Occasional Paper

SCHOOL OF EDUCATION
FACULTY OF HUMANITIES AND EDUCATION
THE UNIVERSITY OF THE WEST INDIES
ST. AUGUSTINE

Lower Secondary Science Teaching and Learning

A Glimpse into the Science Classroom

Summary Report

Susan Herbert
Joycelyn Rampersad
Christopher Akinmade

with assistance from
Rawatee Maharaj-Sharma

School of Education
2004

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.

Published in 2004 by the
School of Education
Faculty of Humanities and Education
The University of the West Indies
St. Augustine
Trinidad

ISBN: 976-622-012-3

TABLE OF CONTENTS

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 schools types within the educational system. While one limitation of this work is that is 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.

ACKNOWLEDGEMENTS

The cooperation of the principals and lower secondary science teachers of the schools that participated in this study is gratefully acknowledged.

Other components of this research project were conducted by Dr. June George, Mrs. Joycelyn Rampersad, Dr. Susan Herbert, and Dr. Rawatee Maharaj-Sharma of the School of Education, UWI, St. Augustine, and Professor Christopher Akinmade, a visiting scholar from the University of Jos, Nigeria.

The entire research team is grateful for the funding for the overall project, which was provided by the Campus Research and Publications Fund Committee of the St. Augustine Campus of UWI.

LIST OF APPENDICES

BACKGROUND TO THE STUDY

Introduction

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). 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. Traditionally, 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.

It is against this backdrop that the following research questions were pursued.

Research Questions

Two main research questions gave rise to a number of sub-questions that were addressed in the study:

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

2. How is science enacted in the lower secondary science classroom?
    - What strategies do lower secondary science teachers use as they teach science?
    - What science process skills are developed in the lower secondary science classroom?

- What assessment practices do lower secondary science teachers use to monitor learning in the classroom?
- What types of interaction take place in the lower secondary science classroom?
- What kinds of questions do lower secondary science teachers and students ask?
- What levels of student thinking are promoted in the lower secondary science classroom?
- What strategies do lower secondary science teachers use to manage classroom behaviours?

METHODOLOGY

This study was qualitative in nature. Four researchers were involved in data collection through semi-structured interviews with classroom teachers, as well as classroom observations. The interview data were coded and categorized and emerging themes were recorded and analyzed. The lessons were audiotaped, transcribed, and summarized. Further analysis of the transcripts by coding and categorizing allowed patterns and themes to emerge.

The Sample

Fourteen of the 115 secondary schools with a lower secondary sector at the time of the study were selected by purposive sampling to reflect the approximate ratio of school types in the population. The criteria used for sampling were educational division and school type. A total of 31 teachers from these schools participated in the study. The principals of the participating schools were asked to select the teachers for the study. This the principals did by themselves, or by asking the head of department to make the selection in collaboration with the teachers, or by requesting the researcher to make personal arrangements with the teachers. The participating teachers were as follows—10 trained teachers (Diploma in Education (Dip.Ed.)), 4 teachers with initial training (On-the-Job Training or 2-week training under the auspices of the Secondary Education Modernisation Programme (SEMP)), 10 untrained, inexperienced teachers (with less than 5 years experience), and 7 untrained, experienced teachers (more than 5 years experience). They were observed during the three-month period between April and June 2002. Each teacher was observed twice and was interviewed prior to teaching the lessons.

FINDINGS

Research Question 1: What are the intentions of lower secondary science teachers as they plan for their science lessons?

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

All of the participating teachers were engaged in some type of planning behaviour (mental or written), but the trained teachers were more proficient in articulating or writing lesson objectives and strategies for concept development. Fourteen teachers said that they considered the objectives of the lesson as they engaged in planning. The untrained teachers (experienced and inexperienced) based their planning on the conceptual framework presented in the textbooks, schemes of work, and their respective syllabuses.

Some of the teachers also planned for practical laboratory exercises to verify concepts that had been addressed in preceding lessons. Nine trained; 5 untrained, experienced; 1 with initial training; and 1 untrained, inexperienced deliberately planned for practical activities. With the exception of selecting laboratory activities, little consideration was given to the choice of pedagogy. Six of the 31 teachers (4 trained; 1 untrained, experienced; and 1 untrained, inexperienced) mentioned that they gave adequate consideration to the selection of other appropriate teaching strategies for science concept development.

The trend in planning behaviours shows that most teachers believe that planning (mental or written) is important. However, the way that planning is conceptualized by many of the teachers, especially the untrained, inexperienced ones, was often limited to the selection of subject content and of practical activities, with little emphasis on pedagogy.

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

Frequently stated intentions

The major intentions that were articulated by most of the teachers were the promotion of understanding on the part of students, having students solve problems, making science relevant to students' daily life, and motivating students. Appendix A gives a breakdown of teachers' stated intentions, from which it is evident that many of the teachers (trained or untrained) share common intentions for their teaching.

Other stated intentions

Science teachers included intentions such as building a sound foundation for further study of science, matching learning activities with students' thinking, developing manipulative skills, creating safety awareness, and helping students to pass examinations. Two intentions that were exclusive to the group of trained teachers were to develop process skills and to challenge students. It was surprising, however, that intentions that were exclusive to the untrained teachers (experienced and inexperienced) were to promote active learning and to sensitize students to the importance of protecting the environment.

Research Question 2: How is science enacted in the lower secondary science classroom?

- *What strategies do lower secondary science-teachers use as they deliver classroom instruction?*

The lower secondary science teachers employed a variety of strategies to facilitate teaching and learning (see Appendix B). 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. One to four different instructional strategies might have been deployed by a science teacher within a lesson, but the effectiveness with which each of these strategies was used varied with the professional training of teachers and their teaching experience.

A summary of the analysis of the most frequently used strategies follows.

Recitation

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

Lecturing and note copying

The lecture method was the next most popular strategy employed by 21 of the 31 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 8 of the 10 untrained, inexperienced teachers adopted this strategy. More often than not, the notes were copied from the student textbook or called out by the teacher. These strategies portray a view of science as a body of knowledge. Students were not exposed to other views of the nature of science, for example, as inquiry, and they were not given opportunities to articulate their own understandings, which were developed during the lessons.

The student textbook

Beside its use as an important source of students' notes, 20 of the 31 teachers referred deliberately 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.

Practical work

Sixteen of the 31 teachers engaged in practical work in at least one of the 2 lessons observed. Six of the trained teachers and 4 of the untrained, experienced teachers implemented verification laboratory activities, where the main intent was to confirm principles and concepts already covered in class. Three trained; 1 untrained, experienced teacher; and 1with initial training involved their students in inductive reasoning through laboratory activities. The main aim of these sessions was the development of science concepts and process skills, for example, observing and interpreting data. 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. Practical activities were restricted to classes that were scheduled for the laboratory (in some cases lower secondary science classes were not allocated any laboratory time) and were more frequently seen in the classrooms of trained teachers. It seems that the availability of the laboratory, support staff, and teacher training impacted on the teachers' choice of strategy.

Eliciting students' prior knowledge

Sixteen teachers (6 trained, 3 with initial training, and 7 untrained) drew on students' prior knowledge to develop science concepts. This strategy was used mainly by trained teachers as part of the set induction. It was also seen during the lessons of all categories of teachers when they attempted to anchor the abstract concepts to examples with which the students were familiar. This trend is noteworthy, but the use of students' prior knowledge was not common practice in the lessons observed.

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

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 in 24 of the 62 science lessons during short activities that formed part of a set induction, a demonstration, or a group activity.

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 in13 of the 62 lessons. Only 2 of the trained teachers addressed the skills of classifying and predicting, and 1 untrained, inexperienced teacher addressed space/time relations.

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 lessons. Students were involved in planning experiments in 10 of the 62 lessons. Three trained teachers; 1 with initial training; and 2 untrained, experienced teachers taught for interpretation of data. Two 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.

- *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. One trained teacher used role-play as a form of assessment, and 1 teacher with some initial training used working models to assess students' understandings of electric circuits. Most of the lessons presented by untrained teachers were concluded without any assessment. Planned formative assessment was not a feature in the majority of classrooms observed (see Appendix C).

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

Five types of interaction were observed in the classrooms of all categories of teachers (see Appendix D). These were identified as the one-way interaction, the two-way interaction, the extended two-way interaction, interaction between students and learning materials/laboratory equipment, and peer collaboration.

The most common type was the two-way interaction, which occurred most frequently during recitation sessions. The teachers used questioning to find out what the students had learnt, 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.

The second most frequently observed type of interaction was the one-way interaction. This type of interaction was typical of lecture sessions, consisting mostly of teacher talk, with no input from the students. The predominant activities of students in these sessions were listening (with possibly some covert engagement) and copying of notes. This interaction was exclusively teacher-centred.

The extended two-way pattern of interaction was observed in discussion sessions in classrooms of all categories of teachers. 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.

The fourth type of interaction, interaction with manipulatives, was observed in the classrooms of 17 teachers. This type of interaction occurred mainly during practical, hands-on and minds-on learning activities when students were given opportunities to observe, explore, and manipulate apparatus and materials.

Peer collaboration was the fifth type of interaction and was observed on 9 occasions. This occurred during small-group activities.

The patterns of interaction indicate that the lower secondary science classrooms are mainly teacher-directed, with students' roles being limited to responding to teachers' questions and comments.

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

Teacher 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. Questions at the levels of knowledge and comprehension according to Bloom's taxonomy are categorized as lower-order questions, while those at the level of 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 E).

Blosser classified some teachers' questions as serving a managerial function. These questions do not assist in concept or process skill development, and are asked so that teachers can determine if the lesson should proceed. Untrained, inexperienced teachers asked the majority of managerial questions.

Only 13 of the 31 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 teachers who asked probing questions used wait-time effectively.

All teachers asked lower-order questions more frequently than higher-order questions, and, in general, 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 higher-order questions.

Questions play an important role in students' cognitive engagement, and it is evident that these teachers were not paying sufficient attention to the use of higher-order questions.

Student questions

Students asked about one-tenth the number of questions asked by their teachers (see Appendix F). 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.

Most of the students' questions were situated at the level of knowledge/comprehension. However, students asked a higher percentage of higher-order questions than their teachers. These higher-order 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. Students of untrained, inexperienced teachers asked more questions than students of teachers who were trained or with initial training. It is commendable that students asked 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.

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

The levels of student thinking promoted were determined by examining the various activities in which students participated during classroom sessions. These included teachers' questions and students' questions, teaching/learning strategies, process skills, and types of classroom interaction.

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

The frequently observed two-way pattern of interaction did not 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 were often lost during these sessions. This was due either to poor task management, or teachers' 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 intended hands-on and minds-on activities.

Although more than half of the teachers selected strategies that allowed students to explore learning materials, some of the explorations remained at superficial levels, since there were few attempts 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.

- *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 to prevent indiscipline (see Appendix G).

Very few incidents of indiscipline were observed during the lessons taught by the trained teachers. However, a variety of off-task behaviours were observed in the classrooms of untrained, inexperienced teachers. These included uncontrolled noise levels, lateness to class, quarrelling, purposeless discussion in class, 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. These classrooms were characterized by threatening/chaotic environments, which are not conducive to optimal student learning.

LEVEL OF CONGRUENCE BETWEEN TEACHERS' STATED INTENTIONS AND OBSERVED BEHAVIOUR

An examination of teachers' stated intentions revealed that promoting understanding, applying scientific knowledge to solve problems, making science relevant, making science fun and motivating students were the predominant intentions. Teacher's actions in the classroom are now examined in light of their stated intentions.

Promoting Students' Understanding

Teachers' actions seemed to be premised on the assumption that students understood their prepositional statements, analogies, and humorous stories/personal experiences as these related to the content being presented. 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 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.

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.

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 of trained teachers and untrained, experienced teachers.

Making Science Fun

This was not experienced in many of the classes 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 the use of role-play as a form of assessment.

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.

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. 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. Experimenting was observed in 7 of the 20 classes conducted by trained teachers.

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 many of the expressed intentions were really reflected in classroom behaviours. It is likely 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 classroom behaviours and, hence, the teaching/learning of science.

CONCLUSION/DISCUSSION

There were some positive features in the lower secondary science teaching of some of the teachers observed. Some of these features, particularly in the classrooms of trained teachers, included the stated intentions of teachers, 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. In general, the trained teachers adopted a more systematic approach to planning than their untrained counterparts.

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 teachers' competence in selecting strategies that enhance student learning in science, 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, assessment of science learning, and an understanding of classroom dynamics can exert a profound effect on the quality of a teacher's plans (intentions) and the execution of those plans. Proper planning also informs the nature of the verbal interactions that occurs in the classroom (Wise & Okey, 1983). As indicated earlier in this report, 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. However, as evidenced in the classrooms observed, there are many issues that warrant attention.

The kinds of interaction that were prevalent in the lower secondary classrooms (mainly one-way interaction and two-way interaction), the prominence of verification-type laboratory activities, and the low level of teachers' questions give rise to concerns. In most classrooms, 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. 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.

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, inexperienced teachers observed seemed to be unaware of, or were unable to adapt general principles of classroom organization and management 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 that 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). It has been suggested in the literature that two important influences on teachers' actions in the classroom are teachers' beliefs and the environment in which they work.

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 teaching and learning that promoted the transmission of knowledge, with a focus on summative assessment, and whose beliefs have been shaped by these ideas and modes of operations may experience difficulty in their attempts to change to the new behaviors that characterize contemporary science teaching. However, teachers are expected to be the mediators of curriculum reform initiatives (Olsen & Kirtman, 2002) and therefore there is the view that training should target teachers' beliefs (Dunkin, 2002).

Teaching/learning is also enhanced by the environment in which teachers work. So, 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 teachers' use of practical work in science teaching. In addition, poor student motivation, student indiscipline, and students' 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, all of which prepare 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 enquiry.

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 would 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, 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.

REFERENCES

Bloom, B. S. (Ed.). (1956). *Taxonomy of educational objectives, Handbook 1: Cognitive domain.* New York: David McKay.

Blosser, P. E. (1991). *How to ask the right questions.* Arlington, VA: National Science Teachers Association.

Chiappetta, E. L., & Koballa Jr., T. R. (2002). *Science instruction in the middle and secondary school* (5th ed.). Columbus, OH: Merrill Prentice Hall.

Chin, C., Brown, D. E., & Bruce, B. C. (2002). Student-generated questions. A meaningful aspect of learning in science. *International Journal of Science Education, 24*(5), 521-549.

Crawley, F. E., III. (1990). Intentions of science teachers to use investigative teaching methods: A test of the theory of planned behavior. *Journal of Research in Science Teaching, 27*(7), 685-697.

Dunkin, M. J. (2002). Novice and award-winning teachers' concepts and beliefs about teaching in higher education. In N. Hativa & P. Goodyear (Eds.), *Teacher thinking, beliefs and knowledge in higher education* (pp. 41-57). Dordrecht, Netherlands: Kluwer.

George, J. (2003). *Lower secondary science teaching and learning: Teachers' characteristics and perspectives*. Summary report. St. Augustine: School of Education, UWI.

Gold, Y. (1996). Beginning teacher support: Attrition, mentoring and induction. In J. Sikula, T. J. Buttery, & E. Guyton (Eds.), *Handbook of research on teacher education* (2nd ed., pp. 548- 594). New York: Macmillan

Haney, J. J., Czerniak, C. M., & Lumpe, A. T. (1996). Teacher beliefs and intentions regarding the implementation of science education reform strands. *Journal of Research in Science Teaching, 33*(9), 971-993.

Jules, V. (1998). *Students' experiences of secondary schooling in Trinidad and Tobago: The first three years*. Unpublished doctoral dissertation, UWI, St. Augustine.

Morine-Dershimer, G., & Kent, T. (1999). The complex nature and sources of teachers' pedagogical knowledge. In J. Gess-Newsome & N. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 21-50). Dordrecht, Netherlands: Kluwer.

Olsen, B., & Kirtman, L. (2002). Teacher as mediator of school reform: An examination of teacher practice in 36 California restructuring schools. *Teachers College Record, 104*(2), 301-324.

Sanchez, G., & Valcarcel, M. V. (1999). Science teachers' views and practices in planning for teaching. *Journal of Research in Science Teaching*, *36*(4), 493-513.

Veenman, S. (1984). Perceived problems of beginning teachers. *Review of Educational Research, 54*(2), 143-178.

Wise, C., & Okey, J. R. (1983). A meta-analysis of the effects of various science teaching strategies on achievement. *Journal of Research in Science Teaching, 20*(5), 419-435.

APPENDIX A

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 B

Strategies used by Lower Secondary Science Teachers for Delivering Instruction

Strategies	Trained N=10	Initial training N=4	Untrained < 5 yrs 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	2	3	2	12
Practical activity	9	2	2	2	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 C

Assessment Practices of Lower Secondary Science Teachers

Practices	Trained teachers	Teachers with initial training	Untrained teachers	
			< 5 yrs	> 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 textbook	4	0	3	2
Relevant homework	5	2	6	5
No assessment	0	0	2	1
Role play	1	0	0	0

APPENDIX D

Interaction patterns in Lower Secondary Science Classrooms

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

APPENDIX E

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 F

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 G

Strategies for Managing Classroom Behaviour

Strategies	Trained teachers	Teachers with initial training	Untrained teachers	
	N=10	N=4	< 5 yrs 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