INNOVATIONS IN SCIENCE EDUCATION: RECONCEPTUALIZING
TEACHING ROLES IN A SELF-DIRECTED PROGRAM

by

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A thesis submitted in conformity with the requirements
for the Degree of Master of Arts
Department of Curriculum, Teaching and Learning
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INNOVATIONS IN SCIENCE EDUCATION: RECONCEPTUALIZING TEACHING ROLES IN A SELF-DIRECTED PROGRAM
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ABSTRACT

This is a qualitative case study intended to identify and explore new and emerging roles adopted by three science teachers when the context of teaching and learning science is drastically changed. The study was conducted in a non-traditional school, which adheres to a philosophy of student-centered, self-paced learning. In this particular setting: 1) traditional classrooms have been replaced by subject-specific resource areas and seminar rooms; and, 2) students do not follow a fixed daily schedule, instead, they plan their own school day and move freely between resource areas at self-directed, often irregular intervals according to daily and weekly goals. The study explores new and emerging teaching roles in order to determine: i) how teachers perceive their roles in different contexts; and, ii) the implications of these ‘new’ roles for teaching and learning science. The changes in teaching roles are illustrated through interviews, classroom observation and personal journals. In similar studies involving the introduction of individualized learning, self-directed learning, self-paced learning, and the extensive use multimedia technology into the teaching and learning context, teacher (as well as student) roles were transformed. This study explores teacher transformation and the reconceptualization of teaching roles in an innovative science program.
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INTRODUCTION

As we approach the 21st century, the stakes for educating students about science and technology have risen and will continue to rise. Fundamental to the preparation for life and living in the next century will be a tacit understanding of the nature of science and technology and their interaction with societal institutions, social mores and people. In addition, calls for increased scientific literacy have come from all quarters of Canadian researchers and policymakers (Aikenhead, 1990; Council of Ministers of Education, 1997; Hodson, 1998).

In an age of technological application and advancement, where business and industry have difficulty recruiting employees with the necessary knowledge of science, evidence suggests that there is something of a crisis in science education (Fraser, Tobin & Kahle, 1992). Over the past decade, science education reform recommendations have been very prominent. For example, influential policy reports recommending comprehensive changes in science teaching and learning were issued by the American Association for the Advancement of Science, 1993, and the National Research Council, 1996. Together, these recommendations hope to prepare a scientifically literate national work force that is equipped to compete in an increasingly scientifically and technologically oriented global economy (Lumpe, Haney & Czerniak, 2000).

Clarke (1985), Gallagher (1989), Humrich (1988), Tobin and Gallagher (1987), and Weiss (1987), report that most science curricula emphasize learning of basic facts and definitions from science notebooks, with relatively little emphasis placed on
applications of knowledge in daily life or on the development of higher order thinking skills. These reports suggest that enhancing science teaching and learning is crucial to increasing scientific literacy in Canadian schools. The goal to increase scientific literacy is further stressed in the Common Framework of Science Learning Outcomes, K to 12, which is guided by the vision that:

All Canadians, regardless of gender or cultural background, will have an opportunity to develop scientific literacy. Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them (Council of Ministers of Education, 1997, p.4).

The above vision is similar to those of AAAS (1989), which states that a scientifically literate person is:

one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific ways of thinking for individual and social purposes (Hodson, 1998, p.2).

In addition to the aforementioned crisis, recent statistics (National Science Board, 1993) show achievement in science on the decline, together with enrollments in science classes. These grim trends (Riggs & Enochs, 1990; Sigda, 1983; Tobias, 1990) have caused many science educators to re-evaluate current science instruction. For example, the National Research Council (1989) report indicates that in the majority of traditional high school science classrooms, science is taught as a body of knowledge with related principles and practices. This type of activity involves the teacher working with the class as a whole group and includes lecturing, using the chalkboard, and administering worksheets, with a heavy reliance on the textbook. These classroom
activities can be described as teacher-centered, with the teacher fulfilling the role of “teller or purveyor of knowledge.” The criticisms include too heavy a reliance on textbook oriented activities, exclusive representation of theories, emphasis on memorization and regurgitation rather than inquiry processes, as well as transmissive modes of delivery (Driver & Leach, 1993; Loving, 1997). Hence, students learn science from textbooks and lectures, and the curriculum is focused by tests which emphasize rote learning of facts and procedures (Fraser, Tobin & Kahle, 1992). This type of learning has removed personal interest. Learning has become regimented, frustrating and meaningless for many students. In a response to this, some students are losing interest in science and their perceptions of science instruction have become negative (Ormerod & Duckworth, 1975; Rossman, 1983; Tobias, 1990). Traditional teaching has taken the majority of blame for this persistent phenomenon. As a result, there has been an attempt on the part of educators to improve science instruction and make it more personal for their students.

Given these criticisms, one might ask: ‘What happens when the context of science teaching and learning is significantly changed?’ Individualized instruction (Betrus, 1995; Bishop, 1971; Bloom, 1971; Green, 1982; Georgiades & Clark, 1974; Sorenson & Haney, 1977), self-directed learning, self-paced learning, and the extensive use of multi-media technology offer alternatives to conventional science teaching. These strategies, when introduced into the teaching context change both teacher and learner expectations. These innovations in science instruction are accompanied by changes in teacher roles as we depart from didactic instructional
practices towards those that foster a student-centered approach to teaching and learning science.

The focus of this case study is to explore new and emerging roles of science teachers in the context of an innovative teaching and learning environment. This qualitative case study involved the participation of three science teachers immersed in a self-paced, individualized mastery-learning program. In addition to exploring these changing roles, implications for teaching and learning science are discussed.

The thesis is organized into 5 chapters. Specifically, Chapter 1 provides a statement of the problem and describes in detail the context in which the study is conducted. Chapter 2 reviews the literature pertaining to teaching and learning science in traditional as well as innovative programs. Literature related to teaching roles and metaphors and beliefs associated with science instruction are also reviewed. Chapter 3 covers the methodological aspects of the study, including a description of the qualitative case study, a description of the participants, the instruments used in data collection, and a general discussion of the validity, reliability, and generalizability of the study. Chapter 4 provides a qualitative analysis and discussion of the findings of the study. This includes: 1) teachers’ beliefs about teaching and learning science; 2) pedagogical orientations and teacher roles; and, 3) traditional and innovative science instruction. Chapter 5 provides some final reflections on the study, including implications, limitations and possible directions for further study in the area of innovative science programs.
CHAPTER 1
THE PROBLEM AND CONTEXT

The Statement of the Problem

The broad focus of this case study is to identify changing and/or emerging role(s) adopted by science teachers in a school which adheres to a philosophy of student-centered, self-paced learning in order to determine:

i) How teachers perceive their role in different contexts; and

ii) The implications of these roles for teaching and learning science.

The Setting

Remington High, located in North-East Toronto, is a co-educational institute founded in 1985. During the period between 1985 and January 1992, Remington High operated as a traditional community school. In February 1992, the school’s philosophy of education was radically changed from a program fostering traditional educational approaches to teaching and learning, to a program of self-directed learning. Currently, this program is in its 7th year of full implementation and it operates in a custom-designed physical plant that is reflective of the ideals of the program (Nigro, 1998).

Remington High is the only school of its kind in Ontario. At present, the school has an enrollment of over 1,000 students in Grade 9, 10, 11 and 12/OAC. The student body is comprised of diverse cultural groups; hence, a multicultural community within the school is promoted. Full programs are available at Advanced, General, and Basic
levels. The school also offers a Resource and Gifted program for students with special needs, an ESL program, an Extended French program and a focus Program in Math, Science and Technological Literacy (Agenda Book, 1999). The teaching and learning environment in the institution is non-traditional and it advocates a program based on self-paced, individual mastery learning.

Remington High School offers its students and teachers an innovative program of study that can be best described as self-directed, individualized learning. In this particular setting, traditional classrooms have been replaced by subject-specific resource areas and seminar rooms. Students do not follow a fixed daily schedule. Instead, they plan their own school day and move freely between resource areas at self-selected, often irregular intervals according to daily and weekly goals. Students work on course content using instructional packages commonly known as learning guides. Students progress at their own pace, usually in the appropriate resource area, thus availing themselves of the help of the subject teacher, if required. At the end of the learning guide, students are asked to demonstrate mastery of the concepts presented within the learning guide by engaging in an evaluative activity (Nigro, 1998).

This unique program consists of at least 5 major components or features, including: individualized education, self-pacing, mastery learning, paraprofessionals, and architectural design. The first component is individualized education, where students learn course content using instructional packages commonly known as learning guides, which are written by the teachers in accordance with Ministry
Curriculum Guidelines. All courses are divided into 20 units of study (i.e. learning guides) of equal length. The learning guides are written to promote student-teacher interaction. In other words, they require a teacher to assist the student as a guide. The teacher is not involved in teaching a lesson, as in a classroom in a traditional school. Instead, the students follow instructions in the guide without the intervention of others, unless the student requests intervention. In addition, individualized learning also refers to the fact that students do not follow a master-timetable or a fixed daily schedule. There is no bell schedule, no “periods,” nor semesters. Instead, each student is free to follow his/her personalized timetable without impediment.

The second feature of this program is self-pacing. At Remington High, students progress through the learning guide at their own pace, usually that pace is agreed upon by the student, the teacher advisor and the parent. This triad of communication—teacher advisor, student and parent—is always required in order to guide a student on a successful path. In addition to self-pacing, there is a mastery component that is essential to the students’ and program’s success. The mastery-learning component is a standard of achievement that students must meet in order for them to progress to the next unit of work. A student must achieve a 60% average on all evaluated work in any one unit in order to be eligible to move onto the next unit. If a student does not achieve the 60% average on all marked work the first time, they are given the opportunity to be re-evaluated. Therefore, retesting, the resubmitting of assignments and redoing projects are allowed in the system.

The fourth component essential to the operation of this program is the
paraprofessional. The paraprofessional in science fulfills the role of the lab technician—maintains the laboratories, performs preparatory functions and serves students ranging from grade 9 to OAC levels at a dispensary counter in the science resource area. In addition, the paraprofessional’s duties include assisting teachers in the preparation of lessons, including assembly of laboratory apparatus and demonstrations.

Traditional school settings do not have lab technicians or paraprofessionals. However, since the program in this study is self-paced, there are many students who will require resources at varying times throughout the course. Therefore, the science laboratory must be stocked to accommodate the needs of all students. Since the teachers are involved in individualized instruction, they cannot accommodate the added responsibilities of laboratory functions or dispensary counter functions. In order to provide these resources, fulltime paraprofessionals are hired to dispense materials, equipment and resources of any kind, throughout the day. Hence, the position of a paraprofessional is of paramount importance in this innovative program.

Each subject area at Remington High includes a dispensary counter (Fig.1), staffed by a paraprofessional. In science, the LABKIT system simplifies the gathering of materials and the general organization of the laboratory. The LABKIT system is designed to accompany each lab, as outlined in the learning guides. The paraprofessional is instrumental in this labour-intensive process of maintaining and monitoring this system through dispensing, preparing, refilling and re-shelving the lab kits in order for them to be readily available to the students.
The final component is the unique design of the building. Remington High is architecturally designed to suit the free flow of students. Classrooms are replaced by large, open, library-like resource centres for each subject area, where students of all grades, ability levels and courses within that discipline gather to work on their units. The science department is architecturally designed to house a central resource area (Fig. 2), which accommodates approximately 60 students, as well as separate laboratories (Fig. 3) for Biology, Chemistry, and Physics, which are monitored by teachers and paraprofessionals.

In addition, one seminar room (Fig. 4) reserved for teaching traditional-style classroom activities is located off the resource area. Science teachers conduct several mandatory seminars in order to clarify misconceptions that students may encounter in their science units. The science resource centre is monitored by teachers who “team-teach,” and assist students on a “needed” basis.

The science department teachers are on a department-specific rotation schedule. They act as subject-specialist consultants (resources) to students who are working within the resource centre. In the laboratory, the teachers monitor the activities, providing assistance when requested by a student. The teachers at Remington High teach structured activities (seminars) that have been strategically located throughout the course of study and must be offered on a repeat basis due to self-pacing.

This non-traditional school setting fosters a student-centered (as opposed to teacher-centered) approach to teaching and learning science in which the student is accountable for his/her learning. In this teaching and learning environment, the
Figure 3: The Laboratory
traditional didactic approach to secondary school science, with its emphasis on formal instruction and written presentation of information and its highly prescriptive knowledge content, is virtually eliminated. It is now replaced by active learning methods that give the learner a significant measure of control and provide opportunities for exploration and reconstruction of ideas (Hodson & Reid, 1988).
CHAPTER 2
THEORETICAL FRAMEWORKS

Teaching and Learning Science

Science Education

Science is more than a collection of facts about the natural world; it is a way of thinking, of approaching problems objectively by theorizing about what might be from careful observation of what is, and then testing the hypothesis (Barba, 1998). The ability to understand and apply scientific concepts and processes to everyday life is vital for all students. The primary goal for all science teaching and learning should be the development of scientific literacy (AAAS, 1993, 1989; Hodson, 1998; Tobias, 1990) at all levels of science education, for all students. In order to accomplish this goal, some common themes, which provide direction, have been identified in various reports (AAAS, 1993; National Research Council, 1996) on science education reform, and they include the following: a) constructivism, b) thematic approach, c) assessment and evaluation, d) equity, e) science-technology-society and environment (STSE), f) educational technology, g) cooperative learning, h) hands-on activities, and i) the nature of science (Lumpe, et al. 2000). Several of these themes and their relationship to pedagogical practices and teacher roles at Remington High will be discussed during the study.

In teaching science, each student needs to be considered as an individual. This fact is often overlooked in traditional programs of instruction. Students are alike in some respects but differ in many others, including needs, interests, abilities, states of
readiness, background of experience, and often in terms of cultural outlook (Sorenson & Haney, 1977). In addition to these student differences, increases in class size, time constraints, new curriculum documents, new assessment practices, and class material have pressured educators to develop better ways to present instructional material.

Four clusters of instructional strategies are commonly used in science classrooms: (1) self-directed activities, (2) small group negotiations, interaction and peer tutoring, (3) large group verbal interactions, and (4) expository sessions (Barba, 1998). Expository instructional techniques are the most teacher-centered or teacher-directed pedagogical methods, and self-directed activities the most child-centered. These strategies are illustrated in Fig. 5 as a continuum.

![Figure 5.0 Continuum of Instructional Strategies (Barba, 1998, p. 165)](image)

In addition, Chinn and Hilgers (2000) suggest that science instructors can be described along a continuum anchored by instructor as “corrector” at the far left end of the spectrum and instructor as “collaborator” at the far right. Typically, traditional science instruction is expository with some large group mediated conversations. The instructional strategies included in the innovative program in the study, are located on
the continuum somewhere between some small group peer tutoring and self-directed learning. This continuum will provide one of the bases for interpreting the data in this study.

**Traditional Science Instruction**

Tobin and Gallagher (1987) reported that the activity type most prevalent in high school science classes involved the teacher working with the class as a whole group. Typically, there is the teacher-student ratio of one to thirty, with group instruction as the central means of teaching. There is the expectation that each teacher will teach the subject in much the same way as the other teachers. It also assumes that the teacher is the most important person in the room. It is the teacher who holds centre stage, and it is the teacher who is the fount of all knowledge and the source of authority, doing up to two-thirds of all the talking (Hodson & Reid, 1988). Too often, teachers have viewed science as a body of facts to be learned or committed to memory (Barba, 1998). Renner and Lawson (1973) state that traditional science-teaching methods embrace the notions that: (1) teaching is telling, (2) memorization is learning, and (3) being able to repeat something on an examination is evidence of understanding.

What seems quite clear is that the traditional didactic approach to secondary school science, with its emphasis on formal instruction and written presentation of information, and its highly prescriptive knowledge content, reduces children to the role of passive receivers of accumulated knowledge rather than elevating them to the role of active constructors and reconstructors of personal knowledge (Hodson & Reid,
1988). In summarizing the status of science education, the American Association for the Advancement in Science has stated that, “conventional science teaching suppresses students’ natural curiosity and leaves them with the impression that they are incapable of understanding science” (AAAS, 1990).

**Teacher Control.** As a result of the traditional culture of schools, Tobin (1993) suggests that teachers tend to manage students as employers would employees in the workplace. Teachers manage students so as to maintain control of student thinking and behaviour. Instead of placing responsibility for behaviour and learning with the student, teachers arrange students in a manner by which they cannot interact with each other. In addition, the teacher chooses tasks and assigns them as a means of keeping students busily engaged in activities. Teachers help to construct the dynamics of social power through the experiences that they organize and provoke in classrooms (Barton, 1998; Cummins, 1996).

According to Tobin (1993), teacher control is seen as of primary importance. In order to maintain control, teachers employ common tactics in classrooms. He states that:

*First gain control over the students. If you don’t manage to do this in the first few days, the remainder of the year will be a disaster. So goes the conventional wisdom of the teaching profession (p. 221).*

Bond (1981) claims that teachers become oppressed by their own actions, and will remain so until students are liberated:

*By creating a rigid and unresponsive structure [teachers] can severely inhibit student self-directedness and establish an unhealthy dependency which not only turns students away from learning in its wider context, but which diminishes the teacher as a person (p. 17).*
Several authors, Green (1982), Rossman, Sigda, Yager and Penick (1983) have recommended a change in our current method of science instruction, which typically uses lecture, class discussion and teacher demonstrations as prescribed by the science textbook. They have stated a need for science instruction to become more personal and less textbook oriented. This "different" mode of science instruction would involve a type of teaching-learning experience in which the teacher gives consideration to the individual learner. An essential characteristic of the innovative program at Remington High is that it incorporates the idea of students taking on the responsibility for self-directed learning.

Each of the changes that are initiated in science instruction will inevitably have a ripple effect. As the teacher changes his/her mode of instruction, there are consequent changes in both content and student (Ellsworth, 1994).

Bruner's (1966) work on discovery learning is a clear example of this principle. When the role of the student was altered, the quantity and type of learning content changed as well. The teacher's role was also dramatically affected. The crucial finding here is that as we vary one, the other two vary as well. If we attempt to vary one without actively addressing the other two we have less control, less success and unpredictable outcomes.

**Teaching Roles**

Revising curriculum, changing the way we teach, and adapting new methods of assessment fall upon schools and those who work in and with them. Yet, the role of the teacher, and particularly the teacher's beliefs about teaching, must not be ignored if
these recommendations are to result in enduring change in the classroom (Lumpe, et al. 2000).

As indicated earlier, the role of the teacher can be described along a continuum from teller and holder of knowledge to coequal learner (Reinsmith, 1992). The models in Figure 6 illustrate the interplay (Ellsworth, 1994) among teacher (T), student (S), and content (C). These four teacher roles introduce a continuum of change, possibly hierarchical in nature, and certainly interlocking with respect to changes in content and student roles. Once the teacher roles have been developed, they can be used interchangeably to enhance and expand the variety and interplay in the classroom. They also aid the work of moving the student into becoming a fully engaged life-long learner through the nature of the student roles (Ibid).

On the continuum of instructional strategies, the role of inducer-persuader would be located to the far left, indicating a teacher-centred approach, and the role of facilitator to the far right. The role of inquirer-catalyst and dialogist would be located somewhere between large group mediated conversations and small group interactions.

The supportive and catalytic role of the teacher is now recognized everywhere. There seems to be no learning device, however sophisticated, which can be effective for any extended period of time without the involvement of the teacher (Green, 1982). However, the roles of the teacher are multi-layered and multi-faceted and they include roles such as: instructor, observer, a critic of the effectiveness of the discussion and, a helper by teaching discussion techniques and evaluating the results. In summary, the role of the teacher ranges from inducer to inquirer to dialogist to facilitator (Ellsworth,
Figure 6: Four Teaching Roles (Ellsworth, 1994, p. 27)

**Inducer-Persuader**
Content driven, teacher led format with student assuming responsibility.

**Inquirer-Catalyst**
Content acquired through discovery, with emphasis on interrelationships.

**Dialogist**
Discourse format with lifelong learner as focus. Mutual and interchanging leadership roles.

**Facilitator**
Mutuality of content, teacher and student, with teacher as support.

1994). Such roles cannot always be fostered effectively in conventional classrooms.

The following section examines the importance of metaphors and beliefs in trying to understand teachers' roles and teachers' professional lives.
**Metaphors and Beliefs**

According to Bandura (1997), beliefs are thought to be the best indicators of the decisions people make throughout their lives. Beliefs are often associated with knowledge, attitudes, and personal convictions, or reflect a person’s acceptance or rejection of a proposition. Obviously science teachers possess beliefs about professional practice. Since beliefs may affect actions, teachers’ beliefs play a critical role in restructuring science education (Lumpe, et al. 2000).

Teachers have many sets of beliefs that are appropriate for a given teaching role in specific contexts. The relevance of beliefs and role conceptualizations are dependent on many factors, including the physical milieu in which learning is to occur, as well as other within and out-of-school factors (Fraser, Kahle & Tobin, 1992). In the case of science teaching, context beliefs (Lumpe, et al. 2000) encompass not only the students, but also administrators, parents, other teachers, institutions, organizations, and the physical environment.

Teaching roles are often conceptualized in terms of metaphors (Tobin, 1990), and are defined by beliefs which influence what teachers endeavour to do during classroom activities. Tobin (1990) maintains that metaphors and beliefs associated with a given role are context dependent and can be “switched” as the teacher perceives that different courses of action are warranted by the context. In addition, metaphors are important in providing partial understanding of one kind of experience in terms of another kind of experience. They are regarded as being essential to human understanding and as a mechanism for creating new realities. According to Tobin,
metaphors pervade the conceptual system and are the primary mechanism for understanding.

On-going research suggests that metaphors such as “teacher as performer,” and “teacher as resource,” used to conceptualize particular teaching roles, guide many of the practices adopted by teachers. Metaphors and images influence how teachers think and talk about teaching and what they do in their classrooms (Tobin, 1993). In addition, teachers’ theories and beliefs about the teaching-learning process play an important part in determining the nature of their classroom roles.

For example, Tobin and Gallagher (1987) reported that metaphors such as “teacher as intimidator” projected images that were a deterrent to students who may contemplate misbehaviour. Similarly, Jonathon, a science teacher in Tobin and Espinet’s (1989) study, used a metaphor of “teacher as preacher” to make sense of teaching. In his life outside the classroom, Jonathon was a preacher. As a teacher, he lectured from the front of the class and set seatwork tasks from the textbook. His lectures had many of the characteristics of a sermon, the textbook was his bible, and his role in the classroom was consistent with the roles which he fulfilled as a preacher. In the classroom, Jonathon projected the image of a preacher.

Innovative student-centered curricula have experienced implementation difficulties attributed to the predominance of teachers’ well-established beliefs in their centralist classroom roles (Olson, 1981). Innovative programs, such as the one described in chapter 1, require that teachers abandon the daily practice of lecturing and adopt a decentralized role, thereby enabling them to interact on an individual basis.
with students (Taylor, 1993). In this decentralized role, the teacher becomes a "facilitator" and a "guide", rather than a "disseminator of knowledge." This study focuses on the "decentralized" roles adopted by teachers in an innovative program and the implications of these roles for teaching and learning science.

**Changing the Context of Science Teaching and Learning**

Until recently, in schools, colleges and universities, the most common model of education has been teacher-directed. To a greater or lesser extent, the objectives, content, pacing, sequence, methodology, and evaluation were all in the hands of the teacher, to whom learners had to submit themselves in order to be "taught." Recently, there seems to be some indication that the traditional role of the instructor is now changing more rapidly and profoundly than at any time in history. According to Candy (1991):

Many educationists have begun to recognize that teacher-controlled instruction is unwieldy, undemocratic, and unsound as a way of conducting education, and that it ought to be abandoned in favor of a greater degree of learner-control (p. 205).

It is suggested that traditional didactic methods be replaced by active learning methods that give the learner a significant measure of control and provide opportunities for exploration and reconstruction of ideas (Hodson & Reid, 1988). Individualized and self-directed learning, self-paced learning and the extensive use of multi-media technology offer possibilities for more student control.

Examples of individualized instruction can be seen as far back as ancient Greece with the teachings of Socrates, and recently in the development of
sophisticated Computer Managed Instruction in the 1980's and 1990's. Examples of programs integrating individualized instruction, self-paced learning and multimedia technology in elementary, secondary, and continuing education have increased throughout the twentieth and early 21st century, as the demand for new teaching innovations increases (Betrus, 1995).

Individualized instruction, according to Betrus (1995) is based on 10 accepted educational principles: active responding, positive conditions and consequences, specifications of objectives, organization of materials, mastery before advancement, evaluation/objective congruence, frequent evaluation, immediate feedback, self-pacing and personalization. Remington High has tried to incorporate these principles in the development of their educational program. In addition to the above principles, the following factors (Jenkins, 1982) are integrated into Remington High's self-directed program:

1) interesting instructional materials adapted to a wide range of student ability;
2) monitoring by teachers of each student's day-to-day progress through his or her study plan;
3) individual student plan forms which help students use their time productively;
4) good records of students' progress;
5) frequent consultation between student and teacher;
6) quiet study areas; and
7) employment of paraprofessionals to distribute materials and equipment.

Even though the above factors are unique to self-directed learning, many of them are also prevalent in traditional educational programs.

There is a long tradition of thought and theory behind the work of advocates of personalized-or autonomized-learning. There are two main strands of work, which are
often identified as ‘personalized’ and ‘individualized’ learning. The first has to do with the traditions of Carl Rogers (1983), who suggests that the locus of evaluation lies within the learner, and that personal learning is of the essence:

When we put together in one scheme such elements as prescribed curriculum, similar assignments for all students, lecturing as almost the only mode of instruction, standard tests by which all students are externally evaluated, and instructor chosen grades as the measure of learning, then we can almost guarantee that meaningful learning will be at an almost minimum (p.18).

The second strand grows from the ‘independent learning’ tradition much in vogue in the late 1960’s and early 1970’s. Much of the early work in science, in this field, has been surveyed by Green (1982), and, though it may now seem to be slightly unfashionable, it is possible to see some of its modern antecedents in a range of current courses (Bentley & Watts, 1989).

In order to successfully depart from traditional modes of instruction in science to those that will empower both teacher and taught, there are 4 essential ingredients that need to be adopted by educational programs. These are i) quantity and quality of teacher talk, ii) provisions for continuous progress, iii) relationships with teachers, and iv) discussion skills and interpersonal relations, (adapted from Georgiades & Clark, 1974). These four features will be discussed below.

**Quantity and Quality of Teacher Talk**

Teachers need to remind themselves constantly that the goal is not for them to cover the subject, but for their pupils to do so. The purpose of teacher talk is to
motivate pupils to learn what they need to learn, and to challenge the creativity and the special interests of pupils to go beyond the required minimums. Teachers also provide pupils with information not readily available to them elsewhere, and create assignments so that each pupil may engage successfully in independent study (Georgiades & Clarke, 1974).

Hand's (1996) classroom observations of teachers indicated that all teachers taught in an information-transfer mode, which had an emphasis on ensuring that the correct scientific content knowledge was given to the students through teacher talk. Within Hand’s study, the major concern expressed by teachers was the need to maintain control of the students and the content knowledge to be covered. These concerns were reflected in the managerial roles adopted by the teachers; for example, metaphors used by teachers included “ring master” and “lecturer.” Classroom observations indicated that two-thirds of the lessons were teacher-controlled and that student-controlled activities were of low order and unlikely to promote higher-order thinking.

In essence, self-directed learning requires a fundamental shift in the locus of control in the classroom, and this shift is difficult for many educators to make. The needs of most educators for authority, visibility, and a sense of personal significance are not very well met in programs based on self-directed learning (Candy, 1991).

Within the context of this study, occasional lectures and seminars are conducted primarily to clarify misconceptions encountered in science courses by students. Hence, teacher talk is significantly reduced. The teacher role is altered and there is a
gradual movement from teacher as “purveyor of knowledge” to teacher as “facilitator of learning.” The teacher in this particular setting relinquishes control of the content and learning environment. Hence, differing the context in which science teaching and learning takes place, illuminates instructional strategies in science that move away from the traditional didactic approach to secondary school science.

**Provisions for Continuous Progress**

In considering essential components of a “continuous progress” education program, Barrington (1987) stated that the two most important components are “an effective student tracking system to monitor progress and provide feedback” and “clear and consistent policies, expectations and consequences for students.” In this study, the two key provisions that will be focused upon for continuous progress are time and feedback from teachers.

In order to relinquish the control of the teacher-centered classroom, each pupil should ideally be placed in a situation where he/she can successfully complete each stage in the learning process and go on to the next without delay, but at their own pace. This arrangement contrasts with the situation in traditional classrooms where bright pupils often are bored because they have to wait for others to catch up, or where less talented pupils are frustrated because the pace is too fast and the materials too difficult for them (Georgiades & Clarke, 1974). Kapuscinski (1982) states that:

...a frequent criticism of conventional large group instruction is that it often fails to meet the educational needs of the wide variety of children found in the typical classroom. Rigid scheduling can bring an end to a class discussion just at the moment when pupils are on the verge of grasping a concept. Little attention may be given to knowledge and experience the pupil may have
previously acquired, thus forcing him/her to repeat work that has already been mastered (p. 707).

Similarly, Bloom (1971) agrees that not only should the student spend the amount of time he/she needs on the learning task, but also that he/she be allowed enough time for the learning to take place. The importance of time is further illustrated by Green (1982) through the responses of secondary science students to his questions about an individualized program:

Have you ever thought about this way of working as compared with the more usual methods in your other subjects?
A lot better because of some things...speeds differ...if you are understanding something you will go faster...and if you don’t understand things then you can slow down and take it easy... and go back...and do your own research.... and you don’t hold back the rest of the class...and the rest of the class can’t hold you back. I get bored a lot on some courses...teacher spends a lot of time introducing new terms, which I’m familiar with. You have some control. There’s a lot more work to do, but you can go at your own pace.

Similarly, in the Technology-Enhanced Secondary Science Instruction project (TESSI), self-pacing was overwhelmingly popular with students. The TESSI project was integrated in a science classroom that fostered a student-centered approach to teaching and learning science. Students spoke of the “flexibility” afforded by setting one’s own learning pace and consistently mentioned how it reduced the “stress” and “pressure” of trying to meet externally set deadlines. Self-pacing required them to monitor their own learning, and contributed to their time management and organizational skills (Pedretti, Smith & Woodrow, 1998).

In self-directed programs, the most important factor in students’ success seems
to be the monitoring of their progress. To be effective, not only must the monitoring system give teachers an accurate report of each student’s progress, but the program must also be designed to ensure that units are completed regularly, and that students having difficulty in mastering units receive help from a teacher as they need it (Jenkins, 1982). Hence, continuous feedback is an essential component in programs adhering to principles of self-directed learning.

The non-traditional school in which this study was conducted adopts features of science instruction similar to those mentioned above. Within this different context of teaching and learning science, the mode of science instruction is focused on self-pacing, unit mastery, student tutors, motivational lectures, and learning from written materials. The components essential to continuous progress—time and feedback—are key features in the program implemented at Remington High. Continuous feedback is provided in order for students to progress from one unit to another without setbacks or interruptions in their program.

**Relationships With Teachers**

According to Chinn and Hilgers (2000), among the many variables known to affect students’ progress in science is experience with instructors. This sentiment is echoed in Wubbels’ (1993) study, in which he concluded that the interpersonal relationships between teachers and their students is an important aspect of the learning
environment, and that it is strongly related to student outcomes. The instructor’s importance is underscored by a set of assumptions about the social nature of learning and science teaching (National Research Council, 1996. p.28).

- What students learn is greatly influenced by how they are taught.
- The actions of teachers are deeply influenced by their perceptions of science as an enterprise and as a subject to be learned and taught.
- Student understanding is actively constructed through individual and social processes.
- Actions of teachers are deeply influenced by their understanding of and relationships with students.

In optimal learning environments, students would find themselves in one-on-one learning situations with a teacher. For practical reasons however, ordinary classrooms cannot provide such situations on a regular basis because the teacher cannot be available to all students at all times (Roth, 1993).

Candy (1991) supports the interpersonal relationships between teachers and students, as illustrated by Wubbels (1993). He comments on the interpersonal relationships that are fostered in self-directed educational programs:

...approaches to teaching that acknowledge the inherent autonomy of learners, and that seek to give them control over certain aspects of the teaching situation explicitly allow for individual differences amongst learners, so that the person who prefers a more active experimental orientation may select that, while a more passive or reflective orientation could be chosen by another learner (p. 186).

Hence, student-controlled modes of instruction have the dual benefit of avoiding the burden on learners of unwelcome direction and fostering motivation in learners who have been responsible for selecting or shaping their own direction. Once the teacher is freed of the role of “motivating” unwilling students, he or she is able to spend more
time assisting learners through a variety of roles (Ellsworth, 1994). This factor is fulfilled in the context of this study as a result of the science teachers implementing team-teaching instructional practices. As a result, pupils are in contact with several teachers, both in group situations and during their independent study. Also, because teachers are free from full-time classroom assignments, students can readily find and talk to them when they need to do so.

**Discussion Skills and Interpersonal Relationships**

Discussion skills and interpersonal relations are entwined in different teacher roles and through class organization. Nothing is more individual than our personal oral communication with others. The need for improvement in personal dialogues is documented by the difficulties individuals have in communicating, arguing, and reaching revised decisions and accords with each other (Georgiades & Clark, 1974). In a student-centered teaching and learning environment, the teacher's role may resemble that of a "dialogist." The focus is on personal dialogue between the teacher and student, through which both are empowered to become lifelong learners. In the TESSI project, students regarded their teachers as "the last resort." This was not a perjorative view, but rather one that reflected students' recognition that they could tackle and resolve problems of conceptual understanding on their own. Whether assuming a speaking or listening role, individuals saw dialogue with peers as a means of monitoring and enhancing understanding. They understood that they were assuming greater responsibility for their own learning (Pedretti, Smith & Woodrow, 1998). In addition, Green (1982) maintains that conversations with the teacher are more realistic
when they relate to an activity or an idea against which there is a question mark in the mind of the student. Much teaching in the past and present has failed to allow the student to reach that point of asking questions.

**Summary**

Generally, in most conventional forms of teaching, intellectual challenge, personal interest and learner control are low, and teacher control is high. Good learning is fostered by a shift to high levels of learner control and personal interest, an appropriate level of intellectual challenge and minimal teacher control (Hodson, 1998). In order to attain the shift, traditional instructional practices in science must undergo changes.

Sustaining a program based on self-directed learning requires that teachers be committed to an alternative educational approach. In addition, they have to guard against their own socialization towards strong teacher-directed learning perspectives. Therefore, it is critical for teachers teaching in these innovative programs to conceptualize their teaching roles in a new way, consciously distancing themselves from the prevailing norms and negative role models associated with teacher directed learning (Hammond & Collins, 1991).

The various roles assumed by a teacher and the methodologies he/she uses are often based on well-entrenched attitudes, beliefs, knowledge, self-concept and
personality traits. In short, teaching is a very personal matter and the teacher’s role in the classroom therefore becomes a very complex task. Any program of change requires a gradual and systematic approach with opportunities for self-evaluation and reflection, and a supportive climate from peers and administrators.

In summary, this study will examine the role of science teachers in an innovative program where teacher-directed learning is replaced by self-directed, individualized education. It will also examine implications of the roles for teaching and learning science. The following chapter outlines the Research Design of this study.
CHAPTER 3
RESEARCH DESIGN

Qualitative Case Studies

Qualitative research in education has roots in many academic disciplines. They include not only the social sciences (e.g., anthropology, sociology and psychology), but also the humanities (e.g., art, literature, and philosophy) and interdisciplinary studies. One of the main characteristics of qualitative research is its focus on the intensive study of specific instances—that is, cases of a phenomenon. For this reason, qualitative research includes case study research. Case study research evolved as a distinctive alternative to scientific inquiry, partly as a reaction to perceived limitations of quantitative research (Gall, Borg & Gall, 1996).

Case study research is not new. Historically, significant “cases” are part of the disciplines of medicine and law. Recently, education has turned to case study research to explore the processes and dynamics of practice (Merriam, 1988; 1998). A case study (Gall, Borg & Gall, 1996) is conducted to shed light on a phenomenon, on the process, events, persons, or things of interest to the researcher. Examples of phenomena are programs, curricula, roles, and events. The interest is in process rather than outcomes, in context rather than a specific variable, in discovery rather than confirmation. Such insights into aspects of educational practice can have a direct influence on policy, practice and future research (Merriam, 1988).
The Study

A qualitative case study methodology (Gall, Borg & Gall, 1996; Merriam, 1988; 1998; Stake, 1994) was used in order to conduct an exploratory study of science teachers' changing/new roles in the context of a different teaching environment. A case study approach is warranted in order to shed light on the phenomenon of teacher roles in non-traditional science instruction. This approach was the preferred methodology for this study because it allowed the researcher to gain an in-depth understanding of the context in which teaching and learning science occurred, as well as identifying the teaching roles fostered in such contexts. In addition, the meaning of the teacher roles, for both researcher and teacher, are brought to the surface and their implications for teaching and learning science are explored.

Procedures for Conducting the Study

Interest in the study was generated during discussions regarding innovations in science education, particularly science instruction, with the head of the science department from the school. The individual was a fellow classmate in a science course in a graduate program in education. He provided personal insights into the program and encouraged my pursuit of this study involving science instruction in non-traditional school settings and the impact on teaching roles. In addition, I arranged a visit to the school in November of 1998. During that time, I toured the school for approximately 4 hours, observing the student culture, team-teaching, and taking note of the environment in which science teaching and learning took place, as well as the
materials used for instruction. I was also introduced to various aspects of the Science, Math and Technology Literacy program.

I arranged a meeting with the Principal and, in January of 1999, the Principal was approached for permission to conduct the study. A brief description of the study was provided and verbal permission was granted. At that time, I was formally introduced to the science teachers at the institution. Consent forms (Appendices A & B) were distributed to the Principal and participating science teachers in February of 1999. An ethical review was also completed through the University. Teacher and school pseudonyms have been used in order to ensure confidentiality. Teachers were recruited on a voluntary basis. They were also free to leave the study at any point without reason, and they were assured that participation in the study would have no "evaluative" component with respect to their teaching performance. Findings and conclusions were shared with the participants for feedback and commentary.

The participants of the study include junior and senior staff in the science department. I believe that the teachers participated in the study for reasons involving professional development. This was an opportunity for teachers to reflect on their practices and roles at Remington High and share their perspectives with someone outside the innovative program. Three science teachers who had taught in traditional science classrooms and non-traditional science classrooms, in different subject areas (biology, chemistry, physics), at different grade levels, volunteered to be part of the study. The duration of the study was approximately four months, during which the researcher visited the school for a period of 2-3 hours a day, at least two days/week,
for the purposes of conducting interviews, making/writing classroom observations, and compiling a research journal.

**DATA COLLECTION**

Qualitative data consists of “detailed descriptions of situations, events, people, interactions, and observed behaviors; direct quotations from people about their experiences, attitudes, beliefs, and thoughts; and excerpts or entire passages from documents, correspondence, records and case histories” (Merriam, 1988, p. 29).

In order to obtain the depth and detail of data that is denotative of case study research, this study relied heavily upon qualitative data obtained from interviews, classroom observations, and personal journals. The use of multiple methods of collecting the data for this study ensured methodological triangulation. The rationale for this strategy (Merriam, 1988) is that the flaws of one method are often the strengths of another, and by combining methods, observers can achieve the best of each, while overcoming their unique deficiencies.

**Interviews**

In case study research of contemporary education, some and occasionally all of the data are collected through interviews. The interview was the preferred method of data collection in this study since I was interested in exploring roles, attitudes, beliefs and things that cannot be observed directly. Interviews allowed me, as the researcher, to inquire into the science teacher’s perspective on teaching roles, science instruction, and non-traditional school settings.
For the purposes of this qualitative case study, two person-to-person, semi-structured interviews were conducted between the researcher and the science teachers. The first sets of interviews were conducted at the beginning of the study and the second set at the conclusion of the study. The interviews were audio taped and the duration of each interview ranged from approximately 45-90 minutes in length. It began with a set of twelve prepared questions that were open-ended (Appendix C). Responses to these questions led the interview in directions that were largely determined by the teachers. The subsequent interview followed the same format as the first; however, it elicited more concrete statements as opposed to the more abstract and divergent comments gathered in the first interview.

In addition to the formal interview, there were informal discussions with the teachers and paraprofessional throughout the study. These were not audio taped; written notes were recorded and were later transcribed into the research journal.

**Classroom Observations**

Classroom observations play a crucial role not only in classroom research, but also more generally in supporting the professional growth of teachers and in the process of school development (Hopkins, 1993). In addition to interviews, classroom observations also provided a source of qualitative data for this study. The science teachers were observed in various roles, including team-teaching, lecturing, and individual instruction. The paraprofessional was observed in the dispensary area, in the laboratory prep room, and in the laboratories.

Activities in seminar rooms, resource areas, laboratories and the dispensary area
were observed for a combined total of 36 hours over a three to four-month period. Each of the teachers was observed in two seminar sessions, two resource area sessions and two laboratory sessions. These classroom observation notes included descriptions of: the setting in which science teaching and learning took place; the participants (teachers as well as students); activities and interactions (including frequency and duration); and other pertinent information. These descriptions were recorded as field notes. In addition to the elements listed above, field notes also included diagrams, direct quotations of conversations and the researcher’s comments.

**Other Data Sources**

According to Richert (1992), journals are a powerful tool, which allow teachers to converse with themselves. She states that:

As a vehicle for cultivating the teacher’s voice journals create an especially powerful means for teachers to explore teaching and their personal experiences of the learning process. The writing process lets you “know what you know, know what you feel, know what you do and how you do it, and know why” (p. 192).

Personal journals provided by the teachers over the period of the study also became a source of qualitative data. These journals were largely comprised of reflections pertaining to the program. These were largely related to assessment, parenting roles, internal politics of the school and science education. In addition, the researcher also kept a personal journal. The researcher’s journal consisted of reflections on the self-directed program in science, as well as reflections on the interviews, classroom observations and informal discussions. These personal sources are first-person accounts of our group’s reflections on individual attitudes, beliefs,
roles and views of science education in a very different context.

On the basis of interviews, observations, and other data sources, the researcher's analysis regarding the teachers' beliefs about science instruction and teaching roles were built, and confirmed, validated, and/or altered, with supporting and/or contradicting evidence (Brickhouse & Bodner, 1992).

**Validity**

Research of this type is less interested in reality per se than it is in the perspectives of those involved in the research and the complexities of human action in particular contexts (Merriam, 1988; 1998). For this reason, it is crucial that the findings be credible to those whose perspectives are portrayed.

In this study, standard means of judging validity and reliability were met through the use of multiple methods of data collection as well as through long-term observation. The influence of the researcher's bias is accounted for in the description of the theoretical orientation of the study (Brickhouse & Bodner, 1992).

**Generalizability**

The degree to which these findings are generalizable to other situations is dependent on the similarities between contexts. In this study, the context in which science teaching and learning occurs is different from the traditional classroom. Hence, the findings of this study may or may not be generalizable to other teaching and learning contexts. I have included as much detail about the context of the study as possible to help readers make their own judgment regarding the extent to which these
findings may inform their own work and experiences (Brickhouse & Bodner, 1992; Yin, 1994).

Participants

Background Information on Mike

Mike is an enthusiastic, dedicated, experienced science teacher who has been teaching science for sixteen years. His educational background includes a degree in biochemistry as well as qualifications from an Ontario Faculty of Education. In his undergraduate years, Mike worked as an assistant in a scientific research laboratory. During the study, Mike was completing a master of education degree.

Mike's first teaching experience was at a private school, where he worked for a period of two years—one year as a science teacher and the second year as acting Principal. He admits that he did not enjoy his first teaching experience as a result of the manner in which the private system operated. Afterwards, he switched careers and returned to scientific research in pharmacology, where he worked for a government agency. After realizing that his career aspirations were not located in research, Mike resumed a career as a secondary school science teacher in a community school until 1990. In 1990, he came to Remington High as the head of the science department.

According to Mike:

... the school had already been established for at least 4 years. However, it was in a temporary port-a-pack structure, a bunch of portables. I think 50 portables were placed on an area of land and they operated a school that way with about 1000 students (March, 1999, interview).

He recalls being informed by the Principal and Vice-Principal that a new building
would be constructed in the coming years. In addition, he was told that the program that would be operational in the new building would be somewhat radical and totally different from the type found in traditional schools. Mike admits that the entire idea at first sounded unintelligible and risky. Nevertheless, he was up to the challenge. In an interview, he noted that:

I saw this as a great opportunity and challenge, because after you’ve been teaching science in a conventional school for more than 10 years, things become pretty well ‘staid.’ New ventures like this in education are really very appealing….. (March, 1999, interview).

Currently, Mike is the head of the science department and he teaches grade 9 science, grade 10 focus program in science, math and technology and OAC physics. Mike and his colleagues also developed the SMT focus program at Remington High.

Mike’s views on science include the fact that certain foundational concepts must be “transmitted” through direct teacher instruction. He feels that it is important for students to develop confidence in science before they are taught about its tentative nature. In essence, Mike believes that students should be taught foundational concepts in science through teacher-directed learning. Beyond that, he advocates a constructivist informed approach to teaching and learning science, which will be discussed in greater detail below.

Constructivism is a very influential learning theory that has been extensively discussed in the science education literature. Educational constructivism draws upon the other constructivist – philosophical and sociological – traditions, but it has its own autonomous roots and history. Educational constructivism of the personal variety
stresses the individual creation of knowledge and construction of concepts (von Glasersfeld, 1987). Within a social-constructivist view, learning is defined as the development of knowledge by individuals through a process of construction that occurs as sensory data are given meaning in terms of prior knowledge in a social context (Driver, et. al 1994). Learning is always an interpretive process and always involves individuals’ construction. From a constructivist perspective, the major curriculum challenge for teachers is to focus on student learning with an emphasis on understanding, rather than stressing content coverage only (Fraser, Tobin & Kahle, 1992).

**Background information on Chris**

Chris is a twenty-six year old teacher who graduated from a Faculty of Education in 1997. During the time he was enrolled in the teacher education program, there was a teacher’s strike. He informed me that he didn’t start teaching immediately because he had a lot of concerns and questions about the teaching profession and the system, particularly in the context of current political debates. Chris’ educational background also includes a degree in visual arts, with a minor in environmental studies.

Chris is also a former student of Remington High, dating from 1988-1992. At that time Remington High functioned as a traditional school, with fixed timetables and classrooms. He states that:

I was contacted by the Principal and she expressed interest in me teaching at my old school. ...a lot of the teachers and colleagues I am teaching with right now are former teachers of mine.....it is interesting to have the first
hand experience as to what it is like to be on the other side of the fence (March 1999, interview).

Currently, Chris is teaching grade 9 science, grade 10 advanced and general level science, and grade 11 human biology. Even though science instruction is not one of Chris’ credentials, he admits that teaching science and environmental science is very important to him. However, he is not too keen to commit to teaching science on a long-term basis. Chris reassures me that his background is in environmental science, and as a result, he prefers an interdisciplinary approach to teaching science, rather than teaching a specialty subject such as chemistry or physics. According to Chris, science is too self-contained a subject and not taught in a manner that makes it relevant to students. He expressed these views as follows:

...science is not a self-contained entity. It seems to be a human perception that science is a unit in itself. That is an incorrect assumption. We still treat science as elite and standing on its own and that no other practice nor subject could even come close to it or relate. We’ve been guilty of doing this for centuries and schools continue to imprint that belief.....and to have that mentality that science can exist by itself is dangerous...(March 1999, interview).

Many of Chris’ views of science and science education are similar to those adopted by nature of science (NOS) proponents. McComas, Clough and Almazroa (1998), describe the nature of science as:

A fertile hybrid arena, which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors (p. 4).

In summary, Chris believes that students as well as teachers must come to the
realization that science is no longer a compilation of theoretical concepts that are somewhat detached from reality. He feels that science is more accountable these days, much more so than in the past. Science as an enterprise, and the concepts associated with it have very concrete social ramifications.

**Background Information on Emma**

Emma has taught science education in secondary schools for 8 years. Her academic qualifications include a combined degree in arts and science. Prior to moving to education, Emma worked as a bank manager. She became disillusioned with the banking profession and the system, and hence, applied to a Faculty of Education and medical school. Emma was accepted by a Faculty of Education and, after graduating from the education program, she worked as a science teacher in a traditional community school. At that time, she designed and implemented the first environmental science program at the school. She also started a master’s degree, which was close to completion.

This is Emma’s first year as a science teacher at Remington High. Emma admits that she moved from a traditional school to this innovative program because she was “very stressed” in the traditional program. In addition, the idea of mastery learning and individualized instruction appealed to her and when the opportunity presented itself, she did not hesitate to join a team of science teachers in this program.

Currently, Emma teaches grade 9 science, grade 10 science and grade 12 physics. Her subject specialty is biology. However, she also enjoys teaching environmental science and physics. According to Emma, science and science
instruction rely heavily on the scientific method, but she also recognizes that science is embedded in society. She believes that "the essence of science is in the scientific method." She states that:

The content really comes out as the scientific method....The science in society aspect, I think, it breaks down barriers....it tries to get us away from science being too hard....also the barriers that exist later in life....where you must be really smart to be a scientist...(March, 1999, interview).

Emma believes that in teaching and learning science, we need to heighten critical awareness amongst students, and encourage them to ask questions such as: "Why are we conducting scientific studies related to, for example, genetics?" and "How will these advances impact society as a whole?"

Many of Emma's ideas related to science in society are congruent with those of Science, Technology, Society (STS) education. STS (Solomon, 1993) is one of the current reform movements pertaining to equality and empowerment. It is one of the most recent trends in science education, with several diverse foci, e.g., science-related social issues (Pedretti, 1996), technology, the history and philosophy of science and technology, environmental crisis, etc. (Ramsey, 1993). In an STS framework, achievements in science and technology are considered in terms of benefiting the common good and fostering the welfare of individuals. Instructional goals are seen as developing an understanding of the natural world and the acquisition of intellectual skills for living and participating responsibly, in a culture that is increasingly characterized by achievements in science and technology (Hurd, 1992). Learners develop a sense of purpose and control about their use of science knowledge and skills.
in the democratic process of social change (Ramsey, 1993). STS education focuses on integrating the needs of society, the discipline and the learner through multiple approaches. These include: 1) approaches through relevance; 2) vocational approaches; 3) transdisciplinary approaches; 4) historical approaches; 5) philosophical approaches; 6) sociological approaches and; 7) issues-based approaches.

In conclusion, Emma’s idea of a good science teacher is one who demonstrates: “good competency in what they teach, they must be open to suggestions and criticism and have a good rapport with kids” (March, 1999, interview). The following chapter presents the data analysis and findings of the study.
CHAPTER 4
DATA ANALYSIS AND FINDINGS

Data Analysis

Interpretational analysis is the process of examining case study data closely in order to find themes and patterns that can be used to describe and explain the phenomenon being studied (Gall, Borg & Gall, 1996).

Data obtained during this study was analyzed using an interpretational analysis approach. By comparing and contrasting the data collected across the set of participants, common patterns and themes emerged pertaining to changes in teaching roles when the context of science teaching and learning was significantly changed.

Interpretational analysis can be carried out either manually or by computer, using computer software programs. In brief, the former approach was employed in this study. The procedures involved included data preparation, which required typing field notes, transcribing the personal journals (4 in total) and the interviews (6 in total) in order to create a "clean record" from which to work. In addition, data identification was utilized in which the data from the transcripts, field notes and journals were organized and cross-referenced. This was executed through the process of coding (Coffey & Atkinson, 1996). During this process, shorthand designation was assigned to various aspects of the data so that specific pieces of data could be easily retrieved during data manipulation. The data was segmented, then coded and grouped into categories. In the final stages of interpretational analysis in this study, there was
continuous comparison of segments within and across categories. Constant comparison method (Merriam, 1988) was employed by the researcher in order to clarify the meaning of each category, create sharp distinctions between categories and decide which categories are most important to the study.

The data are analyzed and presented as a single case study, and include the findings based on all of the participants in the study. Participants’ views and reflections were interpreted using the theoretical framework of this study. Each teacher also had the opportunity to react to, and respond to my interpretations and analyses.

As stated earlier, the purpose of this study was to identify and explore changing and/or emerging roles adopted by science teachers in a different context. In addition, the study looked at the implications of emerging teacher roles for teaching and learning science.

The findings are presented under the broad headings: (i) teachers’ beliefs about teaching and learning science and (ii) pedagogical orientations and teacher roles.

**Teachers’ Beliefs About Teaching and Learning Science**

Studies (Brickhouse, 1989; Tobin, et al. 1990) conducted with both beginning and experienced teachers suggest that classroom instruction is linked to personal beliefs about science and about how students should learn science (Powell, 1994). For example, Brickhouse (1990) found that three experienced teachers’ beliefs about the nature of scientific theories, of scientific progress, and of scientific processes influenced classroom instruction.
A belief is defined as a proposition, according to Tobin, Kahle & Fraser (1990), or a statement of relation among things, accepted as true. To accept a proposition as true is to value it in some way, for logical, empirical, social or emotional reasons. Thus, a belief is used to describe a relationship between a task, an action, an event or another person, and an attitude of a person towards it. For example, the belief that students learn science by listening to the teacher and reading books could link positive attitudes to activities such as lecturing to students, or directing students to read a textbook.

The teachers’ beliefs about teaching and learning science were gathered from responses to the question: What do you consider to be some of the important aspects of science instruction? Mike, Chris and Emma shared similarities and differences in their views, and their responses covered a range of ideas from content knowledge to teacher dedication. In this section I describe the teachers’ beliefs about teaching and learning science and how these beliefs informed their practices.

Mike

Mike’s beliefs about teaching and learning science include the fact that students should engage in: a) an ample amount of teacher-led instruction; b) many hands-on experiences in the science classroom; and c) constructivist learning, only beyond the acquisition of foundational concepts in science. He believes that students should be allowed to develop confidence in science prior to them being taught about the nature of science.

Mike believes that students need direct teacher instruction in the teaching of
science. During an interview, he states that:

I believe that there are certain foundational concepts that need to be transmitted in a very direct way.....very much like an artist would be introduced in a very direct way to the existence of paint of a certain colour…” (June, 1999).

In the following quote, he compares the acquisition of foundational concepts in science to learning a language such as French or Spanish.

A vocabulary has to be mastered before you should even attempt to write a poem or short story in that language. You need to learn the fundamentals ....then the student in science education can go on and explore through inquiry, trial and error and hypothesizing (March, 1999, interview).

Mike believes that there is a time and place for constructivist learning and discovery approaches in science education. He claims that constructivist or discovery approaches would have a place in traditional science instruction if individuals had “all the time in the world” to accomplish this goal. In addition to learning fundamental concepts, he notes that it is essential that students get hands-on experiences in doing science. However, the hands-on experience should be a “good mix” of guided instruction in the laboratory, including design and inquiry, as well as discovery type activities.

Mike maintains that laboratory science is essential in science education. In addition to this, textbook learning and other resources such as audiovisual and computer resources should be included in teaching and learning science. He elaborates on the need for teacher-guided instruction:

Students in science should use up-to-date technologies in the delivery of science. However, computer simulation, computer animation and computer programs should not replace good human teacher instruction or good practical hands-on experiences in the laboratory. I fear that is happening to some degree (June, 1999, interview).
His views on teaching the nature of science (Driver, Leach & Scott, 1996; McComas, et al. 1998), prior to students acquiring a solid foundation of some of the basic conceptual underpinnings include the fact that students should be allowed to develop a confidence in science, and that science does yield reasonable, understandable real results. He stresses this point in the following:

I feel that teaching students early on, I would say grade 9 or 10, that scientific knowledge is tentative, causes a premature loss of confidence. First, we need to build confidence and then we bring students down a notch, at a time they can understand what we mean by the tentative nature of science. If not, students lose faith in science and then figure that science is a very, very tentative thing and you can’t rely on it, and that is not a good thing (March, 1999, interview).

His view on teaching the nature of science differs from Songer and Linn’s (1991) findings, which suggest that knowledge of the nature of science assists students in learning science content.

In summary, to think that in science, students should simply explore without knowing what tools are available with which to explore, is analogous to “putting the cart before the horse.” Therefore, the foundational concepts need to be “transmitted” to students in an efficient way, and the teacher directed method seems to be that “tried, tested and true” mode of instruction. Mike’s beliefs and views on teaching and learning science are sometimes in conflict with the philosophies of the self-directed program. His instructional strategies lie somewhere between exposition and large group mediated conversation on the continuum (Barba, 1998). Mike’s beliefs and views are congruent with those of the role of teacher as “inducer-persuader” or “inquirer-catalyst” (Ellsworth, 1994), see page 21.
Chris’ beliefs and views about teaching and learning science focused on the relevance of science instruction and its impact on society. These are issues central to the five arguments Driver et al. (1996) put forth to support the inclusion of the nature of science as a goal of science instruction. According to Chris:

I think what is really important in science education is relevance. Relevance in the sense ....how science affects students, and how students envision science and their connections to science (March, 1999, interview).

In addition, Chris’ beliefs and views on the impact of science on society are central to STS education (Hurd, 1993; Ramsey, 1993; Solomon, 1993). He repeatedly expressed his frustration with the manner in which science curriculum is implemented. He believes that science is portrayed as being too insulated and the only way to achieve connections is through relevance.

Many concepts in science are very abstract. It becomes relevant to the student and “real-life” if the teacher chooses to make it relevant...I often use metaphors as examples that are readily accessible to anyone...You could talk about subatomic particle theory all day long and not make a connection and that is my focus as a science teacher—how am I going to deliver subatomic particle theory and make it relevant and put it in context for students (June, 1999, interview).

This approach was evident in a grade 9 seminar, conducted by Chris, on “colour.” During the seminar, Chris utilized his artistic background and creativity to provide examples and to make connections to scientific concepts related to the unit.

Chris maintains that the most important thing for students to realize is that science is no longer based solely on theoretical concepts, nor is it detached from present day realities. He adds that students need to understand that science is not a
self-contained entity. Science has been given the status of “elite”:

We do it for centuries and schools imprint the belief that science is elite. That is our role in society...to have that mentality that science can exist by itself is dangerous...because someday you will leave the school system and specializing in one area only is not very good. We take the whole thing of division of labor too literally in our society (June, 1999, interview).

In summary, he believes in and advocates a cross-disciplinary approach, or the idea of “exposing science to other disciplines” in order to (1) make things relevant; (2) make connections, because, after all, individuals differ in backgrounds, experiences, learning styles, mentality and attitudes.

Creativity in science is central to Chris’ views and beliefs about science and science education. In his opinion, art and science are equal. Art deals with harnessing creativity, whereas in science, creativity is used to explore facts and theories. In a conversation with Chris, he expressed his views on creativity in science instruction:

The whole idea of teaching is really performance, if you think about it, you are performing and you are engaging an audience. If I didn’t have to teach color 15 times, I would dress up as an artist and turn that classroom into a studio (May, 1999, conversation).

Nevertheless, even though certain aspects of the self-directed program provide constraints, with respect to teaching and learning, as mentioned above, Chris’ beliefs about teaching and learning science are, for the most part, congruent with his experiences and practices at Remington High.

Emma

Hand (1996) indicates that there is a need for science teachers to change and adopt new pedagogical knowledge and to examine their common practices in order to
implement student-centred rather than teacher-centred approaches. This view parallels Emma’s beliefs regarding teachers’ general knowledge about science. Teaching and learning science, according to Emma, requires 3 components—general knowledge about science, an understanding of the scientific method and an awareness of the societal component. She elaborates on these components by stating:

I see science instruction as having 3 components. One is the general knowledge component. The second is the thought process, behind, what I mean is the scientific method. The scientific method is unique to science the same way a historical method is unique to history. Students have to learn how to ask scientific questions and how to answer them... the third is the societal component. Science and technology are advancing rapidly, however, we need to go back into society and ask critical questions as to the reasons for advances in science (March, 1999, interview).

The components essential to teaching and learning science, as expressed by Emma, are features central to NOS objectives (Driver, et al. 1996; McComas, et al. 1998), as well as STS issues (Hurd, 1993; Ramsey, 1993; Solomon, 1993). Emma stresses the need to relate science to society in order to remove barriers that students may encounter later in life. She maintains that:

The science in society aspect really breaks down barriers. It tries to get us away from science being too hard... also the barriers that exist later in life... where you must be really smart to be a scientist (March, 1999, interview).

In general, Emma’s beliefs about teaching and learning science are sometimes not in agreement with her experiences and practice at Remington High. This aspect of the study will be discussed in the section on innovative science instruction and pedagogical practices.

In summary, Mike, Emma and Chris possessed varying beliefs about science,
and the teaching and learning process in science. These beliefs are an important part in determining the nature of their classroom roles (Tobin, 1993) and their practice (Brickhouse, 1990).

In the following section, Mike, Chris and Emma’s past experiences in traditional classroom instruction will be explored. Emphasis will be placed on: (1) pedagogical practices; and (2) teaching roles and metaphors they use to describe their roles in traditional classrooms.

**Pedagogical Orientations & Changing Teacher Roles**

**Traditional Instruction and Pedagogical Practices**

The dominant traditional instructional model has been termed a “banking” model (Friere, 1983), on the grounds that teachers are expected to deposit information and skills in students’ memory banks. The basic premise of this model is that the teacher’s task is to impart knowledge or skills to a student. This implies that the teacher initiates and controls the interaction, constantly orienting it towards the achievement of instructional objectives (Cummins, 1996).

In this study, several pedagogical practices were identified and utilized by the teachers in their traditional classroom settings from their past experiences. These include: lecture, classroom discourse, collaboration, teacher-guidance, as well as student activities. In addition, the teachers’ beliefs about science, as well as teaching and learning science, largely determined many of their classroom practices, and ultimately, their roles in the classroom. Within their traditional classrooms, several
pedagogical practices were identified, ranging from discourse to lecture activities. The pedagogical practices are discussed below.

**Mike's traditional classroom.** In order to envision traditional classroom instruction, Mike recommends reading the book, *1001 Performances A Year*. He describes his experiences in a traditional classroom as follows:

The impetus is on the teacher to perform and the performance has to do with delivering the curriculum...the student needs the teacher to teach them everything. Teachers feel the pressure and they spend a heck of a lot of time every evening preparing. We learn in teacher’s college how to prepare lesson plans in a recipe style. It is written by the teacher, for the teacher, in preparation for the next performance. It is programmed instruction. The teacher is very much programmed, much like a robot (June, 1999, interview).

Mike admits that even though the organization of traditional classrooms restricts certain pedagogical practices, there are many others that can be implemented. He states that:

Administrators and parents especially, expect teachers to do active learning with students. Now by teaching, I don’t mean lecturing alone...I’ve done a lot of neat stuff with my classes. For instance, you could show a video, have students utilize computer facilities, do role-playing or small group activities, laboratory activities, demonstrations. You can talk about issues and have discussion groups (March, 1999, interview).

Mike maintains that these are “tried and tested” instructional methods, however, they are constrained by the number of students in a class, and time. He painstakingly recalls, in a conversation, “in order to complete the curriculum from the beginning of September to the end of June, teachers know that every moment of every period for the whole year has to be dedicated toward some sort of lesson teaching strategy.” His views and teaching practices employed during traditional instruction are in agreement
with those provided in chapter 2 regarding traditional science instruction (AAAS, 1990; Barba, 1998; Hodson & Reid, 1988; Renner & Lawson, 1973; Tobin & Gallagher, 1987).

**Chris’ traditional classroom.** Chris’ experiences in a traditional classroom were acquired during the practical portion of a teacher education program. According to Chris, his teaching experience in the conventional classroom was:

...similar to a seminar where I have 20 kids in a classroom and I am talking most of the time, if not all the time. I am the focus of attention. It is didactic and all I do is impart knowledge ...the students don’t have a freedom of choice at this point...I am their primary source of information (June 1999, interview).

Chris felt that even though his instructional strategy was somewhat didactic, he made every attempt to engage the students in discussion groups. In the laboratory environment, Chris recalled the following:

I noticed a lot more demonstrations in a traditional school. Students didn’t have many opportunities to explore as much, especially on their own. Their choices were limited in both areas—lecture and self-exploration (March 1999, interview).

He maintains that in a traditional setting, the focal point is the teacher and, as a result, there are a lot of preconceived assumptions when the teacher is teaching in front of the classroom:

One of the assumptions is that every student will understand the method of instruction then and there, and that everyone will be on the same page, so to speak. Unfortunately those assumptions hamper the progress of the students. Some students will be able to understand the instructions right away and work at a pace conducive to learning, while those who need help may not seek help and end up not doing so well in school (June, 1999, interview).

Chris’ accounts of traditional classroom instruction are reflected in similar studies
(Green, 1982; Hand, 1996; Kapuscinski, 1992; Tobin & Gallagher, 1987) in which traditional science instruction was represented as teacher-centered and didactic in nature.

**Emma’s traditional classroom.** After 8 years as a science teacher, Emma describes traditional science instruction as “all consuming.” She recalls that in that setting:

> I was more of an instructor...I found myself trying to take myself out of the role more...It became harder to change my hat because students always expect you to be there for them. I felt that I was in the spotlight all the time (March, 1999, interview).

She admits that teaching and learning in a traditional classroom really “tapped my creativity.” According to Emma, teaching was energy consuming, starting with the lesson plans. She followed a regular sequence of events—a 10 minute talk or activity based work, followed by a question and answer period, and then individual work. This routine of preparing for lessons, and “getting the lines correct” created a lot of stress, which, coincidentally was her reason for leaving the traditional science classroom.

In Emma’s traditional classroom, she insisted that every effort be made to implement a variety of pedagogical practices. For example, in her Science In Society classroom, she provided a forum for discourse amongst students. She noted that:

> The Science In Society course became a discussion of ideas, thoughts and perspectives. Sharing in so many ways provides a forum for students to learn from peers. There is some back and forth sharing between teachers and students....In the laboratory atmosphere, co-operation is definitely fostered. There has to be co-operation when there are 30 or 40 students (June, 1999, interview).

In general, distinctive features associated with traditional instructional practices in science education were common to Mike, Chris and Emma’s teaching in traditional
school settings, as illustrated through their personal testimonials. The prevalence of constraints, such as numbers of students, and the amount of time allocated to science instruction, deterred certain pedagogical approaches. Nevertheless, some pedagogical practices such as classroom discourse, collaboration, co-operation, small group discussion, as well as lecture were adopted and implemented by the teachers in order to facilitate science instruction in a traditional setting. Hence, along the continuum of instructional strategies (Barba, 1998), Mike, Chris and Emma’s traditional instructional strategies could be located between exposition and small group negotiations and interaction.

Teacher Roles & Metaphors. The study revealed that some of the teacher roles occupied by Mike, Chris and Emma in their traditional classroom, and metaphors used to describe these roles, are congruent with teaching roles identified in traditional classrooms (Ellsworth, 1992; Olson, 1981; Tobin, et al. 1990).

According to Mike, the role of the teacher determines the manner in which science instruction is delivered in a traditional classroom. In a conversation, he stated that:

The teacher’s world view, the teacher’s grounding in science, their dedication to science, the teacher’s personality all comes into play in a major way (April, 1999, conversation).

When Mike spoke about teaching science in a traditional classroom, he used metaphors such as “sage on the stage” or “teacher as deliverer” to explain his roles, actions and thoughts. The metaphors reflected teacher-centered activities, which were controlled by the teacher:
Teachers deliver the curriculum to the students in traditional classrooms and they do it by a live performance method. And so teachers feel as though they’re on stage, like they’re the performers and the students are the passive audience (March, 1999, interview).

Mike disagrees with the premise that students need to be taught and ‘told’, and that curriculum delivery must be implemented and delivered by the teacher. Rather, he refers to the teacher as the “pace-setter” and “in control” of everything in traditional science classrooms. He maintains that the pacesetter role is very important to a teacher. According to Mike, teachers ensure that their working conditions are reasonable by having control (Barton, 1996; Bond, 1981; Cummins, 1996; Tobin, 1993). In a classroom setting, teachers have control over what assignments are given, when assignments are collected and evaluated. In fact, he states that teachers have full control over all the activities that occur in a classroom, hence, teachers manage classrooms through control.

Similarly, Chris agreed that the role of the teacher is important in science instruction. He notes that a teacher’s role is important to the “delivery” of instruction. The manner in which they deliver the curriculum, their philosophies about teaching, their personalities as individuals, their openness to new ideas, and their attitude towards the possibility of exposing science to other disciplines and making connections, will determine exactly how students will learn science. When describing his role as a traditional classroom science teacher, Chris uses the metaphor “teacher as purveyor of knowledge”:

From the traditional aspect, it really reiterates the idea that the teacher has all the knowledge. The teacher is the individual who imparts information and knowledge. I am the purveyor of knowledge and everyone else around
me is an empty vessel that I have to fill...the teacher is the focal point of information (March, 1999, interview).

Chris added that a more authoritative, controlling teacher role is fostered in a traditional classroom. As a result of teacher control, he believes that certain students suffer academically:

I think the really "strong" students are the ones that will express themselves individually, but the ones that need more help may not be able to do so in a traditional setting because of a controlling teacher...the stronger students will move forward while the weaker students are moved to the back of the class, so to speak. They're the ones that are marginalized in a traditional classroom (June, 1999, interview).

Emma emphasized the importance of the role of the teacher by stating, "who you are is going to determine what your role is going to be, and ultimately, how you will deliver instruction in science classrooms" (March, 1999, interview). Her traditional classroom roles included those of an authoritarian and a facilitator:

In some ways, traditional classroom teachers play a very authoritarian role. In other ways, I see it being very much sharing. In my Science in Society course, for example, there was a discussion of ideas, thoughts and perspectives. Sharing in so many ways provides a forum for students to learn from peers. In the sharing mode, I would be a facilitator or chairperson. I am definitely a disciplinarian. One of my biggest roles would be maintaining order (March, 1999, interview).

She also used metaphors such as: “teacher as knowledge givers; teacher as authoritarian; and teacher as purveyor of knowledge” to describe some of the teaching roles she assumed while teaching in a traditional classroom environment.

In summary, the study revealed that the role of the teacher is of paramount importance with respect to classroom instruction. Teachers’ philosophies, as well as their personalities, influence the manner in which curriculum is implemented. In
addition, metaphors such as “teacher as performer; teacher as fount of knowledge; and teacher as purveyor of knowledge” succinctly capture the teacher-centered roles they took on while teaching in conventional classrooms and schools. Overall, the role of teacher as inducer-persuader (Ellsworth, 1994) was prevalent in the teachers’ accounts of traditional classroom teaching roles; that is, pedagogical practices were largely content driven, with an emphasis on teacher led instruction (Barba, 1998).

The following section will be devoted to describing the innovative science program in which the study was conducted. Pedagogical practices as well as teaching roles fostered in this self-directed program will be discussed in tandem. Since the teachers did not have their “own” classrooms per se, their stories will be integrated, as opposed to the format employed previously. In addition, the impact of these practices and teaching roles on teaching and learning science will be highlighted.

Remington High: Innovative Science Instruction and Pedagogical Practices

Teaching at Remington High. In the science program at Remington High, the student is considered to be an apprentice. The curriculum is student-centred, hence student initiated, as opposed to teacher-centred or teacher implemented, as in a traditional classroom. In this program, science teaching and learning occur through student modules called learning guides (a brief description was provided at the opening of the study, see chapter 1). Students follow instructions in the learning guides to complete assignments, laboratory exercises and clarify misconceptions. These instructions direct the students to three areas: the resource area (Fig. 2, p.11),
the laboratory areas (Fig. 3, p.12), or the seminar room (Fig. 4, p.13). These areas are located within the science department at Remington High, which also houses the science office and the dispensary.

Upon entering the science department, one is immediately faced with the resource area. Most of the time, the resource area is filled with students (approximately 50 students) from grades 9 to OAC. There is usually a lot of movement, with many students departing or entering this section. This area is architecturally designed to reflect an open concept; hence, there are no partition walls in this central core of the science department. Light beams down through a skylight. The physical arrangement of the area resembles a typical lecture hall, with chairs and desks arranged in rows (Fig. 2, p.11). The surrounding counters are used as computer centres and are often occupied by students using the computers. The walls display many projects done by students. These walls also display cabinets filled with preserved specimens.

In this area, the primary mode of instruction is one-to-one student and teacher discussion. However, it was not uncommon to witness student-student interaction during peer tutoring. All three teachers implemented instructional strategies that reflected one-to-one, self-directed learning in the resource area. For example, on one occasion I observed Mike assisting a student with a question in chemistry for approximately 30 minutes. The one-to-one interaction is highlighted by the manner in which he guided the student through the question by illustrating the concepts via diagrams. During this time, the other students in the resource area were working
and/or involved in conversation with each other. Chris and Emma engaged in a similar mode of instruction in the resource area.

Clearly, in this free-flowing environment, a distinct pedagogical practice emerged. During a conversation, Mike described science teaching and the accompanying teacher role in the resource area as follows:

Science instruction is delivered through the individualized learning guides, with teachers meandering throughout all the rooms in the science area ready to assist students. They act as tutors; basically it is a one-to-one kind of learning (April, 1999).

The instructional strategy implemented reflects self-directed learning (Barba, 1998), which focuses on student-centered rather than teacher-centered learning. This teaching strategy fosters teacher roles equivalent to those of a dialogist, which incorporates a discourse format between the teacher and the student, and a facilitator, in which the teacher provides support for the student (Ellsworth, 1994).

Surrounding the resource area are the laboratories and seminar rooms. The laboratories at Remington High are similar to those found in universities. The students rely on the paraprofessional for the preparation of all glassware and lab equipment. Materials needed for the lab exercises are usually found in the LABKITS. The laboratory is exclusively used for conducting experiments. Therefore, students are not permitted to conduct “bookwork” in the laboratory. Each of the three laboratories has a capacity for 36 students and the students often work in pairs or groups of 4 to complete laboratory exercises. The teacher is usually at the front of the laboratory or moving around the room. Activity within this area, as opposed to the resource area, is greatly reduced.
Chris assured me that there are rarely more than 20 students in the laboratory at a time. No demonstrations are conducted in the laboratories as a result of a variety of experiments occurring concurrently throughout the different grade levels. For example, during one of my visits to Chris’ biology laboratory session, I witnessed 6 different experiments being performed by grade 9, 10, 11, and OAC students at the same time! This aspect of the program provided some challenges for the teachers. For example, during one of the lab sessions when a student approached Chris regarding a question based on a biology exercise, Chris directed the student to a teacher in the resource area. He explained to me that not all of the teachers knew all of the laboratory experiments in detail, and that sometimes they would refer the student to another teacher.

Another feature of this innovative program is the abundance of laboratory exercises included in the science curriculum. The program advocates and presents ample opportunities for students to experience practical work in science. According to Chris, most units have a lab, which amounts to at least 12-15 labs in each science course. He maintains that because of this feature, along with the flexibility of the self-paced program, students can explore science at a deeper level. In particular, students do not feel compelled to move on until they have a deeper understanding of the phenomenon in question.

Both Mike and Emma agreed that this innovative program has enhanced science learning because it allows students more time to rationalize and think about experiments. Mike reminded me that students could take as long as they needed to
prepare for, conduct, analyze, and think about the results of an experiment without ever having to leave the laboratory. This view was also evident during an interview with Emma:

The key to this program is the amount of lab work and activity based learning that takes place. The LABKIT system makes it easy. With the one-on-one advising and questioning, you can be much more in depth about concepts, especially in physics. If a student comes to you and asks you a question, you can respond in depth or not as in-depth, depending on the needs of the student. You can tailor the assistance as the student needs it (March, 1999, interview).

These views, shared by Mike, Chris and Emma, reflect attributes identified as essential to the successful departure from traditional modes of instruction to those that empower both teacher and taught (see chapter 2). These features include: quantity and quality of teacher talk; provisions for continuous progress; relationships with teachers; and, discussion and interpersonal skills (Georgiades & Clarke, 1974). In particular, there is a strong correlation in this study between the teachers’ views and the time provision for continuous progress (Bloom, 1961; Green, 1982; Kapuscinski, 1982; Pedretti, et al. 1998), as well as the quantity and quality of teacher talk (Hand, 1996; Hodson & Reid, 1988).

During observation of laboratory sessions it was not uncommon to notice teachers assisting students, or teachers asking questions about an experiment in progress. For example, Chris’ approach in the laboratory includes questioning the students about the theories behind the lab they were conducting. Hence, one of the roles that Chris fulfills on such occasions is that of a “catalyst” or “inquirer.”

Emma, on the other hand, occupies multiple roles concurrently. During a physics lab session, for example, Emma reminded a student to dress properly before
coming to school, encouraged another student to complete her units after the student informed Emma that she wanted to fail the course, and took care of administrative duties by informing students that their unit grades were recorded and they were now eligible to write the unit test. In addition, she frequently fulfilled the roles of resource person, clarifier and catalyst by providing assistance to, and questioning students who were experiencing difficulties during the laboratory exercise. Emma views her role in the laboratory as an important one:

I think in the lab situation there is less group sharing, so my role becomes paramount in the lab. Because there is less sharing between students and the fact that there are different grade levels doing different experiments, the only other person that knows what is going on, except their group members, is me. In a regular [traditional] classroom, the students can check with others in the class regarding the lab. Whereas, here, I am the only one (June, 1999, interview).

In summary, it is evident that the instructional strategies and teacher roles adopted while in the laboratory areas at Remington High are unique to the program. In this particular environment, instructional strategies utilized are situated between small group interaction and student-centered, self-directed learning on the continuum (Barba, 1998). In addition, teachers fulfil multiple roles including that of a resource “person”, a “catalyst”, a “motivator”, a “parent”, an “inquirer” and a “dialogist”. These roles are congruent with that of the inquirer-catalyst, dialogist and facilitator roles (Ellsworth, 1994), which move away from the content driven, teacher led format or “teacher as purveyor of knowledge” metaphor, which is often indicative of traditional classroom instruction.

In addition to laboratory activities, seminars are conducted at certain “pitfall”
areas in a science course, where it has been predetermined that this mode of instruction would be the most efficient way to “deliver” that part of the curriculum. In addition, seminars are also used for laboratory demonstrations that are too dangerous for students to conduct on their own.

The physical arrangement of the seminar room, the pedagogical practices and the teacher roles associated with seminars, are sometimes reminiscent of traditional science classrooms. In a conversation with Mike, he indicated that:

They [teachers] also perform seminars, which are a more traditional approach where a teacher actually teaches a lesson...so students do attend more traditional style seminars, which are like classroom instruction (April, 1999).

The prevalent instructional strategy identified during the seminars observed was teacher-led, traditional science instruction. This was also evident in Chris’ comments:

Seminars are still quite close to the traditional format of instruction in which I am in front of the room instructing the students. I am talking most of the time, like a “talking head” in front of the class (June, 1999, interview).

This method of science instruction was also evident during Emma’s grade 12 seminar on electricity. The seminar commenced with Emma reviewing concepts in electricity via overhead transparencies. This was followed by a demonstration in which a puffball and rod were used to illustrate the concept of static electricity. Thereafter, the remainder of the seminar was dedicated to Emma copying notes onto the chalkboard and lecturing. She frequently had to remind students that there was no need to copy the notes, because the information was available in their study guides. The students, however, ignored her and diligently copied notes from the chalkboard and overhead transparencies throughout the seminar. During the seminar, Emma provided many
opportunities for students to ask questions pertaining to the lesson. In Mike's SMT focus group seminar on facets of a good debate, Mike was at the front of the classroom, while the students were sitting and listening attentively. Again, the primary instructional strategy during the seminar sessions was lecturing.

The instructional strategies and teacher roles identified during seminar sessions are typical of some conventional science instruction (Hodson & Reid, 1988; Tobin & Gallagher, 1987; Weiss, 1981). The instructional strategy is expository in nature, with some large group mediated conversations, and exclusively teacher-centered (Barba, 1998). This mode of instruction utilized in seminars also fostered teacher roles similar to that of a "teller or purveyor of knowledge" (Reinsmith, 1992).

In conclusion, this innovative science program clearly illustrates that the pedagogical practices and teacher roles fostered in this particular context do not necessarily parallel roles and practices fostered in more conventional classroom contexts. Within this innovative program, there were significant additional instructional strategies and teacher roles adopted by teachers.

Instructional strategies at Remington High varied, depending on the location in which science teaching and learning was taking place. Evidence clearly indicates that the instructional practices prevalent in the resource area are located on the far right of the continuum; that is, one-to-one, student-centered, self-directed learning. The laboratory environment encourages instructional strategies dedicated to small group interactions. Finally, the seminars fostered teaching strategies located on the far left of the continuum; teacher-centered, expository modes of instruction (Barba, 1998).
Traditional teaching roles and metaphors common to both teaching contexts included: “teacher as purveyor of knowledge” and “teacher as performer.” In addition to these traditional roles, the science teachers in the study adopted “new” roles such as: facilitators, mentors, and catalysts, to name a few. Some metaphors used to describe their roles included “teacher as catalyst, teacher as information generator, and teacher as co-learner.”

Reconceptualizing Pedagogical Practices and Teacher Roles. In spite of the positive features identified, this study also revealed some negative aspects associated with teaching in the innovative science program at Remington High. These included: the lack of discussion skills and interpersonal relationships; uncertainty among teachers with respect to certain teacher roles; teachers’ lack of satisfaction and self-fulfillment; and loss of teacher identity.

According to Georgiades and Clarke (1971), one of the key elements for successful self-directed learning is the development of discussion skills and interpersonal relationships. At Remington High, however, teachers commented that discussion skills and interpersonal relationships are not well-developed. This is reflected in Emma’s journal entry:

One of the things that has taken me aback by seminars is that these kids don’t want creativity. You try and do anything different and they’re lost. They expect information generators. There are no discussions, barely one word. They just want the information (April 11, 1999, journal entry).

In addition, group learning, discussion, and collaboration are absent from the program.

Emma points out that:
There is an emphasis on individuality here and let's get on with it. I find absolutely no discussion here. In a regular [traditional] classroom, there would never be a course without talking or engaging in discussion with students and teacher. I don’t find any forum here to do that, so it is isolating in the sense of group work and encouraging different perspectives (June, 1999, interview).

Clearly, the promotion of discussion skills and interpersonal relationships between teacher and student is difficult to accomplish in this environment. An observation that is contrary to Georgiades and Clarke (1971) and Candy’s (1991) declared prerequisites for implementing successful self-directed programs.

Even though many of the teacher roles identified in the study were positive in nature, other roles created uncertainty and insecurity amongst the teachers. Interestingly, the role of teacher as facilitator created uncertainty in Emma’s mind regarding the extent to which learning really occurred in the program. She noted that:

My role is more of a facilitator and because there is very little telling, I don’t really know where they [students] are at...In other classrooms [traditional], I know what I have given them and I know they will complete it. Here, it is not the case. I would love to assume that they have read their textbooks, but they don’t necessarily and I don’t know that...so we have to go back to what they do know (June, 1999, interview).

In addition, Mike compared his teaching role to that of an “assembly line worker,” working on parts without much “holistic” teaching occurring. This role resulted in a lack of satisfaction and self-fulfillment amongst the teachers. Mike maintained that:

Not seeing my own classes of students every day causes me to have little influence on students. Here, we are very much like “flies on the wall.” The classroom experience is missing...there is something immediate about that kind of teaching. It [the program] doesn’t allow a teacher to influence in a very continuous fashion, the developmental progression of a student’s science education...it does cause us to feel a lack of satisfaction...many of us yearn to have our own classes (June, 1999, interview).

Furthermore, Chris expressed his discomfort with the role of teacher as “conformer”.
Team-teaching in science, which is a feature that is essential to the successful implementation of this innovative program, fostered this conformist role. Team-teaching (Roth, 1998) is hailed as a mode of instruction that provides opportunities for teachers to reflect, interact with each other, share, learn, and develop in their practice. However, Chris believes that team teaching in this context fosters the role of teacher as "conformer". He commented that:

"It is woven by the concept of team teaching...and the idea of not necessarily holding on too much to your own ideals...it is one big compromise amongst teachers. You have to be willing to conform to the ideals of your department (June, 1999, interview)."

While the program is conducive to team teaching, it is clear that a lot of "negotiation" and "compromise" is needed. For example, in seminars, all the teachers must teach "the same lesson, and be on the same page." During a conversation, Chris remarked that, "it shatters teacher identity and any sense of territoriality" (June, 1999).

Chris' view of team teaching confirms the results of a study in which team teaching in an innovative environment was virtually abandoned because of the difficulties that some staff experienced in adapting to this model of instruction (Tobin, et al. 1990). It is, however, in conflict with the current argument in the educational literature, which claim that team-teaching is enriching and a viable tool for professional development.

In addition to a lack of satisfaction and self-fulfillment, the teachers also experienced problems associated with teacher identity and teacher isolation. During seminar observations, it was apparent that the teachers were experiencing a loss of teacher identity as well as some form of teacher isolation. Emma corroborated this
observation by stating:

I don’t know most of the students....I can’t be myself...I always get different kids and the comfort level is not there. Not knowing their names, not being able to call them out, not having them feel comfortable to laugh at me—I do want them to do this, but they don’t because they don’t want to know me (June, 1999, interview).

Chris also commented that even though the system advocates one-to-one relationships, it also encourages impersonal relationships because of the fact that the students are not taught by the same teacher, sometimes for the entire year.

It is evident from the preceding examples that there are some negative effects associated with this innovative program, which primarily advocates instructional strategies positioned at the far right of the continuum (Barba, 1998). In this particular innovative program, uncertainty and discomfort, related to certain teacher roles (Ellsworth, 1994; Reinsmith, 1992), amongst teachers, resulted in some loss of teacher identity, teacher isolation and lack of self-fulfillment.

To summarize, Table 1, p.77, presents a synopsis of the findings of the study on teaching and learning science, as well as teaching roles associated with this innovative science program. Mike also captured these features in the following excerpt:

Remington High is more like an emergency department at a hospital. You don’t know who is coming, you don’t know what the problem is, you don’t know how many are coming at a given time. In other words, any possible problem can come in at any time. Literally, hundreds of problems can present themselves at the same time. You are teaching in a very dynamic, very unpredictable, in many cases crisis management fashion than you will ever be exposed to in a traditional school (June, 1999, interview).

In conclusion, even though the program has a rather unique set of pedagogical practices, with its unique set of challenges, all of the teachers agreed that this
innovative program has enhanced (1) science teaching, and (2) the school science experience for students. Some of the major areas of enhancement include: the flexibility of timing, reduced boredom resulting from teachers repeating content material, unlimited progress with no barriers, minimum teaching, increase in hands-on experiences and one-to-one interaction.

**Discussion**

Teachers have many sets of beliefs that are appropriate for a given teaching role in specific contexts. The relevance of beliefs and role conceptualizations are dependent on factors such as the physical milieu in which learning is to occur, the age and ability of students, the time of day, the extent to which the teacher possesses the pedagogical content knowledge needed to implement the curriculum, other subjects to be taught on a given day, and other within and out-of-school factors (Fraser, Tobin & Kahle, 1992). The results of this study indicate that while many sets of beliefs influence and guide teaching roles adopted in a classroom, the context in which teaching and learning occurs plays a crucial role in determining the nature of teaching roles. For example, in their traditional classrooms, the teachers implemented pedagogical practices that paralleled their theories and beliefs about science, and the teaching and learning process. Instructional strategies in the traditional setting focused on teacher-centered exposition techniques, with some integration of group activity and mediated conversation (Barba, 1998). Consequently, their beliefs played an important part in determining the nature of their classroom roles (Tobin, 1993). Their teaching roles in the traditional context can be described as inducer-persuader (Ellsworth, 1994), in
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<td>Seminars, labs, resource areas</td>
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<td>Collaboration</td>
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<td>Teacher-guidance</td>
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<td>Lectures &amp; activities</td>
<td>Learning guides</td>
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which teaching is a content driven activity with the student assuming responsibility for learning. In addition, the teacher is in control of all classroom activities, thus often creating a rigid and unresponsive structure, which can "severely inhibit student self-directedness and establish an unhealthy dependency which turns students away from learning" (Bond, 1981).

Metaphors and beliefs associated with a given role are context dependent and can be "switched" as the teacher perceives that different courses of action are warranted by the context (Fraser, et al. 1992). Findings of the study indicate that when the context of teaching and learning science was drastically changed in an innovative program, the teachers' beliefs and convictions about teaching and learning science did not necessarily coincide with: 1) the pedagogical practices they implemented, and 2) their teaching roles. For example, Mike's belief about the importance of teacher-directed learning in science did not always parallel the pedagogical practices he implemented in the program. His beliefs and convictions about the teaching and learning process were not always reflected in the teaching roles he adopted in the innovative program. Similarly, Emma's beliefs about the importance of discourse in science education were not always highlighted in her pedagogical practices or in her teaching roles she adopted in the innovative program. In general, the teachers adhered to teaching roles that paralleled the philosophies of the innovative program. Hence, some of the common roles shared included: teacher as facilitator, teacher as catalyst, and teacher as resource person.

The teaching roles adopted in this innovative program were a direct result of the
context in which teaching and learning occurred. The resulting disparity between teaching roles and teaching beliefs presented several challenges for the teachers in the study. The new teaching roles fostered in the innovative program conflicted with those adopted in the traditional context. As a result of conforming to prescribed roles associated with the innovative program, the teachers experienced repercussions, sometimes resulting in feelings of teacher isolation, teacher disempowerment and loss of teacher identity.

Making the shift from a traditional classroom to an open learner-directed environment is a difficult undertaking. It requires that we, as teachers, become willing to learn from our students. Adopting a learning-through-teaching stance involves risk. It means giving up security and consciously allowing ourselves to become vulnerable (Newman, 1990). In conclusion, the study is by no means suggesting that one pedagogical orientation is preferred over another in science education. Nor am I suggesting that teachers’ beliefs and roles are the only factors influencing curriculum implementation, and the teaching and learning process in science. I am, however, suggesting that the context in which teaching and learning occurs does impact: 1) teaching beliefs and, 2) teaching roles.
CHAPTER 5
FINAL REFLECTIONS

Implications of the Study

The observed results of this study engender many questions; some of which are easily answered, and others which require further investigation. The major implications of this study are in the area of professional development, curriculum and collaboration to bring about change.

This study could be beneficial for teacher professional development at Remington High, as well as other institutions contemplating innovations in instruction. Over the past 50 years, professional development (Fullan & Hargreaves, 1996) has evolved from a focus on individual growth, to a fostering of organizational growth, and now to a more systemic, integrated perspective. During the past decade, educators have realized that, without the support of the organizations in which they work, teachers are often prevented from using their newly acquired knowledge and skills to benefit their students (Loucks-Horsley, 1995). Hence, the results of this study can provide further insights into pedagogical practices fostered in innovative science education, and the manner in which teachers' beliefs about teaching and learning science impact these practices. In addition, the findings related to the use of metaphors to conceptualize teaching roles, raise the possibility that significant changes in classroom practice are possible if teachers are assisted in understanding the roles of science teachers in terms of new metaphors (Fraser, et al. 1992).
Since the study did not focus on nor assess the content of the science curriculum at Remington High, I cannot address curriculum changes, except to suggest that in order to move from traditional didactic approaches to teaching and learning science, curriculum needs to be modified to include more student-initiated rather than teacher-centered activities.

Finally, change is a relatively slow process and with every innovation comes resistance to change. The implementation of this innovative program at Remington High suggests that in order for educational change to be successful, all stakeholders must work collaboratively to establish common goals, define individual roles, and negotiate an agreed upon course of action to achieve the desired change (Woodrow, Mayer-Smith & Pedretti, 1996).

**Limitations of the Study**

In order to further explore the pedagogical practices, beliefs and teaching roles of the teachers at Remington High, a repertory grid technique (Bezzi, 1996) could be administered to the teachers in order to obtain the teachers’ “personal constructs.” A repertory grid is a two-dimensional matrix depicting relationships amongst a person’s personal “constructs” and specific “elements”. For example, “elements” can be particular teaching strategies and “constructs” can be characteristics of those particular elements.

In addition, as a result of the ethics involved in this case study, and the particular foci I established, I did not obtain students’ account of the teaching roles and pedagogical practices adopted by the science teachers in this program. These data
would provide another perspective on teaching and learning science at Remington High, and would considerably enrich the findings of this study.

**Possible Directions for Further Study**

Many facets of this innovative science program require further study. An extension of this study would be to survey and interview students, to examine their account of teaching and learning in this innovative program. Secondly, it would be worthwhile to look at the effect of teacher belief and teaching roles on student roles and performance in the self-directed program at Remington High. Finally, a detailed investigation exploring the "science" context would be helpful. For example, "What does "science" look like in this new environment?" or "What are the possibilities for conceptual understanding, inquiry, design and communication, and for connecting science to technology, society and the environment?" All of these offer intriguing possibilities for further research.
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Appendix A: School Consent Form.


Principal
School
Toronto, Ontario

Dear Principal:

Following our second conversation, I would like to take this opportunity to further inform you of the research I am conducting involving teaching roles and science instruction. I am most grateful and appreciative of your cooperation and enthusiasm in the research endeavor. As you already know, I am a graduate student in Curriculum at the Ontario Institute for Studies in Education, of the University of Toronto. I am conducting a case study research focusing on the role of the science teacher in a non-traditional school setting. The objectives of the study are: to explore and identify new or emerging teaching roles experienced in a different teaching and learning context; to understand how teachers perceive their roles in different contexts; and the implications of new roles for instruction in science education.

Data collection for the research shall be conducted in a number of ways. Group meetings will be tape-recorded and supplemented with field notes. As well as regular group meetings, I would like to conduct individual interviews throughout the duration of the study. These meetings and interviews will be transcribed and copies made available. I would also like the opportunity to visit the school to observe a non-traditional approach to teaching and learning science, as well as teachers in different roles. Audio tapes, field notes and observation notes will be collected and shared with teachers. These school visits will help me to understand the particular circumstances of science instruction in this setting as I attempt to explore and reflect on teaching roles. Participating teachers will be encouraged to keep a journal. In recording their experiences, participants will reflect on their teaching practices as well as the meaning of the roles they occupy in these practices. Accordingly, I shall also keep a two-part journal throughout the study. The journals will become an important part of the data, as I attempt to explore and understand the role of the teacher in a different context of teaching and learning. All data and interpretations will be shared with the participants. In addition, the participants may withdraw at any time, without reason.
I look forward to visiting your school, and working with a member of your faculty. If you have any questions please do not hesitate to contact me. Thank you for your support, and for your interest in exploring teaching practices, in this unique and innovative school.

Sincerely,

Isha DeCoito
Department of Curriculum, Teaching and Learning
OISE/UT
Appendix B: Teacher Consent Form

February, 1999

Dear Participating Teacher:

I would like to take this opportunity to formally invite you to participate with me in a case study, “Innovations in Science Education: Reconceptualizing Teaching Roles in a Self-Directed Program” conducted from March, 1999 to June, 1999. This research will be submitted in the form of a thesis to fulfill the requirements of a Master of Arts degree at the University of Toronto. Your agreeing to join me in this research will allow us to explore teaching roles experienced by science teachers in a different teaching and learning context.

THE RESEARCH
As a member of the research group you will be invited to participate in discussion and planning of meetings, critically reflect on your current roles in order to understand how they impact your teaching practice, and share with other members, your experiences, feelings and ideas as a way of exploring the different roles teachers fulfill.

DATA COLLECTION
Data collection for the research shall be conducted in a number of ways. Group meetings will be tape-recorded and supplemented with field notes. As well as regular group meetings, I would like to conduct individual interviews throughout the duration of the study. These meetings and interviews will be transcribed and copies made available. I would also like the opportunity to visit the school to observe a non-traditional approach to teaching and learning science, as well as teachers in different roles. Audio tapes, field notes and observation notes will be collected and shared with you. These school visits will help me to understand the particular circumstances of science instruction in this setting as I attempt to explore and reflect on teaching roles.

Participating teachers will be encouraged to keep a journal. In recording their experiences, participants will reflect on their teaching practices as well as the meaning of the roles they occupy in these practices. Accordingly, I shall also keep a two-part journal throughout the study. The journals will become an important part of the data,
as I attempt to explore and understand the role of the teacher in a different context of teaching and learning.

ETHICAL CONSIDERATIONS
A number of steps shall be taken to ensure the anonymity and confidentiality of the research, and to protect participants from the possibility of evaluation on the basis of the written report. All proper names and identifying details will be changed in field notes, interview transcripts and oral and written interpretive accounts. Field notes, interview transcripts and journals will remain confidential (with the exception of my thesis committee). All tapes and journals will be locked away, once the research is entirely completed. Publication of the thesis or of any book or article, which may include data collected from the group, will proceed only with your explicit consent.

I will share my findings and conclusions with you, and clear interpretive accounts prepared from the data as the study progresses. I would like you to read and respond to my accounts and interpretations of the data, suggesting corrections, deletions or noting differences of opinion. These responses will inform further drafts for the purpose of the thesis. The goal here is to present an account of our experiences that is fair, accurate and agreed upon. Should any substantial differences of interpretation remain after a period of discussion, the written account will note these differences of opinions and/or interpretations. You are also free to delete any data that you feel compromises your position in any way. A final written summary of the study will be made available to you.

Finally, I acknowledge that you have the right to withdraw from the study at any time, without reason.

If you are willing to participate in this research project, please complete the attached form. Thank you for your interest and cooperation.

Sincerely,

Isha Decoito
TEACHER CONSENT FORM

I. __________________________ agree to participate in the study “Innovations In Science Education: Reconceptualizing Teaching Roles in a Self-Directed Program” as outlined in the attached letter.

Signature __________________________

Date __________________________
Appendix C: Interview Schedule (to be used in both interviews conducted in March and June, 1999)

1) How long have you been a science instructor?

2) What are you currently teaching? What is your subject specialty?

3) What grade levels have you taught in science?

4) What do you consider to be some of the important aspects of science instruction? Why are they important?

5) Does the role of the teacher influence the manner in which instruction is implemented? Explain.

6) a) Have you taught science in a traditional classroom setting?  
    b) How would you describe your teaching in this setting?

7) What kind of teaching roles are fostered in a traditional approach to science instruction?

8) Describe how science instruction is implemented in the present setting or this non-traditional setting.

9) Does it differ from conventional forms of science instruction? Explain.

10) Why did you move from a traditional setting to this new setting?

11) How would you describe your teaching role(s) at your school?

12) a) How has this innovative program enhanced teaching science?  
    b) How has this innovative program enhanced the school science experience for your students?