (1990) and Shulman (1987). They identify the primary divisions in the knowledge base for teaching as subject matter knowledge, general pedagogical knowledge, and pedagogical content knowledge.

General pedagogical knowledge refers to those principles and strategies of classroom organization and management that go beyond the subject matter. These include interactions, questioning (Blosser, 1991), use of resource materials, and management of classroom behaviours. Pedagogical content knowledge for science teaching, as conceptualized by Magnusson et al. (1999), includes orientations towards science teaching, knowledge about science, knowledge of students' understanding of specific science topics, knowledge of instructional strategies for teaching science, and knowledge about assessment of science (see also Chiappetta & Koballa, Jr., 2002).

1.2. Focus of the Study

It is against the above background that the present study was designed, with the aim of determining the status of teaching and learning science in the lower secondary schools of Trinidad and Tobago. What are teachers' intentions when they plan and implement science lessons? Do teachers encounter any problems as they enact the curriculum? What strategies are being used to implement the lower secondary science curriculum? Specifically, the study sought to investigate the processes and activities that teachers engage in as they plan for and implement the lower secondary science curriculum, in order to document what was happening and to offer suggestions for improving practice in lower secondary science education.

The research was guided by the following broad questions:

- 1. What are the intentions of lower secondary science teachers as they plan for their science lessons?**
- 2. How is science enacted in the lower secondary science classroom?**

The rest of this report is presented in the following chapters. Chapter 2 presents the research methodology. The findings are presented in Chapters 3 and 4: Chapter 3 reports the findings on teachers' intentions, and Chapter 4 gives the findings of the classroom observations. In Chapter 5, the level of congruence between teachers' intentions and their behaviours in the classroom is addressed, and the conclusions, discussion, and recommendations are presented in Chapter 6.

CHAPTER 2

Methodology

This was an exploratory study in which four researchers observed the teaching of science in lower secondary classrooms in a variety of schools throughout Trinidad and Tobago.

2.1. Selecting the Sample of Schools

The 115 secondary schools with a lower secondary intake existing at the time of the research work (Trinidad and Tobago [T&T]. Ministry of Education. Educational Planning Division, 2001) are located within eight educational divisions as follows:

Table 1. Distribution of Schools by Educational Division

Educational division	No. of schools
St. George West	31
St. George East	15
St. Andrew/St. David	09
Caroni	11
Nariva/Mayaro	04
Victoria	25
St. Patrick	13
Tobago	07
Total	115

Approximately 12% of the total number of schools (14 schools) was selected by purposive sampling to approximate the distribution of schools by educational division, as illustrated in Table 2. The criteria used were educational division and school type (see Table 3).

Table 2. Number of Schools Chosen by Educational Division

Educational Division	No. of schools
St. George West	04
St. George East	02
St. Andrew/St. David	01
Caroni	01
Nariva/Mayaro	01
Victoria	03
St. Patrick	01
Tobago	01
Total	14

Table 3. Selection of Schools by School Type

School type	Gov't. asst.	Trad gov't.	Comp.	SEMP	Jnr. sec.	Sen. comp.
No. of schools	4 (2 NCSE pilot)	2 (1 NCSE pilot)	3 (1 NCSE pilot)	2	2 (1 NCSE pilot)	1

2.2. Selecting the Participating Teachers

The principals of the participating schools were asked to select the teachers for the study. They either selected the teachers on their own, asked the head of department to make the selection in collaboration with the teachers, or requested the researchers to make personal arrangements with the teachers who were involved in teaching at the lower secondary level. A total of 31 teachers were eventually selected, and they were observed during the 3-month period between April and June 2002 (see Table 4).

Table 4. Training and Experience of Teachers in the Sample

Teacher type	Trained (Dip.Ed.)	Initial training (OJT/SEMP)	Untrained inexperienced (< 5 years teaching experience)	Untrained experienced (> 5 years teaching experience)
No. of teachers	10	4	10	7

2.3. Data Collection

The data-collecting strategies used were semi-structured interviews with participating teachers, and classroom observations.

2.3.1. Semi-structured interviews

The guiding research question was “**What are the intentions of lower secondary science teachers when they plan for their science lessons?**” The following sub-questions provided the framework for data collection:

- 1a. What do lower secondary science teachers do as they plan for their science lessons?
- 1b. What are the stated intentions of lower secondary science teachers for the implementation of science lessons?

The teachers were interviewed to determine their planning intentions. As far as possible, this was done prior to the lesson. The interviews followed a semi-structured format (see Appendix A). The questions on the interview schedule were used to guide the data collection, but the interviews were allowed to develop naturally and additional questions, or probing questions, were asked as required.

2.3.2. Classroom observations

The researchers observed the teachers for two classroom sessions, and the lessons were recorded either manually and/or by use of an audio-tape recorder. The tapes were transcribed in order to obtain data to answer the guiding research question: “**How is science enacted in the lower secondary science classroom?**”

The following sub-questions provided the framework for data collection:

- 2a. What strategies do lower secondary science teachers use as they deliver classroom instruction?
- 2b. What science process skills are developed in the lower secondary science classroom?
- 2c. What assessment practices do lower secondary science teachers use to monitor learning in the classroom?
- 2d. What types of interaction take place in the lower secondary science classroom?
- 2e. What kinds of questions do lower secondary science teachers and students ask?
- 2f. What level of student thinking is promoted in the lower secondary science classroom?
- 2g. What strategies do lower secondary science teachers use to manage classroom behaviours?

2.4. Data Analysis

2.4.1. The interview

Each researcher engaged in the process of inductive analysis (Patton, 1990) of the interview data for each case. The data were coded and categorized, and the themes emerging in each case were recorded. A meeting of researchers was then held, during which there was discussion and/or clarification of the labels used to identify the themes, and subsequent consensus on the labels to be adopted for the responses obtained. All of the data were then reviewed within the framework established, and the frequency of each theme was determined. The overall patterns or trends for the teachers interviewed then emerged.

2.4.2. Classroom observations

The transcribed data and/or the manually prepared transcripts were subjected to a series of analytical procedures. Firstly, mini-summaries of each 5-minute session were produced (Flanders, 1970). This procedure served to condense the data. Secondly, the data were analyzed qualitatively, either inductively through a process of open coding, which led to emerging categories, or deductively through the use of established theoretical frameworks/models/classification schemes that have been described in the literature (see Table 3). For example, deductive approaches were used for determining questions types and process skills. Frequencies of occurrence of the observed behaviour/factor were then determined for the teacher categories identified earlier. Details of the data analysis procedures are presented in Table 5.

Table 5. Research Questions Matched with Methods of Analysis

Research questions	Data analysis
<p>1. What strategies do lower secondary science teachers use as they deliver science instruction?</p> <p>3. What assessment practices do lower secondary science teachers use to monitor student learning?</p> <p>4. What types of interaction take place in the lower secondary science classroom?</p> <p>7. What strategies do lower secondary science teachers use to manage classroom behaviours?</p>	<p>Open coding of classroom observation data followed by consensus about labels applied to emerging categories. Some use of terms commonly found in the literature to describe instructional strategies, assessment practices, types of interaction, and classroom management strategies. Frequencies for each teacher category determined</p>
<p>5. What kinds of questions do: (i) science teachers and (ii) science students ask?</p>	<ul style="list-style-type: none"> • Use of Bloom's (1956) taxonomy for the classification of questions that fall within the cognitive domain • Use of Blosser's (1991) classification for managerial questions • Open coding and categorizing of other question types • Average number of questions for each category of teacher and students calculated and frequencies determined
<p>2. What science process skills are developed in the lower secondary science classroom?</p>	<p>Pre-established science process skills (basic and integrated) identified and the frequencies determined (Chiappetta & Koballa, Jr., 2002)</p>
<p>6. What level of student thinking is promoted in the lower secondary science classroom?</p>	<p>Inferences made from the analysis of levels of questions asked by teachers and students, strategies used, types of interaction, and process skills used</p>

2.5. Limitations of the Study

The small sample size is the main limitation of this study. The number of researchers available limited the total number of schools selected for observation (12% of the population) and the number of classroom observations (two classroom observations per teacher). Therefore, these findings are exploratory only and cannot be generalized to the entire population of lower secondary science classrooms.

2.6. Significance of the Study

The study may be the first of its kind to focus exclusively on the actual teaching/learning of science at the lower secondary science level in Trinidad and Tobago. It may serve as a springboard for further research into the status of lower secondary science teaching and for subsequent in-depth case study investigations into science teaching/learning at selected schools.

CHAPTER 3

Findings: Science Teachers' Intentions

3.1. Introduction

The first part of this report focuses on the question “**What are the intentions of lower secondary science teachers when they plan for their science lessons?**” The aims were to gain some insights into science teachers’ overall intentions for the implementation of science by examining their pre-teaching behaviours and their statements of intent, and to determine whether these intentions differed among the various categories of teachers (in terms of training) in the sample. The findings are presented as narrative responses with verbatim examples to illustrate or underscore emergent themes.

3.2. Research Question 1a

What do lower secondary science teachers do as they plan for their science lessons?

3.2.1. Written or articulated plans

Seven of the 31 teachers prepared written lesson plans based on well-defined objectives as a sign of their intentions. This group comprised 5 of the 10 trained teachers and 2 of the 10 untrained, inexperienced teachers. In the particular case of one of the untrained teachers, it was school policy that all untrained teachers prepare and present written lesson plans to the head of department, before teaching the lesson.

The trained teachers and teachers with initial training who did not write lesson plans all engaged in some level of mental planning, and were able to clearly articulate the steps taken and the resources consulted as they planned their lessons. They were also able to state the objectives, in terms of learning outcomes, of the lessons. The untrained, experienced teachers, on the other hand, while unable to articulate lesson objectives, had their own personal planning procedures. For example, one said: “I make my own notes... I pull from an archive I have built up over the years...” Another teacher in this category said, “I source my own stimulus material from books, the Internet, the newspaper...” Generally, the trained teachers demonstrated a better awareness of the role of objectives in planning, that is, they were more focused on student outcomes during the planning process than the untrained teachers.

The prescribed student textbook was the main resource drawn upon by a large proportion of all categories of teachers in planning their lessons. Teachers also mentioned other resources such as the syllabus or scheme of work, other print-based material, newspaper clippings, and visual aids, for example, charts and pictures. The scheme of work played a

very important role in the planning process for the untrained, inexperienced teachers (see Appendix B).

Some of the teachers also planned practical laboratory work, either as practical activities in which small groups of students worked together, or as teacher-led demonstrations, primarily to verify concepts that had been addressed in preceding lessons. Nine trained; 5 untrained, experienced; 1 with initial training; and 1 untrained, inexperienced teacher had deliberately planned practical work. For example, one said: “I try to include a practical component in all my lessons.” During the interviews, many of these teachers described their pre-teaching actions when they planned for practical work. For example, they consulted the laboratory technician, set out materials for groups of students, collected live specimens, and conducted the practical activity before the class began. On the other hand, other teachers’ comments indicated that little or no practical work was done at the lower secondary level. For example, one untrained, experienced teacher said explicitly that practical work was not a priority at the lower secondary level. According to this teacher, the lower secondary students could not access the laboratory due to limited resources.

With the exception of the selection of laboratory activities, there was little thought of pedagogy in the planning exercise. Only 6 of the 31 teachers (four trained; one untrained, experienced; and one untrained, inexperienced) gave adequate consideration to the selection of other appropriate teaching strategies for science concept development. These strategies included the use of resources such as models, charts, and specimens, as well as a consideration of students’ characteristics. For example, in planning for concept development, the untrained, inexperienced teacher said: “I prepare my own charts and leave spaces for students to write in words or label diagrams.” An untrained, experienced teacher said: “Sometimes... depending on the lesson, I’ll ask students to bring in a sample [specimen]... like the hibiscus flower or an insect.” None of the teachers with initial training indicated that they gave any consideration to the selection of strategies for concept development other than laboratory work.

In summary, the trend in planning behaviours shows that most teachers believe that planning (mental or written) is important. Among the trained teachers and those with initial training, planning was more deliberate, showed better awareness of objectives, and was more focused on students’ outcomes. However, the way that planning was conceptualized by many of the teachers, especially the untrained, inexperienced ones, was often limited to subject content and selection of practical activities, with little emphasis on pedagogy.

3.2. Research Question 1b

What are the stated intentions of lower secondary science teachers for the implementation of science lessons?

3.3.1. Frequently stated intentions

Promoting understanding

Among the teachers sampled, the most important stated intention for their lessons (see Appendix C) was to “promote understanding.” Eight of the 10 trained teachers; all the teachers with initial training; 5 of the 10 untrained, inexperienced teachers; and 6 of the 7 untrained, experienced teachers planned to achieve this intention. For example, one trained teacher said that his intention was “to get students to learn science concepts by understanding what is happening....” Another with initial training said: “I also want them to understand what they are learning....,” and an untrained, inexperienced teacher said: “I want my students to grasp the content.” An untrained, experienced teacher said: “I plan for students’ mastery of the content.”

Making science relevant/solving problems

Fifteen teachers stated that they deliberately planned to make science relevant and useful to students’ everyday lives. For example, one trained, experienced teacher said: “I plan to make my students use their knowledge to solve problems in daily life.” Another said: “Practical activity lets them apply the learnt knowledge.” Examples of this intention were articulated by all categories of teachers.

Motivating students

Also ranking high on teachers’ hierarchy of intentions was their stated desire to motivate students by making science learning fun and interesting. One trained teacher expressed this intention by saying that she wanted “to get them to want to learn science and to have students enjoy learning science....” Similarly, an untrained, inexperienced teacher said that amongst her intentions was “to make science fun for students.”

Other intentions

Additionally, the science teachers included intentions such as building a sound foundation for further study of science, challenging students, matching learning activities with students’ thinking, developing manipulative skills, creating safety awareness, promoting active learning, and helping them to pass examinations. A few of the teachers who planned for practical work indicated that creating safety awareness in the laboratory was among their intentions. Four of the 31 teachers in this sample said that they teach in a manner that allows students to be challenged and this sub-group comprised only the trained teachers. Only two of the teachers spoke directly about planning for development of process skills and these were trained teachers.

3.4. Summary and Discussion

It is evident from the interviews that all of the participating teachers were engaged in some type of planning behaviour, but the trained teachers were more proficient in

articulating or writing lesson objectives—indicative of learning outcomes and strategies for concept development. For the other teachers, planning was based on the conceptual framework presented in the textbooks, schemes of work, and the respective syllabuses. In general, 16 of the teachers observed mentioned that they selected appropriate practical activities for their students as they planned, and 14 said that they considered the objectives of the lesson as they engaged in planning.

Promoting understanding and making science relevant to students' daily life were the two major intentions that were articulated by all categories of teachers irrespective of training and experience. The teachers suggested that these two intentions impacted upon and guided their planning activities to a large extent. Understanding is crucial for achieving scientific literacy, but the term "understanding" is difficult to define. Bigge and Shermis (1999) define understanding as a generalized meaning or insight. They posit that teachers who present patterns of general ideas and supporting facts in a way that would enable students to see the relationship between the generalizations and the particulars through meaningful insights are teaching at the *explanatory understanding level*. However, they go on to say that *exploratory understanding* comes about when there is more active participation, more imagination, and creativity. This is brought about in an atmosphere that is critical and penetrating, and open to fresh and original thinking, and where the focus is on problem-centred teaching.

Tobin and McRobbie (1999), on the other hand, describe three levels of understanding science. They speak of *limited understanding*, which comes about when links with other science knowledge are not extensive, for example, knowledge of facts and definitions; *relational understanding*, which requires conceptual reorganization as learners construct webs of relationships for given scientific subject matter; and *transformational understanding*, where students are able to link scientific knowledge to actions in the real world, and to create patterns of understanding from everyday life experiences.

When the teachers mentioned that teaching for understanding was one of their intentions, it seems that they intended to achieve mixed levels of understanding as described above. For example, they spoke of wanting students to understand facts and principles in order to pass their examinations, as well as to solve problems. While these intentions are important and are reflected in the various science curricula in use (NCSE, SEMP, and the Caribbean Examinations Council (CXC)), there are some other equally important intentions that were not considered by some of the teachers in the planning process.

The development of process skills, for example, did not rank high in the teachers' hierarchy of intentions. Only 2 trained teachers of the 31 observed mentioned this intention. By nature, science is not only product, that is, a body of knowledge, but also process, a way of generating or creating new knowledge for solving problems in daily life (Chiappetta & Koballa, Jr., 2002; Padilla, 1990). It is therefore noteworthy that the development of process skills was of low priority. Of concern also is that all categories of teachers did not intend to challenge students to think critically as they engaged in science learning, which is also a primary goal of all the syllabuses in use. Other goals related to student engagement and the management of students' classroom behaviour (Wise &

Okey, 1983), the development of technical and scientific vocabulary; the appreciation of the interaction among science, technology, and society; the development of scientific attitudes such as curiosity, honesty, suspended judgement, critical mindedness, persistence, painstakingness, and open-mindedness. Some other important affective goals such as individual work and cooperative learning, as cited in the syllabuses, were not mentioned by any of the teachers. The teachers observed used the syllabuses to select content, and they did not seem to be guided by any of the underlying philosophical statements/principles contained therein.

CHAPTER 4

Findings: Classroom Observations

4.1. Introduction

This part of the report focuses on the question “**How is science enacted in the lower secondary science classroom?**” and examines these events in terms of their implications for students’ learning outcomes. The aim was to gain some insights into the ways in which science is presented in the classroom, and an understanding of the factors that facilitate or challenge the teaching/learning processes.

4.2. Research Question 2a

What strategies do lower secondary science teachers use to teach science?

The data from the classroom observations revealed that the lower secondary science teachers employed a variety of strategies to facilitate teaching and learning (see Appendix D). The most frequently used strategies were recitation (question and answer sequence), followed by lecturing, using the textbook, note copying, and practical activities, in that order. This study revealed that while one to four different instructional strategies might be deployed by a science teacher within a lesson, the effectiveness with which these strategies was used varied with the professional training of the teacher and his/her teaching experience.

4.2.1. Recitation (question/answer sequence)

The data show that recitation was the most commonly used strategy. It was deployed by 23 of the 32 teachers. Recitation is defined as a sequence of teacher question, student answer, and teacher reaction (cited by Chiappetta & Koballa, Jr., 2002). The teachers used recitation mostly at the beginning of a lesson to arouse student interest, check understanding of previously learned concepts, and link prior knowledge with new. The following excerpt illustrates the use of the recitation strategy at the beginning of a Form 3 lesson on reproduction:

T: What are some examples of organisms that show asexual reproduction?

S: Amoeba

T: Amoeba. Very good.

S: Algae

T: Some algae, what else?

S: Some cells

T: No. New cells aren’t organisms.

Six of the 10 trained teachers and 2 of the 4 teachers with initial training taught by recitation in segments of the lessons, while 15 of the 18 untrained teachers adopted this strategy. While this is a good strategy for recalling prior learning, it is a poor strategy for concept development (since it assumes prior knowledge). At least four of the untrained teachers used the recitation strategy almost exclusively throughout the duration of a lesson. This has implications for the quality of student learning outcomes.

4.2.2. Lecturing and note copying

The lecture method was the next most popular strategy employed by 21 of the teachers. The lecturing behaviour of most of the teachers who employed this strategy was the traditional teacher monologue. There were few opportunities for interaction. However, on occasion, a few teachers used questions and visual materials to enhance the effectiveness of their presentations. Closely associated with the lecture method was note copying. Six of the 10 trained teachers and eight of the untrained, inexperienced teachers adopted this strategy. More often than not, the notes were copied from the student textbook or dictated by the teacher. These strategies portray a view of science as a body of knowledge. In both of these strategies students were not exposed to other views of the nature of science, and they were not given opportunities to articulate their own understandings.

4.2.3. The student textbook

Beside its use as an important source of students' notes, 20 of the 32 teachers deliberately referred to the textbook during the lessons observed. The textbook was used by trained as well as untrained teachers for a variety of other purposes. Students learned from worked examples in the textbook and also practised how to solve problems using the textbook. The textbook was also used as a source of information (students read from the text or copied diagrams/drawings), practical activities, and homework assignments. While the textbook was validated as an essential science resource by most of the teachers, it raises the question about the infrequent use of other kinds of resources in the classroom.

4.2.4. Practical work

Sixteen of the 31 teachers in all categories engaged in practical work in at least one of the two lessons observed. Six of the trained teachers and 4 of the untrained, experienced teachers implemented verification laboratory activities, either as group activities, primarily for sharing equipment, or as demonstrations. The main intent of these sessions was to confirm principles and concepts already covered in class. The students were therefore involved in deductive reasoning. For example, after a series of lessons on balancing equations, the mole concept, and neutralization reactions, an untrained, experienced teacher took the students into the laboratory to engage in procedures to verify the concepts and then to apply the concepts to solve a problem.

Three trained and 1 untrained, experienced teacher, as well as 1 teacher with initial training, involved their students in inductive reasoning through laboratory activities. In one case, students were provided with apparatus and materials and asked to induce

Hooke's law. In another, students did calculations of surface area/volume ratios using cheese, and then made inferences with respect to surface area and absorption in the small intestine, as well as in the lungs. The main aim of these sessions was the development of science concepts. In addition, process skills, for example, observing and interpreting data, were also developed in these lessons. Two untrained, experienced teachers designed and implemented laboratory activities with the primary purpose of teaching students how to measure accurately. They also implemented hands-on activities that focused on safety procedures in the laboratory.

The general practice among the teachers was to restrict practical activities to classes that were scheduled for the laboratory (in some cases, lower secondary science classes were not allocated any laboratory time), and these were more frequently seen in the classrooms of trained teachers. It is reasonable to conclude that the availability of the laboratory, support staff, and teacher training influenced the choice of practical activities as a teaching/learning strategy.

4.2.5. Eliciting students' prior knowledge

Sixteen teachers (6 trained, 3 with initial training, and 7 untrained) drew on students' prior knowledge to develop science concepts. For example, a trained teacher elicited students' prior knowledge as part of a set induction of a lesson to develop the concept of properties of magnets by asking: "Have you ever played with magnets? What can you do with a magnet? What kinds of things stick on magnets? Why do these metals stick to the magnet?" An untrained, inexperienced teacher used students' prior knowledge of pressure and water pumps at the Water and Sewerage Authority (WASA) to make the link between the structure of the heart (muscular walls) and its functions in withstanding pressure. This trend is noteworthy, but the use of students' prior knowledge was not common practice in the lessons observed.

4.2.6. Other strategies seen

Less-seen strategies that were used primarily by trained teachers included activities such as:

- *Demonstrations*: For example, in a lesson on forces, a teacher pushed a duster across a desk to show the effect of a force.
- *Discussions*: These were mainly teacher-led discussions, and they occurred when teachers were aware that students had been exposed to some aspects of the topic under consideration. For example, one teacher planned a discussion lesson on the nature of science and the qualities of a scientist. Another discussion was based on the topic "forms of energy." Different scenarios were presented to students and questions were asked to elicit responses.
- *Small group activities*: This approach was mainly used during "practical" exercises and involved having students answer questions related to an investigation.

- *Interactive advanced organizer:* For example, one teacher presented an incomplete table, which was completed with students' input as the lesson progressed.

Other less-seen strategies that were used by trained and untrained teachers were:

- *Analogy:* Mainly biology teachers used analogies. Among the examples used were: the heart as a pump and food webs as analogous to ducks' feet.
- *Visual aids/models:* An untrained, experienced teacher used a diagram of the digestive system and a model of the human brain to teach these concepts to a Form 3 class.
- *Concept mapping:* An untrained, inexperienced teacher used this technique once.
- *Learning cycle:* This strategy was seen twice. It involves concept exploration, concept introduction, and concept application. In one lesson, the teacher brought a model, which was used as a representation of airflow in a system. Students then made comparisons between the parts of the model and the respiratory system. Finally, they applied the principles behind the operation of the model to the mechanism of breathing in the lungs.

4.3. Research Question 2b

What science process skills are developed in the lower secondary science classroom?

The process skills observed (see Appendix E) were categorized as basic skills and integrated skills (Chiappetta & Koballa, Jr., 2002).

All categories of teachers planned and implemented activities to assist students to develop some of the basic process skills. The skill of observation received attention from all categories of teachers, and was observed in 24 of the 62 science lessons observed during short activities that formed part of a set induction, a demonstration, or a group activity. For example, an experienced, untrained teacher demonstrated the difference in reactivity of metals (magnesium, zinc, and copper) with dilute acids to her Form 3 students. They observed the rate at which gas was produced as a measure of reactivity of the metal. A teacher with initial training designed an activity in which Form 2 integrated science students were given magnets and asked to observe the bipolar nature of the magnet.

All categories of teachers also designed activities to develop skills in the use of numbers and inferring. Development of the skill in the use of numbers was observed in 10 of the 62 lessons, and development of the skill of inferring was observed in 13 of the 62 lessons. However, only two of the trained teachers addressed the skills of classifying and predicting, and one untrained, inexperienced teacher addressed space/time relations. For example, one trained teacher provided opportunities for students to make predictions. He began his Form 1 integrated science class on expansion and contraction of substances with a demonstration using the ball and ring apparatus. Students were asked to make

predictions about the effect of heat on the ball. He further developed the concept by asking his students to make similar predictions about the expansion of liquids and gases.

Teaching to facilitate development of integrated skills was sometimes seen. Communicating scientific ideas, for example, how to present data on tables was the most popular integrated skill seen and it was observed in 24 of the 62 classes. Additionally, students were involved in planning experiments in 10 of the 62 lessons. These kinds of experiences were provided by trained teachers; untrained, inexperienced; and untrained, experienced teachers. Three trained teachers; one teacher with initial training; and 2 untrained, experienced teachers taught for interpretation of data, and 2 trained teachers involved their students in constructing operational definitions. Other integrated skills such as formulating models and controlling variables were not observed in any of the classes, and the skill of hypothesizing was seen only once.

From the observations noted above, it seems that not much attention is being paid to the processes of science.

4.4. Research Question 2c

What assessment practices do lower secondary science teachers use to monitor learning in the classroom?

Oral questions were the most commonly used form of assessment observed, and was used by 21 teachers. This was followed by homework assignments, used by 11 teachers, and paper and pencil tests used by 9 teachers. These assessment practices were observed in the classrooms of all categories of teachers. In addition, one trained teacher used role-play as a form of assessment, and one teacher with some initial training used working models to assess students' understandings of electric circuits. Three untrained teachers presented lessons that did not include an evaluation component. Planned formative assessment for immediate feedback was not a feature in the majority of classrooms observed (see Appendix F).

4.5. Research Question 2d

What types of interaction take place in the lower secondary science classroom?

Five types of interaction were observed, namely, the one-way interaction, the two-way interaction, the extended two-way interaction, interaction between students and learning materials/laboratory equipment, and peer collaboration (see Table 4 for observed interaction patterns).

Table 6. Interaction Patterns in Lower Secondary Science Classrooms

Types of Interaction	Trained teachers N=10	Initial training N=4	Untrained teachers	
			Less than 5 yrs	More than 5 yrs
Two-way	9	2	8	8
One-way	8	4	N=10	N=7
Extended two-way	7	3	5	3
Interaction with manipulatives	9	3	3	2
Peer collaboration	3	2	1	3

The most common type was the two-way interaction between teacher and students (see Figure 1), which occurred most frequently during recitation sessions. The teachers used questioning to find out what the students had learnt in order to identify gaps in their knowledge, to draw attention to misconceptions, or to link existing prior knowledge to new learning. Generally, the question/answer sessions were very brisk so that students had little opportunity for reflection.

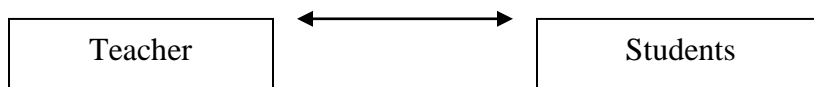


Figure 1. Two-way interaction.

The second most frequently observed type of interaction in the classrooms of both trained and untrained teachers (see Table 4) was the one-way interaction (Figure 2). This type of interaction was typical of lecture sessions—mostly teacher talk with no input from the students. The predominant activity of students in these sessions was listening, with possibly some covert engagement, and copying of notes.

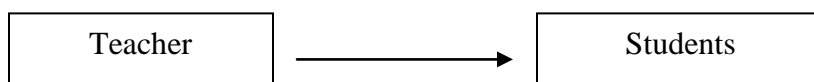


Figure 2. One-way interaction.

The extended two-way pattern of interaction (Figure 3) was observed in discussion sessions where the teacher asked fewer questions at a slower pace (than recitation), allowing wait-time for students to think and formulate their answers. This interaction was more varied and more flexible than the two-way pattern. Two or more students responded

to teachers' questions before the teacher intervened. Students also commented on, or reacted to, each other's responses on a limited scale.

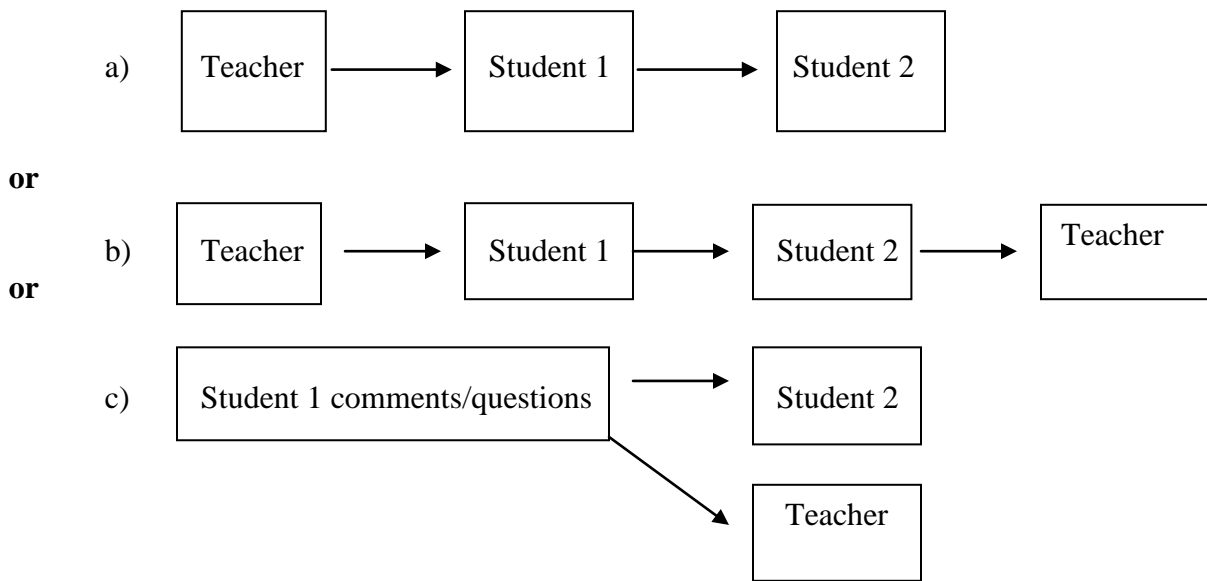


Figure 3. Extended two-way interaction.

Though not a common occurrence, the environment for extended two-way interactions was created on occasion by all categories of teachers (see Table 6). The following excerpt is an example of this type of interaction during a lesson about the nature of science, the scientific enterprise, and the qualities of a scientist:

- T: How did they find out that the earth was not flat?
- S1: When the man in the boat did not fall off.
- S2 :He was able to travel further.
- S3: He went all around.
- S4: It could be that oval, triangular, etc. How did they know that it was round?
- T: Well, they did as S1 suggested. They were able to travel without falling off.

The fourth type of interaction, interaction with manipulatives, was observed during practical, hands-on and minds-on learning activities in which students were given opportunities to observe, explore, and manipulate apparatus and materials. This form of interaction was observed in the classrooms of 17 teachers, trained as well as untrained (see Table 6).

Peer collaboration was the fifth type of interaction and was observed on nine occasions (see Table 6). This occurred during some small-group activities. For example, small groups of Form 1 students worked together to construct a food web in a lesson on feeding relationships.

The predominant pattern of two-way interaction observed indicates that the classrooms observed were mainly teacher-directed. The students' role was limited to responding to teachers' questions and comments. It should be noted that three-way interaction (that is, interaction between teacher and students, among multiple students, and back to teacher) was not observed at all.

4.6. Research Question 2e

What kinds of questions do lower secondary science teachers and students ask?

4.6.1. Teachers' questions

Lower secondary science teachers asked a variety of questions that were classified using Bloom's (1956) *Taxonomy of Educational Objectives*, and Blosser's (1991) scheme. According to Bloom's taxonomy, questions at the levels of knowledge and comprehension are categorized as lower-order questions, while those at application and above are categorized as higher-order questions. The questions asked by all categories of teachers were predominantly the low-level type (see Appendix G). The following questions are examples of lower-order questions:

- What is grafting? What are some examples?
- What is a hormone? What are some examples of hormones you know?
- What kinds of bonding occur between atoms?

In all of the above cases, when students responded their answers were short, knowledge-based responses. Students had very limited opportunity to think before responding to teacher questions.

Blosser classified some teachers' questions as serving a managerial function. These questions were asked by teachers to gauge students' understanding. Some examples of managerial questions asked by all categories of teachers include the following: "Do you understand?" "Can we move on?" "Are you with me?" However, untrained, inexperienced teachers asked the majority of managerial questions. These questions do not assist in concept or process skill development.

Only 12 of the 32 teachers, 7 of whom were trained, used probing questions to challenge students to reflect and improve on their thinking or make their explanations more robust. The majority of the teachers who asked probing questions used wait-time effectively. The following is an example how one trained teacher used probing questions:

- T: What did it take to become a scientist?
S: Hard work.
T: Why was it hard?
S: Because they had to search for answers.
T: And what does that involve?
S: Being able to know what the answer is.
T: Yes. But in doing that, what do you need?
S: Patience, time, investigation, instruments.

The teacher then continued with the qualities of a scientist.

The analysis of the data revealed that all teachers asked lower-order questions more frequently than higher-order questions. Of the 580 questions asked by teachers, 321 were lower order, 80 were higher order, and the remainder were managerial type. Table 7 shows details of the types of questions asked by the teachers observed.

Table 7. Percentage of Question Types asked by Category of Teacher

	Trained N=10	Initial training N=4	Untrained < 5 yrs N=10	Untrained > 5 yrs N=7
No. of questions asked	180	41	207	152
% higher-order questions	22%	10%	8%	13%
% lower-order questions	64%	66%	43%	58%
% managerial questions	14%	24%	48%	29%

In general, the majority of teacher questions were not used to stimulate student thinking. Although the trend was towards lower-order questions, there was a tendency for trained teachers and untrained, experienced teachers to ask more of the higher-order questions. Untrained, inexperienced teachers focused on managerial-type questions. Questions play an important role in students' cognitive engagement, and it is evident that these teachers did not pay much attention to the use of higher order questions.

4.6.2. Student questions

Students asked 55 questions compared to the 580 questions asked by teachers (see Appendix H). These were classified as 19 knowledge, 12 comprehension, 13 application, and 10 clarification questions. Clarification questions are those questions asked by students when they missed, or were unsure of, teachers' statements/explanations, or when they sought information related to instructional or testing procedures. For example, "Sir, more notes coming?"; "Sir, what? The male or the main?" (This was a student's response as the teacher dictated notes on sexual reproduction in plants); and "Is this coming on the test?"

Most of the students' questions were situated at the knowledge/comprehension levels. For example, one Form 3 student asked the following question during a chemistry lesson on the mole concept: "Miss, I'm not following the logic behind the working. Why do we balance equations first?" This student was obviously thinking at the comprehension level, seeking a rationale for balancing equations. The findings also revealed that students

asked a higher percentage of higher-order questions (30%) compared to their teachers (20%). These students' questions were mainly at the level of application, with one or two questions pitched at higher levels. In some cases, the higher-order student questions were not handled satisfactorily. For example, during a lesson on blood circulation a male student sought some explanations on what seemed to be a discrepancy. The untrained, inexperienced teacher had referred to "wrist slashing" as a common method of suicide. This immediately resulted in some cognitive conflict for the student who asked: "Miss, and they does cut off people hand?" (The reasoning here was that since people do not die from amputations then they should not die from wrist slashing.) The teacher, however, did not respond to the question and missed the opportunity to bring some resolution for the student by comparing procedures in a controlled environment, such as tying off blood vessels during surgery to prevent blood loss, to what occurs in an uncontrolled situation. This was a missed opportunity for *transformational understanding*, where the student would have been able to link his science knowledge to what happens in the real world.

When the questions asked by students of the different categories of teachers were compared, it was observed that students of trained teachers asked 14 questions, 9 of which were lower-order, 2 higher-order, and 3 for clarification. Students of a teacher with initial training asked one question and this was a lower-order question. Students of untrained, inexperienced teachers asked 33 questions, 18 of which were lower-order, 11 higher-order, and 4 were for clarification. Students of untrained, experienced teachers asked 7 questions: 3 were lower-order, 1 higher-order, and 3 for clarification. It seems that the untrained, inexperienced teachers did facilitate and encourage more students' questions than teachers in the other categories. It is commendable that students asked so many higher-order questions as this indicates their search for relevance and meaning. Even so, the majority of questions asked were lower-order questions, and this indicates that the learning activities are not likely to facilitate that spirit of inquiry among students.

4.7. Research Question 2f

What levels of student thinking are promoted in the lower secondary science classroom?

The conceptual framework outlined in Figure 4 informed this part of the research. It drew on the work of Vygotsky on the relationship between higher mental functioning and social interaction (cited by Mortimer & Scott, 2000). Critical thinking—requiring skills of analysis and evaluation—is an important goal of curriculum documents (see T&T. Ministry of Education, 1994, 1995, 2002). The levels of student thinking promoted in the classrooms observed were determined by examining the various activities in which students participated during classroom sessions. These included teachers' and students' questions, teaching/learning strategies, process skills addressed, and types of classroom interaction. Each of these areas will now be explored.

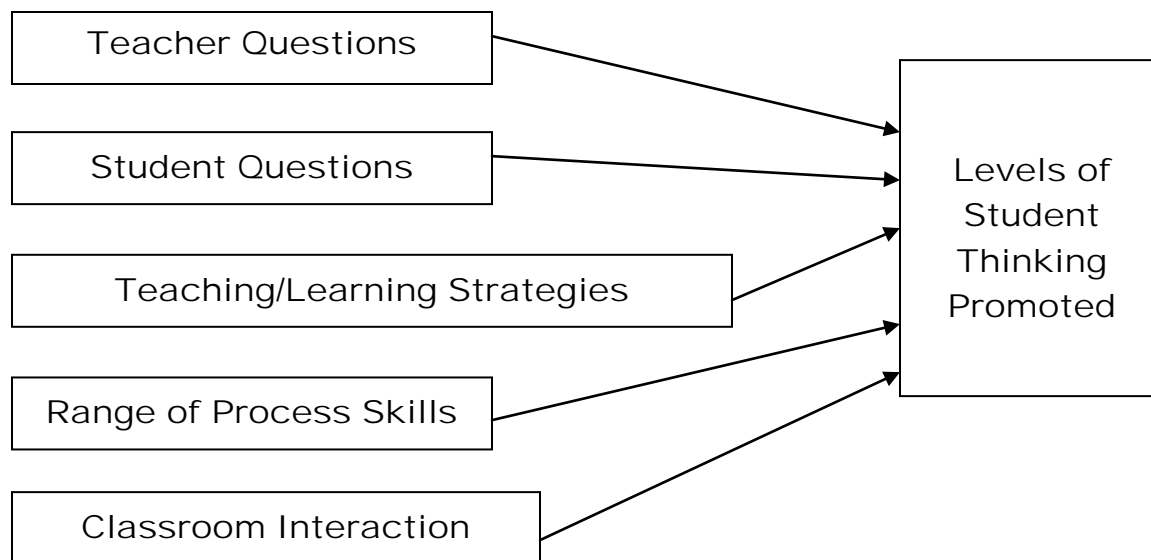


Figure 4. Activities linked to promotion of student thinking.

Questions asked by the teachers rarely challenged students to get involved in any reflective thinking. These questions, as revealed by the data, were predominantly low-level/recall asked during quick-paced recitation sessions. Students' questions, pitched mainly at the levels of knowledge and comprehension, also revealed that students too were operating at low levels of thinking.

The frequently observed two-way pattern of interaction did not seem to encourage student thinking. For example, there was no opportunity for students to discern patterns among concepts/data/ideas, or to make decisions based on predetermined evaluative criteria. However, many of the teachers planned and implemented hands-on activities, which provided students with opportunities for meaningful engagement with learning materials and allowed them to use some basic science process skills to solve problems. Unfortunately, the opportunity for developing reflective thought processes was often lost during these sessions, either due to poor task management or teacher inability to use probing questions to help students interpret what they were doing, why they were doing it, and how what they learned might affect their lives. Additionally, teachers did not focus sufficiently on teaching the integrated process skills, which provide opportunities for students to give explanations, to ask questions, to adopt a new idea, or to highlight a discrepancy, all of which are examples of thinking behaviours. In a few cases, students' off-task behaviours impaired their meaningful involvement in the hands-on and minds-on activities.

Although some teachers selected strategies that allowed students to explore learning materials, the explorations remained at superficial levels, since there was little attempt to apply the information gleaned to solve problems in a new setting. Consequently, students

were engaged most of the time in thinking for recall and understanding, that is, low-level thinking.

4.8. Research Question 2g

What strategies do lower secondary science teachers use to manage classroom behaviours?

The teachers observed used a combination of strategies to keep students optimally engaged and prevent indiscipline (see Appendix I).

Very few incidents of indiscipline were observed during the lessons taught by the trained teachers. Most of these teachers were organized, gave clear instructions, and used strategies that kept students engaged, for example, they used small-group activities, interactive discussions, and provided adequate resources for practical work. One trained teacher, during a small-group practical activity, was challenged to keep some groups of students motivated and on-task. There were limited resources, the class was large (40+ students), and the students seemed to have had little experience with hands-on practical work. The teacher resorted to closer monitoring and used motivating comments to encourage the groups to wait their turn, but some students continued to demonstrate off-task behaviours.

On the other hand, a variety of off-task behaviours were observed in the classrooms of untrained teachers. These included uncontrolled noise levels, lateness to class, quarrelling, purposeless discussion, disruption of teaching and learning activities, rowdiness and confusion, dragging of chairs and tables, throwing of missiles, careless breaking of laboratory apparatus, and inadequate attention to safety procedures. Instances of off-task behaviour were frequently observed during the lessons taught by untrained, inexperienced teachers in the laboratory when there was either insufficient apparatus and materials, or lack of support staff. The most popular strategies for managing indiscipline among this category of teachers were the use of threats, warning and cautioning, and ignoring indiscipline. One teacher even used note giving as a management strategy. These classrooms were characterized by threatening/chaotic environments, which are not conducive to optimal student learning.

Generally, teachers in each category applied some preventive management strategies to a limited extent, for example, counselling and threatening/warning. Sixteen teachers gave detailed instructions to students on how to proceed. Thirteen provided adequate materials and equipment to prevent off-task behaviours, and 13 also referred to rules and policies regarding safety and behaviour. Nineteen teachers diligently managed individual and group work by monitoring students closely and addressing issues that arose.

4.9. Summary and Discussion

The instructional strategies that were observed in the lower secondary science classrooms were primarily teacher-centred. Teachers in all categories generally presented

information through recitation or lecturing based on pre-packaged information in textbooks. The lessons, therefore, were characterized by an image of science as a body of knowledge, and the majority of teachers adopted a didactic orientation. In many instances, students were given notes and they spent considerable time in this note-taking activity. It seems that teachers are still presenting science as a body of knowledge, which students are expected to acquire. Other views of science as reasoning (Fensham, 2000), as argument (Kuhn, 1993), or as process were rarely observed.

The high levels of one-way interaction or two-way interaction, characterized by teacher monologue and the use of “recitation” as a teaching strategy, resulted in frequent use of lower-order questions. The students asked few questions, and when they were encouraged to ask, they were given little time to formulate thoughts. In these modes, the purpose of questioning was to ensure that students knew the “facts.” The resulting imbalance of power in the classroom, as indicated by the dominance of teacher talk, resulted in few opportunities for high levels of student engagement and restricted the behaviours that are indicative of student thinking.

The literature suggests that student thinking, most especially at the higher reflective level, is facilitated when teachers and students ask good questions (Brown & Edmondson, 1984), which are equally distributed between lower-order and higher-order levels, and where there is appropriate wait-time (Rowe, 1974). The development of higher-order thinking skills is also facilitated when teachers deliberately and systematically develop in their students the thinking skills that are important for science concept development, for example, the science processes (Pressley & McCormick, 1995), and when they have opportunities to interact with each other in reflective discussion sessions. There were some occasions that allowed for student/student interaction, which facilitated higher-order thinking. This was primarily during a few practical laboratory activities, when students were given opportunities (by both trained and untrained teachers) to experiment and to interpret data. However, in the absence of three-way interaction, students had little opportunity for open expression of ideas, or for the creative and critical thinking that is promoted by this type of interaction.

Practical laboratory activities were included in only 24 of the 62 lessons observed. When implemented, most of these activities were primarily for verification of concepts taught or were teacher-led demonstrations. There were a few investigations that used inductive reasoning for concept development, and the focus was on basic skill development. Most of the teachers, trained as well as untrained, experienced and inexperienced, paid little attention to the development of some of the important integrated process skills, such as experimenting. One explanation is that teachers may think that the development of the integrated science processes is demanding, requiring higher-level thought processes that are beyond the capability of the majority of lower secondary science students. However, the literature shows (Padilla, 1990) that students cannot master the integrated skills unless they are given multiple opportunities to acquire them, and to apply them to different content areas and contexts. Teachers must see these process skills as important learning outcomes, plan appropriately, and maximize opportunities that arise in the normal classroom interactions.

Assessment of science learning is also an important component of classroom interaction. Some teachers in all categories questioned students orally during the lessons and assigned homework at the end of the lessons. However, there was some evidence in the majority of classrooms of untrained teachers that the assessment of science learning was not a top priority during the teaching/learning encounter. In general, the teachers observed displayed little knowledge of the range of assessment strategies that could be used to assess students' knowledge and skills during the lesson. Research reports indicate that it is not unusual for teachers to focus on summative assessment only, which is indicative of teaching as transmission of knowledge (Sanchez & Valcarcel, 1999; Sorenson, 2000). However, there is a body of evidence which suggests that the use of formative assessment is the key to improving learning (Bell, 2000; Sorenson, 2000). Students get immediate feedback and they can then plan for the next step in the learning process. Sorenson therefore suggests that formative assessment procedures should be built into all levels of planning for teaching, if they are to become integral to the learning process.

Classroom behaviour was well managed by trained teachers. In these classrooms, learning experiences were well structured and paced so that most students remained on-task. There was, however, a problem with off-task behaviours in the classrooms of untrained teachers. While those with some experience were more adept at using preventive management strategies, it seemed that the untrained teachers with little experience lacked the knowledge of strategies and principles of classroom organization and management. The resulting disorder and chaos in these classrooms were not conducive to student learning. Additionally, the inability of most of the participating teachers in all categories to engage students in behaviours that promote high-level thinking, either through questioning, the diverse classroom interactions, or through open-ended kinds of practical activities, has implications for how students conceptualize science. It is highly likely that the students may have developed a view of science as a static body of preformed knowledge to which they can make no contribution, and which is not always relevant to their daily life experiences. Based on their experiences in the science classroom, it is reasonable to conclude that the students would not have constructed a view of science as a dynamic, creative human endeavour characterized by inquiry.

These findings show how the lower secondary science curriculum was enacted in the classrooms observed, but did they reflect the teachers' intentions? The following chapter reports on the congruence between teachers' intentions and their actions in the lower secondary science classroom.

CHAPTER 5

Level of Congruence Between Teachers' Stated Intentions and Observed Behaviour

5.1. Introduction

An examination of teachers' stated intentions (see Chapter 3) shows that promoting understanding, applying scientific knowledge to solve problems, making science relevant, making science fun, and motivating students were the predominant intentions. Teachers' actions in the classroom are now examined in light of their stated intentions.

5.2. Promoting Students' Understanding

Teachers' actions seemed to be premised on the assumption that students understood their propositional statements, analogies, and humorous stories/personal experiences as these related to the content being presented. Furthermore, teachers' actions were geared toward the *limited* level of understanding, although their statements had indicated some concern to have students acquire *exploratory* and *transformational* levels of understanding. From the classrooms observed, little attention was paid to how students were constructing meaning from the learning experiences presented. Students were not encouraged to ask questions or to interrogate their understandings in order to promote *exploratory* levels of understanding. A few teachers attempted to promote student understanding by linking scientific knowledge to actions in the real world, but there was very little emphasis on helping students to see the patterns in their own understandings of everyday phenomena, and to compare them with those agreed on by the scientific community, as is indicative of *transformational* understanding.

5.3. Making Science Relevant/Applying Scientific Knowledge to Solve Problems

A few teachers deliberately tried to show students how the concepts that were being developed were related to the students' everyday experiences. For example, during a Form 1 integrated science lesson on mixtures, the teacher used the example of carbon dioxide gas in soft drinks to explain the sparkling, refreshing taste. He also referred to the presence of oxygen and carbon dioxide in seawater, which allow for gaseous exchange in aquatic animals and plants.

There was also some congruence between teachers' stated intention to have students apply concepts developed in the classroom to real-life situations and the implementation of this intention in the classrooms by trained teachers and untrained, experienced teachers. The following are three examples from the classrooms of trained teachers. During a science lesson on the relationship between force and surface area, Form 3 students were asked to explain why Eskimos wear large snowshoes and why camels have

large flat feet. In another lesson on refraction and reflection, students were asked to explain why an amateur fisherman is often unsuccessful when attempting to catch fish with a spear. In a Form 1 integrated science class on expansion and contraction, students were asked to explain how they would put a metal tyre on a wheel rim that was made of wood, and how they would remove a tight ring from a finger.

5.4. Making Science Fun

This was not experienced in many of the classrooms of the eight teachers who expressed this intention. Most activities, while keeping students engaged, could not be described as fun-filled activities. The single teacher-initiated activity that could be described as “fun” was role-play as a form of assessment.

5.5. Motivating Students

There was some congruence between the intention to motivate students and implementation of activities that motivated students in the lower secondary science classroom. This was observed primarily during practical laboratory sessions, which generated fairly high levels of student interest and engagement. There were, however, instances where the activities were highly motivating although motivation was not a stated intention. For example, in the classroom of a teacher with initial training, both teacher and students demonstrated motivating behaviours. The teacher complimented the students on completion of assigned projects. In addition, the students were eager to present their projects, complimented their peers, made comparisons between their projects and other students’ projects, and were even willing to continue with presentations after the bell had signalled the end of class. Some other presentations that were motivating involved the use of visual aids and puppetry.

5.6. Other Stated Intentions

Teachers also stated that they wanted to help students build a solid foundation in science, and to help them to pass examinations. Evidence of this intention was obtained mainly from Form 3 teachers who selected specific topics that were foundational to CXC. For example, teachers taught the mole concept, moments and forces, systems in the body, properties of ionic and covalent substances, and, on occasions, made references to specific concepts that were to be learnt in order to succeed at CXC examinations. Three teachers (2 trained and 1 untrained, inexperienced) intended to match activities with student thinking; 4 trained teachers intended to challenge students; and 4 untrained teachers intended to promote active learning. There was no evidence that these teachers deliberately executed lessons that displayed these intentions. There was, however, evidence of actions for which intentions had not been articulated, as described next.

Only 2 trained teachers stated explicitly that they intended to develop process skills. However, all categories of teachers planned activities that led to the development of basic process skills (24 lessons for development of skills of observation, and 13 for inferring), and the integrated skill of communicating. The development of integrated skills (defining

operationally, interpreting data, hypothesizing, and experimenting) was observed mainly in the classrooms of trained teachers. The skill of experimenting was observed in 7 of the 20 classes conducted by trained teachers.

5.7. Summary

The teachers' stated intentions were worthwhile, and many of them are congruent with curriculum/national goals for science education. However, there was little evidence from observation that the expressed intentions were really reflected in classroom behaviours. It is evident that teachers' behaviours were influenced by their intentions, but that intentions were not the sole factors that governed their actions in the classroom. Other factors, such as resources (both material and physical), teachers' knowledge of pedagogy, and their classroom management skills seemed to have impacted on teachers' classroom behaviours and, hence, the teaching/learning of science.

CHAPTER 6

Conclusions and General Discussion

6.1. Introduction

The evidence shows that the enactment of science in the classrooms observed was not characterized by a wide range of practices. What was discovered instead was a high degree of convergence toward traditional transmission teaching. However, there were some positive features in the teaching of some of the science teachers observed. Some of these features, particularly in the classrooms of trained teachers, included the stated intentions of teachers, which in some instances were congruent with the goals of syllabus documents, the use of practical work for concept development, and evidence of enactment of contemporary ideas on the role of students' prior knowledge in the learning process. They also used a variety of strategies for concept and process skill development, and seemed to be more knowledgeable about principles of classroom management. In addition, the untrained, experienced teachers displayed behaviours that reflected personal and practical knowledge developed during years of practice. They also displayed considerable skill in structuring learning experiences; in organizing key principles, ideas, and concepts on the blackboard; and in maintaining discipline. Many of these positive features were absent from the classrooms of the untrained, inexperienced teachers, and may be related to inadequate planning.

6.2. Planning

Planning is an integral component of teaching. The quality of the planning a teacher does is influenced by his skills, beliefs, and understandings, and these in turn impact on student learning (Chiappetta & Koballa, Jr., 2002). The teacher's competence in selecting appropriate strategies, in the use of questioning, in managing the classroom appropriately, in knowledge of subject matter, and in assessment strategies is fundamental to the planning process. In addition, knowledge of aims and goals of science education, the underlying philosophy of the guiding syllabus, the nature of the student, science assessment techniques, and an understanding of classroom dynamics can exert a profound effect on the quality of a teacher's plans and the execution of those plans. Proper planning also informs the nature of the verbal interactions that occurs (Wise & Okey, 1983). As indicated in Chapter 3, many of the teachers interviewed did not engage in formal lesson planning, but relied on "head knowledge" or mental planning in which their focus was mainly on content. The trained teachers, however, adopted a more systematic approach to planning than their untrained counterparts.

6.3. Inside the Science Classroom

6.3.1. Classroom interactions

In addition to the teachers' planning behaviours, teachers' decisions about other aspects of the teaching/learning process have the potential to facilitate or hinder the attainment of student learning outcomes as outlined in syllabus documents. In light of the goals enunciated in the NCSE and SEMP curricula (e.g., stimulating curiosity, creativity, and critical thinking), the kinds of interaction that were prevalent in the lower secondary classrooms—mainly one-way and two-way interactions—the prominence of verification-type laboratory activities, the low level of teachers' questions, and the virtual absence of any systematic attempts at formative assessment are somewhat worrisome. In most classrooms observed, little attention was given to providing a forum for students' ideas or to the generation of students' questions. In all, the ratio of student questions to teacher questions was very low. Yet, "true learning is characterized not so much by the answering of questions, as by the asking of them" (UNESCO, 1980). Questioning, however, is a complex practice that requires training, since teachers need to think carefully about the purposes of questioning, how questioning facilitates student thinking, and the types of activities that encourage questioning. Problem-solving activities have been shown to elicit more, and a wider range of, students' questions at the higher-order level than teacher-directed activities (Chin, Brown, & Bruce, 2002), but there was little evidence of problem solving in the classrooms observed. Teachers, therefore, need to select strategies that facilitate students' questions and their search for answers.

6.3.2. Classroom management

The issue of classroom management is also critical. Gold (1996) suggests that, "teachers cannot create a learning environment without classroom management skills" (p. 548). Many of the untrained and inexperienced teachers observed seemed to be unaware of general principles of classroom organization and management, or were unable to adapt them to their own particular situations. Teacher behaviours associated with good management and high student achievement include effective use of teacher time, implementation of group and instructional strategies with high levels of involvement, and clear communication of rules and expectations (Morine-Dershimer & Kent, 1999). While experienced teachers develop some of this practical knowledge through personal experiences in the classroom, inexperienced teachers often perceive classroom management and indiscipline as their most serious problems (Veenman, 1984). The relationship between experience and skill in classroom management was a critical finding in this exploratory study.

The management of science classrooms can be addressed to some extent by training. However, it was evident from this study that training alone does not guarantee the implementation of contemporary approaches to science teaching, as some of the trained teachers employed many strategies that were not conducive to optimal learning in the science classroom. This finding is not unique to Trinidad and Tobago. Sanchez and Valcarcel (1999, p. 507), in a study that explored science teachers' views and practices in

planning, reported that "fewer than half (40%) of the teachers, all of them diploma holders, mentioned their initial training as the origin of their preparation strategy; the rest emphasized their experiences." In addition, there has been research that indicates that much of what teachers have learned disappears when they enter the classroom (Gold, 1996). Two important influences on teachers' actions in the classroom that are mentioned in the literature are teachers' beliefs and the environment in which they work.

6.4. Factors that Influence Teachers' Actions

It has been reported that teachers' beliefs are significant factors in determining their intentions for teaching (Crawley, 1990; Haney, Czerniak, & Lumpe, 1996). Teachers who have been exposed to the older forms of thinking that promoted the transmission of knowledge, with a focus on summative assessment of knowledge, and whose beliefs have been shaped by these ideas and modes of operation, may experience difficulty in their attempts to change to the new behaviours that characterize contemporary science teaching. However, teachers are expected to be the mediators of curriculum reform initiatives (Olsen & Kirtman, 2002). Therefore, there is the view that training should target teachers' beliefs (Dunkin, 2002).

Science teaching/learning is enhanced by the environment in which teachers work. Limited laboratory space, insufficient laboratory equipment and materials, lack of laboratory support staff, and inadequate or no allocation of laboratory time were some of the factors that limited the teachers' use of practical work in science teaching. In addition, poor student motivation, student indiscipline, and short attention span were among the variables that impacted on the quality of science teaching and learning.

If the role of the science teacher is to expose students to the nature of science as a way of thinking, a way of investigating, as well as a body of knowledge that prepares them for life in an increasingly scientific and technological society, then teachers should move away from the traditional didactic approaches to the more student-centred inquiry-based approaches that facilitate student thinking. This change in practice would require a shift in teachers' beliefs about the nature of science and the teaching/learning of science, as well as the creation of an environment that supports student inquiry.

6.5. Recommendations

- Provision of adequate resources to support science teaching at the lower levels of the school. Schools are in dire need of physical laboratory space and equipment at the lower secondary level and they lack teaching aids (audio-visual equipment and software, hands-on manipulatives like models) that assist in concept development (see George, 2003).
- Teacher training. Untrained science teachers should benefit from teacher education programmes in pedagogy and assessment. Training can provide novice teachers with opportunities to: (a) examine their personal beliefs about teaching/learning, (b) develop new ways of thinking about teaching and learning,

(c) increase their professional knowledge base, and (d) become exposed to a wide repertoire of strategies upon which to draw as they interact with diverse students in the classroom setting. Untrained, experienced teachers with wide-ranging experiential knowledge/“craft” knowledge can serve as valuable site-based resources for staff development, especially with regard to classroom management and discipline. At the same time, they too should be encouraged to participate in on-going professional training. All teachers should be exposed to short-term or long-term training in strategies that facilitate student questioning, that address quality of teacher questioning, and that promote deep thinking in the science classroom.

- Investigation of science teachers’ beliefs about teaching and learning. Researchers at UWI could be co-opted to assist science teachers in Trinidad and Tobago to investigate their beliefs and the impact of these beliefs on classroom practices. The findings of such research projects could, in turn, inform teacher education programmes.
- Action research projects. If science teachers can be supported in conducting action research projects, they would provide valuable insights into the process of transformation of practice. The findings of these research projects could, in turn, be used to improve school environments, and to impact on teacher development programmes.

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APPENDIX A

Interview Questions (Lower Secondary Science Teachers' Planning Behaviours and Intentions)

1. What activities do you engage in as you plan for your science lessons?
2. How did you plan for this lesson (the one just observed)?
3. What are your intentions when you plan your science lessons?
4. What difficulties do you encounter as you plan your science lessons?
5. Do you inform your students about procedures that must be followed in the submission of assignments?
6. Are your students informed about procedures for the return of assignments?

APPENDIX B

Planning Behaviours of Lower Secondary Science Teachers

Teachers' planning behaviours	Trained N=10	Initial training N= 4	Untrained < 5 yrs N=10	Untrained > 5yrs N=7	Total N=31
Prepare written plans	4	0	2	0	6
Plan mentally	10	4	1	5	20
Think about objectives	7	3	3	1	14
Consult prescribed textbook	9	4	8	5	26
Consult syllabus	5	3	2	0	10
Consult scheme of work	2	0	7	2	11
Use other resources					
• Other textbooks	2	2	3	2	9
• Personal notes	0	0	1	1	2
• Models, charts, clippings, specimens, slides	4	0	0	3	7
• Departmental meetings	0	0	3	0	3
Select practical/laboratory activity	9	1	1	5	16
Select teaching strategy/pedagogy	4	1	1	0	6
Consider students' characteristics	4	0	0	1	4
Consider past experiences as teacher or learner	1	1	0	0	2
Review content	0	2	0	0	2
Select assessment strategy	3	0	2	1	6

APPENDIX C

Planning Intentions of Lower Secondary Science Teachers

Intentions	Trained N=10	Initial training N=4	Untrained < 5 yrs N=10	Untrained > 5 yrs N=7	Total N=31
Promote understanding	8	4	5	6	23
Motivate students	3	0	4	0	7
Achieve relevance	5	1	5	3	14
Make science fun/interesting	3	1	2	2	8
Build a sound foundation for further study	1	2	2	0	5
Help students pass exams	1	1	2	1	5
Enable students to apply knowledge to solve problems	6	1	4	4	15
Challenge students (match activities with ability)	4	0	0	0	4
Match learning with students' thinking	2	0	1	0	3
Other intentions: Develop process skills	2	0	0	0	2
Develop manipulative lab skills	1	0	3	1	5
Safety awareness	3	0	0	1	4
Demystify science	1	0	0	0	1
Environmental protection	0	0	2	2	4
Promote active learning	0	0	2	2	4
Equity	0	0	0	1	1
Accuracy	0	0	1	0	1
Dissemination of knowledge	1	0	0	0	1

APPENDIX D

Strategies used by Lower Secondary Science Teachers for Delivering Instruction

Strategies	Trained N=10	Initial training N=4	Untrained < 5yrs N=10	Untrained > 5 yrs N=7	Total N=31
Questioning (Probing)	7	2	2	1	12
Questioning (Recitation)	6	2	9	6	23
Use of textbook	5	2	7	6	20
Copying/reading/collecting teacher notes	6	1	8	2	17
Lecturing/teacher presentation	4	3	7	7	21
Interactive advance organizer	4	0	1	0	5
Demonstration	5	1	1	3	10
Practical activity involving groups of students	9	1	1	5	16
Small-group activities	9	1	3	2	15
Wait-time strategy	5	2	3	1	11
Use of visual aids/models	4	1	3	2	10
Learning cycle	1	0	0	1	2
Using Ss past everyday experiences to develop science concepts	6	3	3	4	16
Humorous stories	2	0	1	0	3
Blackboard/oral summaries	4	0	2	1	7
Homework	4	4	1	4	13
Drill and practice	0	1	1	3	5
Problem solving	0	0	0	1	1
Focusing/set induction	6	2	2	2	12
Discussion	5	1	1	2	9
Teaching relevant vocabulary	1	0	0	1	2
Field experience	0	0	1	0	1
Concept mapping	0	0	1	0	1
Student questions	0	0	0	1	1
Linking new concepts to everyday experience	4	1	3	1	9
Analogies	3	0	3	0	6

APPENDIX E

Process Skills Developed in Lower Secondary Science

Process skills	Frequency of skills developed			
	Trained teachers N=10	Initial training N=4	Untrained teachers	
			< 5 years N=10	> 5 years N=7
Basic skills				
Observing	8	2	7	7
Classifying	2	0	0	0
Using numbers	5	1	1	3
Measuring	7	0	1	2
Inferring	7	2	1	3
Predicting	3	0	0	1
Space/time relation	0	0	1	0
Data gathering	5	0	1	2
Integrated skills				
Defining operationally	2	0	0	0
Formulating models	0	0	0	0
Controlling variables	0	0	0	0
Interpreting data	3	1	0	2
Hypothesizing	1	0	0	0
Experimenting	7	0	1	2
Communicating	10	4	5	5

APPENDIX F

Assessment Practices of Lower Secondary Science Teachers

Practices	Trained teachers	Teachers with initial training	Untrained teachers	
			< 5yrs	> 5 yrs
	N=10	N=4	N=10	N=7
Paper and pencil tests	4	1	3	1
Oral questions	7	3	6	5
Assigned tasks from student text book	4	0	3	2
Relevant home work	5	2	6	5
No assessment	0	0	2	1
Role play	1	0	0	0

APPENDIX G

Average Number and Type of Questions Asked by Lower Secondary Science Teachers (per lesson)

Teacher category	Question categories							Total
	Know.	Comp.	App.	Anal.	Syn.	Eval.	Man.	
Trained teachers	78	38	23	14	1	1	25	180
Teachers with initial training	19	8	1	3	0	0	10	41
Untrained < 5 yrs experience	65	25	14	3	0	0	100	207
Untrained > 5 yrs experience	66	22	18	2	0	0	44	152
Total	228	93	56	22	1	1	179	580

Key

Know. = Knowledge
 Comp. = Comprehension
 App. = Application
 Anal. = Analysis
 Syn. = Synthesis
 Eval. = Evaluation
 Man. = Managerial

APPENDIX H

Average Number and Type of Questions Asked by Lower Secondary Science Students (per lesson)

Student category	Question categories							Total
	Know.	Comp.	App.	Anal.	Syn.	Eval.	Clar.	
Students of trained teachers	6	3	1	0	0	1	3	14
Students of teachers with initial training	0	1	0	0	0	0	0	1
Students of teachers with < 5 yrs. experience	11	7	11	0	0	0	4	33
Students of teachers with > 5 yrs. experience	2	1	1	0	0	0	3	7
Total	19	12	13	0	0	1	10	55

Key

Know. = Knowledge

Comp. = Comprehension

App. = Application

Anal. = Analysis

Syn. = Synthesis

Eval. = Evaluation

Clar. = Clarification

APPENDIX I

Strategies for Managing Classroom Behaviour

Strategies	Trained teachers N=10	Teachers with initial training N=4	Untrained teachers	
			< 5yrs N=10	> 5 yrs N=7
Advising/Counselling	3	1	2	1
Threatening/Warning/Cautioning	3	1	4	1
Punishing	0	1	2	1
Building group spirit	6	0	1	1
Assigning and rotating roles during group activities	5	2	0	1
Structuring, controlling, and detailing instructions to students on how to proceed.	8	1	2	5
Diligent management of individual and group work	9	3	4	3
Provision of adequate materials and equipment for learning activities	8	1	2	2
Rules/policy regarding safety and behaviour	6	1	3	3
Ignore/overlook indisciplined behaviour	1	0	4	0
Rebuke/scold	5	0	3	1
Frowning/facial expression followed by “what is the problem?” (eye movement/contact)	0	0	2	0
Note-giving	0	0	1	0