Motivating High School Students to Persist in Science through Teacher-Scientist Partnerships

By

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Table of Contents

Abstract ......................................................................................................................................................... 4
Acknowledgements ....................................................................................................................................... 5

CHAPTER 1: Introduction .............................................................................................................................. 6
  Background of Study ................................................................................................................................. 6
  Purpose of Study ....................................................................................................................................... 8
  Research Questions ................................................................................................................................ 10
  Background of Researcher ...................................................................................................................... 11

CHAPTER 2: Literature Review .................................................................................................................... 14
  Introduction ............................................................................................................................................ 14
  Purpose of Science Education ................................................................................................................. 14
  Important Definitions .............................................................................................................................. 16
  Theoretical Framework ........................................................................................................................... 16
  Teacher-Scientist Partnership Strategies ............................................................................................... 19
  Benefits of Partnerships .......................................................................................................................... 20
  Challenges to Collaboration .................................................................................................................... 23
  Semiotic roles of teachers and scientists in helping students make meaning ....................................... 26
  Conclusion ............................................................................................................................................... 28

CHAPTER 3: Methods .................................................................................................................................. 29
  Introduction ............................................................................................................................................ 29
  Participants ............................................................................................................................................. 29
  Data Collection ........................................................................................................................................ 31
  Data Analysis ........................................................................................................................................... 32
  Ethical Review Procedures ...................................................................................................................... 32
  Limitations .............................................................................................................................................. 33
  Further Study .......................................................................................................................................... 34

CHAPTER 4: Findings ................................................................................................................................... 36
  Introduction ............................................................................................................................................ 36
  Factors Influencing the Formation of Teacher-Scientist Partnerships ................................................... 36
    Availability of Resources ..................................................................................................................... 36
    Apathy/Disinterest .................................................................................................................................. 37
### Table of Contents

Institutional Structure & Support ................................................................. 38
Curriculum demands .................................................................................. 40
Partnership Strategies ................................................................................. 40
Outcomes of Teacher-Scientist Partnerships .............................................. 42
Immersion & Authentic Experiences .......................................................... 42
Interaction & Feedback Opportunities ....................................................... 44
Opportunities for Professional Development ............................................ 44
Curriculum Impacts .................................................................................... 46
Mentorship Opportunities .......................................................................... 47
Factors Influencing Science Engagement and Persistence ....................... 48
  a) Reasons Students Remain Engaged and Persist in Science .................. 48
    Types of Experiences ............................................................................. 48
    Personal Characteristics ........................................................................ 50
    Family, Social and Cultural Influences ................................................. 51
  b) Reasons Students Fail to Remain Engaged and Persist in Science ............ 53

CHAPTER 5: Discussion ............................................................................... 56
Introduction ............................................................................................... 56
How Findings relate to the literature ......................................................... 56
Implications of this study .......................................................................... 61
Limitations and Further study ................................................................. 62
References ............................................................................................... 64
Appendix A: Informed Consent Document ............................................... 67
Appendix B: Interview Questions ............................................................... 69
Abstract

The improvement of science education has been the focus of numerous studies in the past, however few education researchers have questioned both secondary school teachers and practicing scientist themselves to determine ways in which they could collaborate to make the learning of science a more authentic experience for students. Toward this end, this qualitative study was conducted using semi-structured interviews with secondary school teachers and scientists who were involved in partnerships. During the interviews the following primary research question was addressed: How do secondary school science teachers and practising scientist collaborate to motivate and encourage students to remain engaged in science and/or to pursue careers in science? The data collected was then analyzed to identify common themes. The findings indicate that there are several reasons why students remain engaged in science including types of science-related experiences, family influences, and personal characteristics. Conversely, fear of failure, misconceptions about the nature of science, and time investment were some of the reasons given for the failure of students to persist in science. In addition, although scientists and teachers collaborate in a variety of ways; the availability of resources, teacher apathy, institutional culture and organizational structures act as barriers/hindrances to the formation of these partnerships.

Keywords: teacher-scientist partnerships; science persistence; science education
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CHAPTER 1: Introduction

Background of Study

Why do we teach science in schools? Is it important to build societies in which all citizens are scientifically literate? What does it take to develop young high school scientists who have a passion for science and understand the value of building the right habits of mind and acquiring the most important investigative and technical skills needed to become practicing scientists? I believe that just like skillful musicians, great scientists need to be trained from an early age. Students at the pre-university level may not possess all of the knowledge and expertise that professional scientists do, but, are they not capable of learning skills and ways of thinking that will better prepare them to pursue science careers if they choose to do so in the future? Of course, not all students will want to pursue science careers, but is there a way to keep even students who may not be considering science as a career engaged in science after they have left the confines of the secondary school classroom?

We live in a world that is dominated by science. Every aspect of our lives seems to be influenced in some way by the scientific enterprise. The Ontario Ministry of Education in The Ontario curriculum grades 11 and 12: Science (2008) states:

During the twentieth century, science played an increasingly important role in the lives of all Canadians. It underpins much of what we take for granted, from life-saving pharmaceuticals to clean water, the places we live and work in, computers and other information technologies, and how we communicate with others. The impact of science on our lives will continue to grow as the twenty-first century unfolds. Consequently, scientific literacy for all has become a goal of science education throughout the world.(p.3)
However, beyond producing scientifically literate individuals there is also a growing need for more practicing scientists, or professionals in the field of science. “Canada is in many ways a powerhouse of academic science: its university researchers are prolific publishers and strong contributors to the national research and development enterprise” (“Call for a bigger vision”, 2010). How can this status be maintained? Is it important to continue to recruit and train scientists? This is a very relevant question which deserves our attention. The expert panel on the state of science and technology in Canada (2012) believe that science and technology (S&T) performance is critically dependent on S &T capacity, which includes access to highly qualified and skilled personnel and to infrastructure in the form of facilities, networks, and research programs. In the panel’s opinion, it is fundamental measure of the state of S&T in Canada. They argue that people and infrastructure are the “who” and the “where” of Canadian S&T. These factors do not in themselves denote strength, but Canadian research needs capacity in both of these areas to be strong now, and in order to build for the future.

In his speech at the Canada-China Academic Forum held in the summer of 2010, the honourable Gary Goodyear, Minister of state (Science and Technology) indicated that there is a need for more people with graduate degrees in the sciences and engineering to replace retiring workers and to meet a stronger demand for skills in the realm of S&T. In outlining this argument Hodson (2008) states:

Contemporary society is undergoing rapid and far-reaching economic, sociocultural and technological changes that impact substantially on the way we live, but school science education has failed to respond quickly and effectively. Only by reformulating science education can a satisfactory flow of talented people into science and engineering be achieved and our economy revitalized. (p.103)
The state of things may appear to be fine now, but what is being done to ensure that there is a steady stream of well-trained science professionals ready to lead us into new areas of research and innovation in the future? How can we prepare a citizenry that is informed enough to make sound science related decisions which will affect the lives of the future generation?

**Purpose of Study**

Recently, concerns have been raised about the quality of science education worldwide. Is there really a problem with the current state of science education, or is it all a myth? Hodson (2008) states:

> Over the past decade, expressions of public concern about the state of science education have become almost universal, and in some countries have escalated to feelings of crisis. In Canada, these concerns have been fuelled by lamentations over the country’s allegedly poor performance in international tests of scientific attainment – no matter that the data show Canadian children performing at least as well as students in the United States or that the tests may not be measuring those things that Canadian science educators have prioritized. The press and politicians of Ontario are even more vociferous in their condemnation of the efforts of science teachers because of data showing that Ontario’s children are performing less well than those in the country’s western provinces. (p.103)

Today’s curriculum is very similar to the curriculum that was initially implemented in Euro-American schools in the 1900s. Aikenhead (2006) agrees that today’s traditional science curriculum is essentially a 19th–century curriculum in intent and organization. He explains that science teachers today teach to very similar goals and identifies those goals as pre-professional
training, mental development of abstract concepts, eschewing practical outcomes, and screening for university entrance. It is difficult to dispute this argument because from my personal experience as a student and a teacher, I have noticed that indeed many teachers, science departments, and schools on a whole, tend to consciously or unconsciously structure their science programs toward attaining these goals. Maybe, this happens because teachers are inclined to teach in the way they were taught, or because other external factors continue to influence the pedagogical practices that teachers choose to employ in the classroom. For example, a teacher may want to take his or her students on more field trips or work with them in a real research facility with practicing researchers, but, how can this plan become a reality with the limited contact hours that he or she has with students and the structured school program that students are expected to follow? However, whatever the case maybe, it is quite evident that science education in schools still appears to be focussed on accomplishing the same objectives which it was initially intended to achieve. For some, this may be a great accomplishment, but to many this indicates stagnation, rigidity, and inflexibility. I say this because we live in a dynamic world where the educational environment is changing at an unbelievable rate. This rate of change therefore imposes its own pressures on traditional and well established systems that people have become used to, and in many instances, even fail to question. Aikenhead (2006) explains that “from the time of the science curriculum’s formal inauguration, attempts have been made to make science a subject that connects to everyday life.” However, he asserts that the traditional goals and perceptions of science education that have been held for so many years continue to resist any movement toward change.

Though much research has been done on improving science education, and numerous projects have been done to support it, few researchers have questioned both high school science
teachers and practicing scientists to determine ways in which they could collaborate to nurture an interest in science and to develop future scientists needed to ensure that Canada remains on the cutting edge of scientific research and innovation. “The number of scientists in the ‘pipeline’ is declining” (Shaw, 2005), and although this may be happening for various reasons, for Canada to remain one of the world’s leaders in science and innovation, this trend cannot be accommodated. Scientists spend several years in our various educational institutions developing and refining their skills, so why aren’t they more actively involved in the actual education of those who will take their place in the very near future? “It is important for institutions of higher learning to reach out to students “earlier in order to meaningfully affect their visions of themselves, their world, and their career choices” (Claudio, 2001, p. 81).

Therefore, the purpose of this study is to investigate the perceptions of teachers and scientists involved in collaborations regarding the effectiveness of the teacher-scientist partnership model of teaching science to secondary school students in order to determine the implications that this instructional model may have for the future of science education

**Research Questions**

The primary question that this study endeavours to answer is: *How do high school science teachers and practicing scientists collaborate to motivate and encourage high school students to remain engaged in science and/or pursue careers in science?* However, in order to add more insight to this study, the following *sub-questions* will also be considered:

- What are the experiences and perceptions of teachers and scientists relating to teacher-scientist partnerships?
- What outcomes have been observed for students involved in these partnerships?
Background of Researcher

As a researcher, I bring a variety of educational experiences to this study. After spending more than 10 years in the secondary science classroom with various kinds of students, in different settings, both in the Caribbean island of Dominica and here in Ontario, Canada; I have observed that many high school students perceive the world of science as something that belongs to an exclusive few – “those who are smart.” On the other hand, I have also noticed that among those who consider themselves to be smart, and fit for the world of science, there are some who believe that their pre-university experience in science is not about real science, but about doing what it takes to obtain a grade to ensure that they are given the opportunity to meet with the professors at universities who are the ones who will really teach them about the world of science and give them the tools that they need to become scientists or science professionals. Although these perceptions may be subjective, the fact remains that I have observed this general attitude in many students at the secondary level and this has raised several questions in my mind. When does learning to become a scientist begin? Does this process begin at university, or does it begin long before the university experience? How do scientists become successful? What habits of mind and skills do they possess? What encourages students to remain engaged and/or persist in science?

Students develop many stereotypes about science as they grow up and the experiences that lead to these stereotypes are as diverse as the stereotypes themselves. The media, textbooks, teachers, parents, peers, and culture are just a few of the factors that can influence one’s perception of science. The problem though is that once a mental construct has been created, it is very difficult to get rid of it. As Claudio (2001) says:
Changing stereotypes is not an easy task. Think of the many racial, cultural, and gender stereotypes that are so much a part of our society. By the time students are in college, most already have ruled out science as a viable career choice, and thus the applicant pool continues to be reduced.

Who are scientists? A scientist can be defined in many ways, however, for the purposes of this study, I would like to considered a scientist to be a graduate student doing research in science, a science career professional engaged in research, or a person who has expert knowledge of one or more of the natural or physical sciences – a research scientist. This definition brings to the forefront the idea that scientists are individuals who are focussed on research and the creation of new knowledge. They are sometimes accomplished professionals, but sometimes they are just students. Maybe, if science teachers endeavour to help students to understand who scientists really are and what they do, and employ instructional strategies that help them understand the true nature of science, they may begin to view science differently. Students can only make informed decisions about persisting in science when they are exposed to the real world of science. What therefore can the practitioners in the high school science classrooms and those in postsecondary settings do to motivate and support young aspiring scientists?

As I recall my high school years in the science classroom, many memories come to mind. For the most part, I was very interested in the content that my teachers had to share whether they delivered it in an enthusiastic and stimulating way or not. Therefore, for me, laboratory experiments, demonstrations, field trips, and other science activities just served as added motivators to my intrinsic desire to learn. However, not many of my classmates shared this same innate and enthusiastic attitude. In fact, most of my colleagues thought that science was boring and difficult. Although I did not agree with this stance, I did at times feel that science was
overwhelming. Of course, these perceptions may have been related to the way in which my teachers taught science. The lessons were generally content driven, and very little time was given for exploration and understanding of the actual nature of science. In retrospect, however, I can now identify with my teachers and understand why they took the approach that they did. After all, they had to ensure that we were prepared for our external exams which basically decided our academic fates. That being said, however, the fact remains that although my teachers were well intentioned, their approach, eventually led to many of my high school colleagues giving up on the whole idea of pursuing science careers.

As a science teacher, and currently, a graduate student in the Master of Teaching program at the University of Toronto, I have used many teaching strategies with my science students. I have also observed many of my colleagues doing their best to motivate their students and keep them engaged. However, in spite of all these efforts, there is still a sense that there is a level of disconnection between what we do in the high school science classroom and what happens in the real world of the research scientist or science professional. Yes, it is true that many of my students have gone on to be successful professionals in the area of science, however, I can’t help but wonder if there is more that can be done to ensure that promising science students don’t give up midway on their journey of becoming science professionals, or that interested students remain engaged in science after their school life even though they do not pursue science as a career. There has to be a way to make the experience of students less discouraging. It is my wish that this research project will serve as a link in the chain of reform efforts concerned with the discovery of new ways of ensuring that the interest of students in studying the sciences continues to grow, and that our future in this fast changing world of science and technology continues to look ever brighter.
CHAPTER 2: Literature Review

Introduction

Some important studies have been conducted in the area of improving science education and pedagogy through teacher-scientists partnerships. At the beginning of my research, the literature appeared to be silent on the idea of collaboration between practising scientists and science teachers in encouraging students to remain engaged or persist in science. However, as I continued my research, I encountered a variety of sources directly or indirectly addressing this area of study. The primary focus of this literature review was to gather as much information as possible regarding collaborative efforts between high school teachers and practising scientists towards the goal of keeping students engaged in science. However, by extension, other themes such as the purpose of science education in schools and the influence of schools, communities, universities, industries, administrators, policy makers, governments and other stakeholders in the endeavour to reform science education through teacher-scientists partnerships (TSPs) was also investigated. In addition, this perusal of the literature sought to uncover the theoretical perspectives that influence the formation of experienced-based models of science education such as TSPs in order to discover the history, nature, and effectiveness of these strategies. Overall, the literature reveals that teacher-scientist partnerships are effective in increasing students’ interests in science. In spite of the challenges involved in implementing this approach, it holds great promise for the future of science education.

Purpose of Science Education

Before looking at what the literature reveals about collaborative approaches towards science education, let us first look at what it says regarding the general goals of science
education. Why do we teach science in our schools? In a detailed examination of the purposes of science education Black (as cited by Wellington, 2001) argues that the main purposes of science education are as follows: 1) To provide students with a basis for understanding and coping with their lives; 2) To enable students to understand the applications and effects of science in society; 3) To teach and learn about the concepts and the methods which are combined in scientific inquiry; 4) To give insight into what science, seen as a human activity, is really like; 5) To contribute to the general personal and intellectual development of the students; 6) To provide students with a basis for making choices, together with positive motivation, to consider seriously a further commitment to science.

In my opinion, all of these goals for teaching science in our schools are very important. However, it is the last goal that this research focuses on. The literature indicates that for this goal to be accomplished, students must be situated in what I refer to as an appropriate academic space; teacher-scientists collaborations support this goal.

In this study a variety of concepts will be investigated. However, the ideas that students learn best by engaging in meaningful activity, that experiential learning is motivating in its very nature, that knowledge is constructed not transmitted, and that teacher-scientist partnerships are essential in motivating students to pursue careers in science are the key concepts guiding this study. All of these themes are prevalent in the literature.

Science is for everyone and all citizens should be engaged in science, however, I am particularly concerned about the students who once had an interest for science but eventually decided to pursue other paths. Why do some students give up? Could it be that those students were not provided with enough authentic experiences to keep them motivated to follow their early desires of pursuing science-related careers?
Important Definitions

There are several key terms that will be used in this paper. The term **scientist–teacher partnership** refers to any collaboration among a group of college, university, museum or industrial research scientists and high school science educators with the goal of improving science education at the secondary and postsecondary educational levels (Tanner, Chatman & Allen, 2003). In defining scientist–teacher partnerships, the term **scientist** includes:

All participants in the enterprise of science in higher education – not just faculty, but also research associates, postdoctoral fellows, graduate students, and other trainees in the science and health professions. In many instances, scientist–teacher partnerships involve scientific trainees who are closer in age to secondary students and who often have greater flexibility in their professional lives (Tanner, Chatman & Allen, 2003, p.196).

By **science teacher**, I refer to members of the secondary teaching profession, including middle school science teachers. The inclusion of middle school teachers in scientist–teacher partnerships is important because although this study is focused on high school students, middle school science teachers are also expected to take science as a specific teachable subject. Therefore, like secondary school teachers they can also be considered to be expert teachers of science.

Theoretical Framework

Previous research studies have indicated that experienced-based science creates much more interest in science and provides students with an inside view of the skills, knowledge, and habits of mind needed in a given occupation (Tuss, 1996). The theory underlying experiential education argues that information “gained through experience, provides a requisite contextual base for assimilating information obtained through symbolic, vicarious, and other indirect
means” (Conrad and Hedin, 1981, p.443). Joplin (as cited in Tuss, 1996) explains that this realm of educational thought has led to a variety of projects, programs, and curricula. However, in the midst of such diversity two fundamental elements of an experiential education program remain consistent: (1) provision of a concrete experience for the learner, and (2) facilitation of reflection on that experience. These two fundamental elements lay the foundation for this study. For students to maintain their interests in science and/or pursue science careers, they need to experience science, and the work that scientists do in more authentic ways. One way to ensure that they have this experience is to invite practising scientists to play a more active role in the academic lives of students from as early as possible.

If students are given the opportunity to interact with the science professionals working in the area of their career aspirations they will be able to make more informed choices concerning their careers. Furthermore, this could also benefit all students and encourage them to remain engaged in science even though they do not intend to pursue science-related careers. Kraft (as cited by Tuss, 1996) point out that, “The modern experiential education movement emerged as a reactionary response to the failure of traditional schooling to meet the needs of the vast majority of youth”(p. 444). Some of the ideas espoused by this movement include involving the individual learner in what is to be learned, learning through experiences both in the classroom and outside of it, learning through experiences immediately relevant to the learner, and preparing individuals for a changing world. The work of developmental psychologist Piaget, has also had a profound influence on the experiential education movement. According to Piaget concepts and ideas are constructed in a specific sequence of stages beginning in a concrete, action-oriented modality and moving to progressively more internalized, symbolic modes.
Science learning activities based on the experiential model are better able to promote student construction of scientific knowledge and provoke students into making the transition from naïve to higher order thinking. Experiential education strategies will strengthen school science performance, particularly among students from underrepresented groups, and create an increased pool of scientific and technical workers (Tuss, 1996). Lave and Wenger (1991) describe learning as a situated activity which is essentially defined in a process that they refer to as *legitimate peripheral participation*. They point out that “learners inevitably participate in communities of practitioners and that the mastery of knowledge and skill requires newcomers to move toward full participation in the sociocultural practices of a community” (p.29). Therefore, by establishing collaborations by which students can interact with professional scientists provides them with an opportunity to converse about activities, identities, artefacts, and communities of knowledge and practice.

Students are drawn to science for a variety of reasons. One frequently cited reason is because they do well in science classes. Although on a superficial level this may appear to be a reasonable perspective, it is not an entirely adequate basis for career choice. One needs to consider what a person in such a field does, not just the class work encountered as a student (Loehle, 2009). Some scientists make up their minds about choosing science as a career before they even enter high school, while others do not make a decision about a science career until after they had graduated from college/university. Still, for some, high school is a significant turning point in their career decision-making process. The prevailing conviction, however, is that the encouragement from others (though not exclusively by teachers), the excellence of teaching (regardless of pedagogical style), and the richness of science related experiences are the most influential factors in either maintaining or initiating a persistence in the pursuit of a science
career (Shaw, 2005). In addition, the idea that partnerships across the divide between K–12 schools and institutions of higher education could be essential in increasing the coherency of science education in the educational system should not be neglected (Tanner, Chatman & Allen, 2003).

According to Barton and the Commission on the Skills of the American Workforce (as cited by Tuss, 1996), “career-related learning is an important part of secondary and postsecondary education. However, vocational development programs for young adults have been found to be inadequate in several recent reports” (p.446). If these programs are failing to meet the needs of learners, there must be something essentially wrong about them or the manner in which they are implemented. The literature indicates that with mutual cooperation between program planners and practitioners these vocational programs should work.

**Teacher-Scientist Partnership Strategies**

Teacher-Scientist partnerships provide an excellent platform for the teaching of scientific inquiry through experiential and authentic experiences. It is important to explore this model of teaching science because “engaging students in science-based inquiry is at the center of current science education reform efforts” (Houseal, Abd-El-Khalick, Destefano, 2014). Teachers can become involved in collaborations with scientists in a variety of ways. However, which collaborative strategies work best and how can collaborative efforts be streamlined to meet the needs of individual students? Drayton and Falk (2006) explain that there are five general approaches noted in the literature that science teachers and scientists use to collaborate. Scientist could be involved as: 1) Key members of a curriculum development effort; 2) Deliverers of content in teacher enhancement (in-service or pre-service) as lecturer in a course, or workshop leader; 3) Visitors to the classroom or alternatively hosts when students are taken to field trips or
lab visits conducted by a scientist or advisors being accessible to answer queries and seek resources for students, teachers and parents; 4) Teacher mentors, providing teachers with the opportunity to work on research projects; or 5) Partners in student-teacher-scientist partnerships (STSPs). All these strategies are effective ways of collaborating, but the last strategy seems to be the most comprehensive and effective practice.

More and more, the value of teacher-scientists partnerships is being recognized. It is believed that these partnerships provide a “flexible framework for collaboration between the school community and institutions of higher education, and the proposed benefits of these scientist–teacher partnerships are enormous” (Tanner, Chatman & Allen, 2003, p.195). Although scientist–teacher partnerships have been emerging over the course of several decades, there has been an increasing attention to, and funding of these efforts as an approach to science education reform (Tanner, Chatman & Allen, 2003, p.195).

Benefits of Partnerships

As indicated earlier, there are immense benefits that can be derived from partnerships between scientists and teachers. These benefits include:

(1) Insight into the nature of scientific inquiry and deepened content knowledge for teachers, (2) Increased communication and teaching skills for scientists, and (3) Enriched science learning experiences for all students involved. Teacher-scientist partnerships can involve co-planning and co-teaching of science lessons in classrooms, professional development courses for novice teachers, and after-school academic enrichment for students. Partnerships can also occur in scientific laboratories, engaging teachers in the culture of science and the doing of research (Tanner, Chatman, & Allen 2003, p. 195).
Drayton and Falk (2006) explain that, “scientists can make an important contribution to the professional development of science teachers: they represent a special source of insight about science content and process, the structure of their field of knowledge, and key approaches to curriculum and pedagogy in their area of expertise” (p.735). A growing body of research suggests that collaboration with scientists can be a powerful way to affect teachers’ understanding of science, science learning, and science teaching. The general goal is that this will eventually lead to improved student engagement and achievement in science (Dresner & Worley, 2006; Kahle & Kronebusch, 2003; Houseal, Fouad, Abd-El-Khalick, 2014). Curious and reflective teachers who have a good understanding of science inquiry are necessary for the development of curious and reflective students. Scientist can contribute to the development of such teachers. Therefore, the professional development role served by teacher-scientist partnerships cannot be overlooked.

The evidence in the research literature also indicates that partnerships between teachers, scientists, and university science educators have the potential to improve significantly the content and effectiveness of science education (Taking science to school: Learning and teaching science in grades K-8, Brewer & Brown, 2000). However, to develop effective collaborations between scientists and teachers, Caton et al (2000) propose that the following components are necessary:

1. Bringing together key partners involved in scientific research and education to develop a common vision for instruction and collaboration

2. Fostering interaction between scientists and educators through experiences focused on a shared vision, inquiry instruction, and learning related to the science content of interest.
3. Compiling and developing (as needed) excellent curriculum resources that translate basic research so that it is accessible to a broad audience.

4. Developing and piloting a series of “demonstration curricula” in open and guided inquiry formats.

5. Developing and implementing a plan to sustain and expand the program to include new collaborative partners.

These partnerships also benefit students. Students who are given the opportunity to interact with practicing scientists change their conceptions of science. In one such case mentioned by Flick (as cited in Tuss, 1996), it was explained:

After participating in a scientist in residence program that provided students with access to scientists in their classroom and a field trip to the scientist’s lab, students’ beliefs that science is serious and not enjoyable and that science is proven through a variety of incomprehensible practices changed in a positive direction.

The value of teacher-student-scientists collaborations should not be underestimated in our efforts to reform science education. Claudio (2001) explains that one approach to reach students at an earlier age entails having students of various abilities, including high school students, work together to perform tasks appropriate to their level of training within a research team. In spite of the level of training that students might have undergone they are all valuable members of the team, whether they have limited formal training in biomedical sciences or are advanced postdoctoral fellows. This approach motivates advanced students to serve as mentors and promotes a collaborative atmosphere among participants.
Challenges to Collaboration

Although there are many benefits to be gained from the working together of teachers and scientists there are many obstacles to overcome in order for this approach to be successful. Most schools still follow the traditional methods of teaching science, and one should not assume that this is because teachers are not aware of the benefits of exploring new, innovative and authentic ways to improve the experience of their students in the classroom. Sometimes, even when a teacher can sense the ineffectiveness of the instructional strategies employed in the classroom he/she is almost powerless to effect any change if institutional structures and constraints do not allow for change to be implemented. In addition to this, teachers and scientists must be willing to work together. Tanner, Chatman, and Allen (2003) highlight three issues which “can impede collaboration: (1) the importance of mutual learning in partnerships, (2) the professional cultures of scientists and educators, and (3) barriers of language in partnerships”(p.197).

Both teachers and scientists must enter these partnerships with mutual respect for each other. There is much that teachers can learn from collaborating with professional scientists, but there is also much that each scientist will learn by interacting with teachers and their students. Both parties need to be open-minded and enthusiastic about the idea of collaboration. Many research scientists affiliated with universities or colleges have teaching requirements and have an interest in science education at the precollege and pre-university levels. Yet, researchers tend to have little or no formal training in teaching and often have inadequate knowledge of methods appropriate for teaching younger students. Participation in precollege or pre-university science education programs can teach valuable lessons about education to researchers as they work with experts in the education field. According to Tanner, Chatman and Allen (2003),
Mutual learning requires that all participants in a partnership bring to their conversations and collaborations a learning stance, a willingness to be open to new ideas, a capacity to listen, and, most important, the professionalism to examine their own teaching beliefs and practices critically. The relative expertise each scientist or teacher brings to the partnership is dependent on his or her own depth and breadth of experience in teaching and scientific research. Therefore, in forging a partnership, it is important that both teachers and scientists ask themselves questions such as, “What is it that I want to learn?” “What aspect of my own teaching do I need to improve?” and “What scientific ideas or pedagogical skills could I explore with or learn from my partner?” (p.197)

Cultural issues could also hinder the progress of collaboration. These cultural differences include differences in the level of resources available, the level of autonomy, and the nature of peer relations as well as scientists’ unfamiliarity with issues of classroom management and logistics (Kim & Fortner, 2006; Drayton & Falk, 2006). It is important for scientists and teachers to truly immerse themselves into each other’s culture to get a genuine view of each other’s world.

Collaboration requires effort and compromise. As partners become familiar with the differences in communication style, customs, values and traditions of each other’s professional culture; they can build a more productive partnership, teach and learn from one another, and develop new knowledge and skills.

An awareness of these issues of common and uncommon ground can remind partners that many of their differences are not personal but a reflection of their professional preparation, practice, and culture. In fact, insights gained through partnership into the
similarities and differences in the professional cultures of science and education can lead to shifts in one’s own professional identity and goals (Phillips 2002; and Tanner, 2000).

Language is also a mitigating factor against good collaboration between scientists and teachers. Some terms may not always be used in the same way, and this may cause a communication block. It is impossible for good teaching and planning to take place if there is a communication barrier, so this problem cannot be overlooked. This however, should not be a major issue once it is identified.

Another significant challenge is the preparedness of students to enter into these partnerships. According to Schallies (2010), students needed to be properly prepared in order for them to experience success while working along scientists. As he explains, students’ abilities to independently state hypotheses, put forward solutions, check experimental parameters systematically, and evaluate procedures may need to be enhanced. Otherwise, the practical tasks and projects that they may be asked to perform could prove to be overwhelming. This challenge however can be overcome by making available special open learning environments for students to improve their skills prior to the commencement of the partnership.

In speaking to this same issue regarding the readiness of students to enter these partnerships, Wormstead, Becker and Congalton (2002) examined one of the world’s largest student-teacher-scientist partnerships (STSPs) – Globe (Global Learning and Observations to Benefit the Environment). This is an international science education initiative where students, teachers and scientists team up to study the environment. The students’ main role in these partnerships is to collect data that will be used in professional research studies. By studying this program, they were able to make a number of recommendations to scientists indicating how these long-term affiliations can benefit all parties involved. Their research was conducted
specifically to identify and recommend a set of criteria that would be used in the design of training materials for the proper implementation of STSPs. Among the recommendations made are the following: a) engage students in the full process of science from identifying questions to data analysis; b) provide curriculum standards integration assistance; c) provide student assessment ideas; d) include specific information to make science lessons relevant to students; e) recognize the importance of the involvement of the entire learning community, especially school administration, and other teachers, but also including the students’ parents and community members; f) consider funding constraints; and g) involve student in inquiry type lessons. These are just a few of the twenty recommendations that they made, but they all indicate the complexity of the issues that are involved in the establishment of these collaborations.

There are also other barriers that could affect the collaborative process. Budget constraints and limited time could present difficulties for teachers who want to work along with scientists for improved science teaching. The unavailability of funds needed to conduct various activities and to purchase essential resources could prove to be rather frustrating. Also, teachers may be worried about curriculum coverage while scientist may be concerned about the allocation of their time to a project that might not be directly connected to their research. Lack of a reward system could also be another barrier. If there is no incentive, teachers may not feel inclined to make an effort (Kim and Fortner, 2007).

*Semiotic roles of teachers and scientists in helping students make meaning*

In one study aimed at exploring the roles of teachers and scientists as they interact with students in general and in inquiry learning environments, Peker and Dolan (2012) explained that teachers and scientists function in similar and different ways when working together in student-teacher-scientist partnerships. Teachers and scientists act in similar ways by promoting a sense of
scientific community in referring to the research of others, by helping students to navigate the process of considering and reconsidering the methods of their investigations, and by helping students manage unanticipated outcomes. Teachers and scientist also act in distinct ways. Teachers act more frequently and in more varied ways than scientists to perform pedagogical functions of meaning making because they are better prepared and positioned to act in this domain. They are not limited by timing and context. The manner in which teachers and scientists promoted a sense of scientific community is also unique. Teachers promote community by emphasizing the value of establishing a common understanding about the meaning of variables and making consistent measurements. But, scientists promote a sense of community by using scientific terminology over daily life terms in their dialogue with students. Scientists also tend to address more diverse issues related to the nature of science than teachers. They characterized scientists’ and teachers’ acts as being “conceptual, social, pedagogical and epistemological” (p.226). According to their study, Peker and Dolan (2012) discovered that teachers and scientists:

1. Enacted the **conceptual function** of making meaning by aiming to increase students’ understanding of concepts so they were better positioned to make meaning of their experimental results;

2. Enacted the **social function** of meaning making by presenting themselves as knowledge authorities and promoting the idea of scientific community;

3. Enacted **pedagogical functions** of meaning making by organizing students’ ideas, increasing accessibility of knowledge, and checking students’ knowledge;

4. Enacted the **epistemological function** of meaning making by offering students ways of knowing scientific ideas and explaining aspects of the nature of science;
Conclusion

All of the research mentioned in this literature review supports the idea that teacher-scientist partnerships will significantly improve the present status quo of science education. However, although the evidence supports this effective but different way of teaching science, most schools still teach science in a very traditional way. I believe that collaboration between educators at different levels of the education ladder is now an imperative. Students are ready to learn, but the current education system still appears rigid and inflexible in nature. The education system must change to meet the demands of the modern science student. How can we move from this state of inertia? This research project will seek to find some answers to this very pertinent question. Some of our best minds are failing to persist in science, and many who are determined and committed to the scientific enterprise are being frustrated. It is time to act.
CHAPTER 3: Methods

Introduction
This study is a qualitative study of collaborations occurring between high school teachers and practicing scientists. Prior to conducting my field work, I conducted a comprehensive literature review. The primary aim of this perusal of the literature was to gain a better understanding of the themes related to the establishment of collaborations between high school science teachers and practicing scientists, and to familiarize myself with the current issues being raised in science education from a worldwide perspective. I also used this opportunity to explore the theoretical premise on which the teacher-scientist model originated. I used a wide variety of sources to gather information. These included peer-reviewed articles, theoretical articles, professional development literature, government reports, books and other printed sources. Most of the sources used were very recent. As much as possible, I avoided using sources that were more than ten years old. Following my literature review, I then began my field work. My field work was conducted through interviews with three participants. The interviews were then subsequently transcribed, analyzed and synthesized. This chapter is an outline of how the research process unfolded.

Participants
In order to obtain meaningful data from the interviews, all participants were carefully selected. The main requirement for the selection of the participants of this research study was that they had to be teachers, science professionals, or scientists involved in some form of collaboration with students for at least five years. This criterion was put in place to ensure that the data collected represented perceptions gained from real experiences rather than hypothetical conjectures. This meant that the recruitment process for this study took a very deliberate
approached to ensure that the most suitable candidates were chosen. I recruited participants through phone calls, emails, and referrals or recommendations. I first contacted each potential interviewee or their immediate supervisor by calling to determine their suitability, availability, level of interest in the topic, and willingness to participate in my research. Once I determined that a participant met all the criteria for my research and would be a suitable respondent, I then proceeded to email the informed consent document and interview questions to them. Apart from my initial conversations with participants to determine their suitability as research participants, I had no further encounters with them before the day of the interview. Each participant showed great interest in the study. **Pseudonyms** will be used to refer to the participants throughout this research paper. The pseudonyms chosen are as follows: Bob, Jane and Greg.

The first participant, Bob, currently holds dual roles in the Division of Teaching Laboratories at a university in Ontario. He works as a medical laboratory technician setting up undergraduate lab courses in the area of life sciences, and as the program coordinator for the Faculty of Medicine's Youth Summer Program (MED YSP). As the program coordinator, he oversees the modules: physiology, molecular biology & genetics, microbiology, pharmacology & toxicology, and research. He plans the academic program and labs, selects the speakers, workshops, and liaison with high school teachers to organize school visits, lab demonstrations, workshops, et cetera. He also trains undergraduate students to be instructors for the program and are involved in hiring, managing and execution of the program.

The second participant, Jane, is a scientist who currently works as the coordinator of school programs and a science educator at a science museum. She develops and delivers school programs to students and other patrons of her institution. She works along with teachers and
other scientists, and science educators to develop ideas and strategies to communicate scientific concepts to grade 9-12 students and the public.

The third and final participant, Greg, is a science teacher, who teaches physics to grade 11 and 12 students with a public school board. He is currently on secondment at the same institution where Jane works and partners with scientists and science educators to develop and deliver school programs. He also teaches physics to high school students at this institution.

Data Collection

I collected the data for this study through face-to-face semi-structured interviews. Each interview lasted for approximately 40-60 minutes and was audio recorded and transcribed. Before each interview, the participants were sent a copy of the informed consent document and a list of the interview questions via email (see Appendix A and B.). I decided to allow each participant to have the interview questions ahead of time because I wanted them to reflect carefully on the questions and to prepare informed answers. However, participants were not allowed to read through their answers during the interviews. They were expected to engage in an interesting and naturally flowing conversation. They were allowed to voice their concerns and discuss the potential benefits and risks of the study prior to the interview date. This was done in order to create, as much as possible, a relaxing, and nonthreatening atmosphere during the interviewing process. Two recording devices were used during the interviews to ensure safe storage of the data. One of the recording devices used was an iPhone together with a software application known as Smart Recorder. The other recording device used was the Olympus digital voice recorder (VN-702PC).
Data Analysis

Following the interviews, I personally and carefully transcribed each interview using the smooth verbatim approach focusing mainly on capturing the essence of each conversation. While transcribing, I began analyzing the data by carefully jotting down notes on significant and recurring ideas. Once the transcription process was completed, I read each transcript closely, taking additional notes on words, ideas, themes and concepts. I then reread and marked each transcript; creating codes, highlighting key words and sentences, and looking for analytical ideas. After marking the transcripts, I systematically code them by using key words and phrases to label important portions of the text. I then reviewed the codes I created in order to eliminate similar ones and combine ideas while at the same time thinking of categories. I then eventually sought to refine ideas by relating general groups of codes or categories to the text, the research question and the literature in order to discover the main themes emerging from the data. To avoid clutter and excessive printing most of this work was done using Microsoft word. All important statements from participants were organized in a table and labelled based on the codes and themes created.

Ethical Review Procedures

All ethical procedures agreed upon by the research ethics board (REB) and the department of Curriculum Teaching and Learning (CTL) of the Ontario Institute for Studies in Education of the University of Toronto (OISE) were followed during the research process. All participants demonstrated great willingness to participate in this research study and were given sufficient information about the research project before making their decision.

As indicated earlier, the participants were sent a copy of the letter of consent (see Appendix A), prior to the interview date via email. This gave them the opportunity to reflect on
the purpose of the research and make an informed decision. The informed consent letter notified
the participants about the length, purpose, and conditions of the interview. They were informed
that the interviews would be recorded and transcribed and that only the researcher and research
supervisor would have direct access to the data collected. They were also informed that their
identity and that of their employers would be would remain anonymous.

The participants were allowed to choose the time and location of the interviews. They
were made aware that they could withdraw from the study at any time and that their participation
was completely voluntary. I ensured that the interviewees felt comfortable and unthreatened
throughout the entire time that they were involved in the research process. No changes were
made to the agreement referred to in the letter of consent.

**Limitations**

The methods used in this research were limited in certain ways. The sample size, the
type of participants, data sources, time allotted to complete research, and the length and number
of interview questions all worked together to influence the final outcomes of this research. Only
three participants were interviewed in this research, as such, the findings of this research are
limited in their generalizability in that they cannot be used to draw inferences or overall
conclusions about the entire population. However, because each participant was carefully
selected, it is important to note that the data obtained from this study give valuable insight about
the perceptions of the participants with regards to the nature of teacher-scientists partnerships
and how these collaborations can be used to influence students to persist in science.

The type of participants interviewed and the time allotted to conduct this research also
limit the results of this research. Only one science professional, scientist and teacher was
interviewed in this research. This means that the perspectives of students, parents, administrators
and other stakeholders involved in science education are not represented by the data. Although this research was conducted over the period of the two years which I spent in the Master of Teaching program at the Ontario Institute for Studies in Education of the University of Toronto (OISE/UT), the time allotted to the research component of this program constrained the entire research process.

In addition, because only interviews were used as the source of data collection, the data gathered from this research project do not include the entire body of knowledge available on the topic of research from the contexts in which this research was carried out. Multiple sources of data were not used in the research process. There was lack of triangulation. The data from observations, documents, and other sources were not included in the analysis. However, the significance of the findings of this research should not be underestimated because the data retrieved from the interviews were sufficient for the purposes of this research project.

Finally, the number of questions asked during the interview process was limited due to the time limit agreed upon for each interview (40-60 minutes). Although the interviews were semi-structured and room was allowed for other questions to be asked, only eleven interview questions were initially posed to the participants. Thus, the information gathered reflects a small segment of knowledge on the topic. The participants were interviewed only once and they were not given the opportunity to do any member checking (reviewing of the transcripts).

**Further Study**

In the future, I intend to expand this study to include other stakeholders of the science education enterprise – student, parents, community members, administrators, and policy makers. This will allow me to uncover some of the details of the research topic that did not become
apparent due to the limitations of this study. I will also conduct a more extensive research of the literature to uncover themes that may not have been addressed in this study. By increasing the sample size, varying the type of respondents, increasing data sources and extending the length of time over which this study is conducted it is my hope that a more comprehensive understanding of my research topic can be reached.
CHAPTER 4: Findings

Introduction

This chapter outlines the findings from the data collected from the interviews conducted with the three participants in this study. These interviews yielded a rich array of data and several themes emerged about how the teacher-scientist partnership model could be used to keep secondary students engaged in science. After analysing and synthesizing the data, four common themes emerged: a) factors influencing the formation of teacher-scientists partnerships, b) Partnership strategies, c) outcomes of teacher-scientist partnerships, and d) factors influencing science engagement and persistence which include the subthemes: i) reasons students remain engaged and persist in science, and ii) reasons students fail to persist in science. This chapter will present each of these themes individually in order to give an accurate representation of the main ideas and concepts that were revealed by the data.

Factors Influencing the Formation of Teacher-Scientist Partnerships

One of the major themes to emerge from the data collected was that many factors can work together to prevent the formation of teacher-scientists partnerships. All three participants saw value in having these partnerships, but they all thought that there were several factors preventing more of these collaborations from happening.

Availability of Resources

The availability of resources was seen as cited as one factor. The common resources referred to by the participants were human resources, time, material resources and financial resources. Bob explains that it is extremely rare that scientists will reach out to high school students or teachers because they are “too busy.” He believes that more human resources will
need to be available for the collaborations to work effectively. He proposed that someone will have to come to them with a plan that would work. Someone needs to be designated to do that job. He stated, “You just need to have a person whose job it is to do that.” Jane argued that support can come in many forms: in kind, time, or other ways. She explains, “It doesn’t necessarily have to be funding per se, but someone’s time is also very important.” With regard to the need for more human resources to be made available to ensure that more partnerships could happen, she said: “Within a partnership program, someone should mentor or direct the partnership in order to have a good understanding of where the partnership might go or could go, and create the time and space to talk about the future of the partnership.” Greg highlighted the fact that it costs his school board and the organization to which he is now seconded “a reasonable amount of money” to foster their partnership. He commented that “an effective partnership requires time to build relationships and transfer ideas. He also pointed out that the partnership needs to be developed in a way that benefits both parties. He reasoned that, “The scheduling in a regular school is crazy on a daily basis, so being able to have …that partnership requires a lot of people with flexibility.” He insisted that, “it would take a lot of time from somebody and a lot of money.”

Apathy/Disinterest

The participants suggested that one of the reasons why more partnerships were not being formed was because of disinterest from teachers and scientists. They said that teachers and scientists are too busy carrying out the duties of their regular jobs to be concerned about forming partnerships. Bob said, “They would have to see a benefit.” The following statement summarizes the essence of how he feels:
I mean something could come from the top, but if as a teacher, I don’t want to partake in it because I don’t think it’s something relevant, you are going to be pushed back from that level.

He continued by saying “I don’t think they [scientists] have the time and energy to develop partnerships with high school students. They’d rather devote their time and energy to undergraduate students who are trying to do research with them.” Jane believes that because teachers tend to get “incredibly busy in teaching all their courses,” they sometimes cannot find “the time and space to cultivate that partnership.” On the other hand, although Greg agrees that partnerships are relevant and can help to keep students motivated, he reasoned that “the brunt of the planning, implementing and motivating” where students are concerned is “the teacher’s job and it can be done very effectively without partnerships.” He acknowledges that scientists can help to answer the “why” questions that students who are interested in learning things beyond the curriculum might ask. However, he is convinced that because “scientists aren’t experts in teaching,” the task of motivating students to remain engaged in science, or pursue science careers is primarily the teacher’s job.

Institutional Structure & Support

The culture of institutions was also seen as a factor influencing the formation of teacher-scientist partnerships. Teachers and scientists tend to follow the natural routines of their work environment. They would prefer not to disrupt the status quo, than to experiment with different ways of doing things. In addition universities, industries, and schools are not set up in a way to support teacher-scientist partnerships. Jane expressed that “science educators [scientists teaching and developing school programs] would like to do a lot more partnerships, but a lot of our day is taken up …” She is convinced that, “Institutional investment” is the biggest barrier to the
establishment of partnerships. Her argument is that both parties in a partnership need to get what they want out of a partnership in order for it to work. She also alluded to the fact that protectionism could be a factor:

The idea that my intellectual property is my intellectual property and I don’t necessarily want to share that intellectual property with other individuals – that’s our brand- that’s what we do as hands-on, minds-on.

She admits that her organisation collaborates with the Science Teachers Association of Ontario (STAO) by doing workshops, but that “institutional culture” sometimes hinders the formation of partnerships. Bob believes that “lack of support” is one of the hindrances to the establishment of teacher-scientist partnerships. He said, “Scientists would want to be part of partnerships, but I don’t think they want to start them up.” They need to be given some sort of incentive from higher organizations – a department or the government. His argument is:

If the ministry of education wants to engage more youth in science, and they want to develop partnerships, they should develop some sort of framework with funding to back it up, and then just run it out of a department.

For him, having some sort of “administrative support” or “centralized place” to help in the organization of these collaborations is important.

Greg was very candid in his views. In his opinion, “It would take a lot of organization to make sure that every school has a chance and has that partnership.” He brought up the idea that some partnerships may not necessarily have to rely on face-to-face interaction at all times and that students could communicate with scientists via technology. However, in spite of the method used, his argument is that it would take a great deal of organization.
Curriculum demands

Teachers are always under constant pressure to ensure that curriculum expectations are met. However, at the same time they would like to provide engaging and meaningful experiences to their students. Jane stated that sometimes when she talks to teachers they tell her that they “just don’t have the time.” Greg articulated his concern in this way: “Obviously, the more time you spend doing stuff that’s sort of beyond the curriculum, the less time you spend doing stuff that’s in the curriculum. There has to be a balance.”

Partnership Strategies

This study revealed that teacher-scientists partnerships take a variety of forms. All three participants identified a number of strategies used by teachers and scientists to collaborate. These strategies included on-site visits, summer programs, internships, day events, contest/competitions, award and scholarship programs, special projects, workshops, consultancy agreements, secondments and other informal arrangements or personal connections. They can occur in classrooms, in afterschool settings, or in educational or industrial laboratories.

Bob asserted that partnerships need to take a tangible form, whether it’s an event, a lab, or a visit. A day event could be, for example, focussed on a particular area of research. For example, researchers who are involved in stem cell research could organize “stem cell day”, or the physiology department could organize “physiology day”. He explained that his department takes part in physiology day at his University and that during that event they run various types of labs – spirometry labs, blood pressure labs, et cetera.

Jane explained that at the institution where she works, teachers and scientists co-develop programs. She expressed that teachers sometimes voice certain curriculum concerns and
approach her organization with an idea; they then work together to build resources to meet that particular curriculum need. When she was asked to explain how teachers and scientists could collaborate to plan high school related extracurricular activities, she explained that sometimes her organization hosts science fairs. During these events they are asked to be judges and share their expertise in a variety of ways. Another interesting strategy mentioned by Jane was the creation of Youth Innovation Awards for high school students. For example, she mentions students who recently won an award for creating a new spinal board for children. These students were lifeguards and figured out that the backboards weren’t perfect for younger children, so they created one that was safer. By creating these awards, teachers and scientists can work together to support students in creating solutions for real-life problems. In addition, Jane also mentioned that her institution offers internships to teacher candidates. She explains that these teacher candidates bring with them their expertise and knowledge of students and in turn they gain science knowledge through the partnership. Secondment opportunities are also made available to contract teachers where they could work with her organization for 2 to 3 years. She acknowledged that teachers bring ideas and expertise to the partnership that scientists could benefit from. Jane also mentioned that her organization supports youth volunteer programs such as youth advisory boards and clubs which organize engaging events based on their everyday lives.

Both Bob and Greg mentioned that many informal partnerships are formed through personal connections. Bob suggests that it is important for schools, universities or other organizations to reach out. He pointed out that the partnership formed between one of the schools that his department partners with was formed because two people wound up “in the right place at the right time.” Individuals have to show interest and network with each other. Greg
supported this idea by explaining that most guest speakers that come to speak to students at the institution to which he is seconded come because a teacher or someone else knew them from school. They had some connection with that individual in the past. He said, “Unless you know people at the universities it is difficult to bridge those gaps.” He reasons that because there are so many schools out there compared to the number of professors, establishing partnerships could be difficult without some sort of connection. He also remarked that sometimes the guest speaker is a parent of a student at the school who chose to make connections with the school that his or her child attends.

**Outcomes of Teacher-Scientist Partnerships**

All three participants in this study agreed that there were many positive outcomes of using the teacher-scientist partnership model as a strategy for keeping students engaged in science and motivating them to persist in science. They agreed that this model is not only beneficial to students but to all stakeholders involved in the science enterprise. Several benefits were revealed. The most prevalent benefits mentioned were: immersion into the scientific environment, interaction and feedback, opportunities, creating interests, professional development, and mentorship opportunities.

**Immersion & Authentic Experiences**

The idea that students, teachers and scientists get immersed into each other’s environment was seen as one of the major benefits of these collaborations. Students involved in these partnerships are able to make better decisions about their future as it relates to science and scientific careers when they get to experience science in a more authentic setting through
programs organized by these partnerships. For example, in discussing the reaction of students to the nature of the summer program which he coordinates, Bob commented that,

They sort of get immersed in undergraduate education and hopefully by seeing the level of what is required to be an undergraduate student they will be able to make better choices, and by that we hope they will realize how much it takes to study, and improve their time management skills.

By organizing programs in which students are immersed in the scientific culture, they get firsthand knowledge of what it actually means to study science or become a research scientist or science professional. When teachers collaborate with scientists they themselves also get immersed and benefit immensely from these authentic experiences. Greg says,

The fact that we [teachers] get sort of immersed in what they do, and understand it, then we can discuss how they present their programs. What we take back to our classes that’s sort of up to us. If we do enough programs, we see enough things done in different ways and we can then take some of those ideas back to our classroom and communicate them.

Scientists also receive tremendous rewards from these partnerships. In these types of collaborations one may think that teachers may be the main ones to profit from the relationship, but contrary to this belief, there are also rewards for scientists. Commenting on this idea, Jane explains that she would cherish the opportunity to be seconded to a school. Currently, teachers are seconded to her organization, but scientists from her organization never get to go into schools for extended periods of time. She said, “I’d love to be able to go to them [schools].” From her perspective, it would be very effective to be “immersed in that different environment.”
**Interaction & Feedback Opportunities**

The level of interaction and feedback received while engaging in teacher-scientist collaborations was also noted as a benefit. Students receive honest and open opinions which help to inform their choices. In speaking of the instructors hired to teach in the summer programs which he coordinates Bob says, “We encourage our instructors which are hired to be very honest and open with those students because that’s what’s valued in the program.” The feedback is also immediate, which means that students can be more efficient in their decision making. Feedback is important not only in determining future goals, but also in informing the choices that students make in the present moment. Teachers and scientists also gain a lot from interacting and giving feedback to one another. Greg identified that one of the effective moments of the partnership program that he is involved in occurs when they “sit down and discuss.” He also mentions that the fact that they get exposed to what the scientists do gives him lots of ideas on ways to make his classroom more interesting. He believes that regular interaction with scientists is important. He articulated this belief by saying: “We work at the same site, so lots of contact with each other is going to be a key to an effective partnership.”

**Opportunities for Professional Development**

Both Jane and Greg – the scientist and the teacher, believe that teacher-scientist partnerships provide a variety of professional development opportunities. Teachers learn new ideas to make their classrooms more interesting and scientists get to learn more about students, and how they learn. By interacting with students and teachers, scientists learn new and more effective methods of delivering content, and develop more effective strategies to communicate their ideas. In expressing how his collaborating with scientists has help him as a teacher, Greg declared,
My partnership has benefitted me in that I have now learned some new ways in presenting material. In a sense that becomes amalgamated into everything that I do on a regular basis. I have been influenced in the way I teach and that’s not a measurable thing.

According to him some of the ways in which partnerships help are not always measurable, but he thinks that his students have definitely benefitted and hopes that their interest in learning has increased. He states, “I have seen new ways to present ideas and so it makes my course a little bit more interesting.” Jane also shared her thoughts about how she is benefitting professionally from her partnership experience. She expressed:

So understanding the language that students are coming with benefits me because I can teach the program to what their level of knowledge is at that moment. I would say that the teachers have a very innate knowledge of the classroom and the classroom experience and also the textbooks, et cetera, and that helps me develop and teach better school programs.

She made this statement while referring to a conversation that she had with a teacher about the language used in different science textbooks. To be specific, she explained that the language used by Nelson and McGraw-Hill to explain the concept of bacterial transformation varied. As stated earlier, her job description is to develop school programs and effective communication strategies to reach children of school age. Therefore, through collaborations with teachers and students she gains insight about the kind of language that she should use with them and also gets a better understanding of their knowledge base and learning needs.
Curriculum Impacts

According to the participants, teacher-scientist partnerships can also have a positive impact on science curriculum reform. Jane commented: “I think that as scientists we can help to create curricula that would be more inclusive.” She believes that one of the ways in which school partnerships benefits her as a scientist is by helping her to see the connections between the various grade levels. She gains a better understanding of how the various levels of the science curricula can be scaffolded because she gets to work with students from different grade levels and obtains what she describes as “an overarching look all the way from junior kindergarten to grade 12”. She explained: “We can see the connections between the grades and see where there might be gaps in that knowledge, or where we can help in scaffolding that knowledge.”

Greg has a slightly different opinion about how collaborations between teachers and scientists will impact curriculum reform. According to him, curricula change is cyclical and comes at the expense of some knowledge. He says, “I don’t necessarily see that there have been improvements in curriculum from when I started teaching, but there have been changes.” He believes that scientist have a role to play in determining scientific content. He suggests that scientist should be the ones saying, “this is what we see lacking, this is what we need, this is what we want when students get to us.” He also expressed that, “getting people who are really cutting edge can really make a difference in terms of keeping students interested.” He further elaborates on this idea by stating that, “It exposes them to some of the modern things that are out there in science.”

Bob thinks that, “teachers and scientists should drive curricula.” He explains that the faculty of medicine Youth Summer Program which he coordinates for his university program has
a partnership with two school boards where they collaborate to develop and implement a new initiative by the government called the Specialist High Skills Major (SHSM). This program, which was started about four or five years ago, allows high school students to start a career in industries that the ministry has identified will be in high demand of workers in the future. According to Bob, the school boards have developed a partnership with them to offer this program as part of their curriculum. In order for students who are involved in this partnership to receive their secondary diploma they are obligated to participate in a number of activities at a university or industry including on-site visits and “reach ahead” experiences. By collaborating to provide such opportunities to students, teachers and scientists become directly involved in the implementation of curriculum.

*Mentorship Opportunities*

The mentorship opportunities that result from these collaborations are perceived to be a significant outcome of these partnerships. They believe that through these partnerships, students form relationships with individuals whom they could look up to for advice and guidance. Teacher-scientist partnerships provide the ideal platform for such relationships. When asked to share her opinion about the outcomes for students involved in teacher-scientist partnerships, Jane commented: “I’ve been lucky enough to be here for 12 years which means that I have been a mentor for a lot of students in high school.” She speaks specifically of how she was able to help one of her students to succeed. She explains that this student was failing her high school classes, but that she eventually ended up going to university, and now works in the field of science. She believes that taking weak students who may not necessarily be on the path to science and mentoring them is a wonderful opportunity provided by these partnerships. She would not have been able to meet those students in the capacity that she did had it not been from the
collaborative efforts between her organization and the school boards. She explains, “We’d rather take students that need a little more mentorship.” She explains that mentorship programs are really a key to staying engaged and that when students form relationships with scientists this encourages them to stay interested.

When he was asked to share his thoughts on what he thinks the outcomes will be for students involved in teacher-scientist partnerships, Bob explains that there is great benefit, although it is hard to quantify. He believes that the mentorship opportunities and experiences offered through these partnerships are invaluable to students because they provide an avenue for students to get answers to their questions at a time when they are making life altering decisions.

Factors Influencing Science Engagement and Persistence

The participants suggested several factors that influence the engagement or persistence of students in science. They listed both positive and negative influences which impact the decisions of students towards science. These have been organized into two subthemes: a) Reasons students remain engaged and persist in science, and b) Reasons students fail to engage and persist in science. Let us now take a look at each of these subthemes in more detail.

a) Reasons Students Remain Engaged and Persist in Science

Types of Experiences

The participants proposed that the nature of student experiences, family influences, social and cultural background, and the availability of opportunities are important factors that influence students to remain engaged and persist in science. They suggested that students need to have certain types of experiences with science to develop interest in it. These experiences need to be
real-life experiences which involve hands-on activities. They also need to be based on interesting topics and expose students to novel ideas and developments.

When Bob was asked about his perceptions concerning the components of an effective partnership program, he recommended that effective programs must be comprised of engaging activities. If the curriculum is not interesting to students they are going to be bored and the organizers of the program could become discouraged and conclude that it isn’t worth their time to engage in such a partnership. He suggested that hand-on activities based on common societal problems should be used to spark interest. The information has to be relevant to students. It cannot be based only on abstract concepts like pH – determining the level of acidity or alkalinity of a substance. In such a case, students are not going to ask intelligent questions and they are not going to reflect and think deeply about the activity they engaged in. He explains that for the program he is associated with they take world problems related to personalized medicine and challenge the students to investigate these problems. For example, he mentioned that one of the labs that they do involves students measuring their reaction time and relating it to the issue of driving and using cell phones. He also mentioned allowing students to perform clinical trials with drugs like caffeine to assist them in refining their ideas on common life experiences. He states that educators have to be exciting and humorous even when “it’s a topic that is complicated.” He said that many good teachers “use a level of humour in their lectures.” He gave an anecdote about one of the lecturers involved with his program who introduces her lecture on drugs by using stories of celebrities who have overdosed on illegal substances to catch students’ attention before going into her lecture. He said it takes a level of skill to know when students are not engaged and to modify whatever activity the students are doing to maintain their
interest. Apart from humour, he recommended that art, history, politics, or any subject that can elicit interests from students should be used.

Jane also shared similar sentiments to those expressed by Bob. She found that engaging students in a manner that is not necessarily related to the curriculum, but provides an avenue for them to connect with science in a way that is specific to their age group proves to be valuable.

Greg is convinced that experts can help to motivate students by sharing new ideas. He said that “getting people who are really cutting edge can make a difference.” He claims that in order to keep students’ interest, he has had a huge number of experts come into his classes over the years. He explains that the presence of these experts does not necessarily further his students knowledge in terms of what they are learning in the class at the moment, however, it exposes them to some of the modern developments in science. Ensuring that students have these experiences with experts may be instrumental in getting them excited about learning science.

**Personal Characteristics**

The participants of this study believe that students who remain engaged in science tend to have a number of personal characteristics that influence their persistence in science. Among the personal traits listed were: curiosity, internal drive, the ability to keep focussed and avoid distractions, good study habits, good time management skills, perseverance/persistence, determination, open-mindedness, and good communication skills.

In Bob’s opinion, students who remain engaged in science tend to be very curious; they have an internal drive or motivation to learn. They also have good study habits and time management skills. He has noticed in his experience that high school students tend to get distracted very easily by their cell phones, their peers, or other things. Therefore, the ability to
focus can be considered to be a valuable personal trait. He also believes that perseverance and determination can help them to be successful.

Jane said that, “a drive for knowledge, curiosity, persistence, and open-mindedness – the ability to see a situation from many sides,” are very important personal characteristics that appear to influence students who persist in science. She also stressed the value of communication skills. She commented: “We know that science is really not done in a vacuum, so being a good communicator is also a key.” Greg argued that these students just “want to learn.” They are more concerned about learning than they are about grades. He explains, “They were not students that said: Is this on the test? Do we have to know it? They just wanted to know.” They asked a lot of why questions and wanted to learn more than the course required them to learn. He believes that the students who ended up doing science research were just keen about learning. He gave an example of a student who is now doing research at Jet Propulsion Laboratories. He said that this student would come and wait outside the science room almost every day to talk to him about physics. This student was not even taking his senior level course at that time, he was only in grade 10, but he just wanted to talk to him about physics because he was interested. Greg strongly believes that, “interest can almost overcome everything.”

Family, Social and Cultural Influences

All three research participants agreed that family, social, and cultural factors are crucial determinants of student engagement in science. They believe that parents, friends and societal norms play subversive roles in student engagement and persistence. Bob says that many of the students that he is involved with “study science because someone in their family does.” He also referred to friends as being strongly influential in his personal choice to pursue science as a
career. He revealed that he had a friend with whom he constantly competed and that this always kept him engaged.

Jane explained that one of the questions they ask students when they interview for internship opportunities inquires about what influences them to become engaged in science. She commented: “Quite a few of them said my mom and dad want me to be a scientist.” She also stated that in many societies it is deemed very important to pursue certain careers whether it is to become a doctor, or a pharmacist; it is just within their social structure. One student told her outright that they selected science because of parental pressure. Therefore, family and parental pressure are thought of as being highly important in determining students’ choice toward science.

Greg thinks that students at his school are pressured to go into science because of the school culture. He said that the school that he teaches at is very academic and many students decide to choose science at the senior level. A reasonable number eventually go on to pursue science at university. He says, “There are a lot of cultural influences to go into science. Science is seen as a way to get a better job. He also cited parental coercion as an influencing factor. He said:

There is a lot of parental pushing towards that [science], so that’s probably societal. Parents are saying this is where you need to go to get a good job. This is what you should be studying. So a lot of students are pushed into taking all three sciences in grade 11, and all three sciences in grade 12. At least 2 out of 3 are taking math and trying to go into science. A lot of students who don’t have an interest are also pushed by their parents to take science.

Another idea brought up by Greg was the concept of how experiencing success in an area of study can be a motivating factor to staying engaged in that area. He stated that people who have done well in science get rewarded extrinsically and intrinsically. They get to feel good
about themselves which is intrinsically motivating and they are also validated by others which is extrinsically motivating. Greg believes that society attaches intelligence to how well you do in science and math. You could be very good in English and art but that is not seen as intelligence. It’s seen as being creative. He continued to explain that because parents and society seem to talk about science as a path that leads to success, a lot of students apply into science. Here again he is demonstrating how powerful societal and cultural influences could be in determining science persistence.

b) Reasons Students Fail to Remain Engaged and Persist in Science

The participants also acknowledge that there are many factors that cause students to opt out of science. Among the reasons cited were: individual perception, the amount of time invested in studying, discouragement caused by poor grades, and fear of mistakes/failure, misconceptions about the process of science, not having learning needs met and other competing interests.

Bob reasoned that when science is presented in a way that seems difficult, students may choose not to pursue it. If they are made to believe that science is for “the smart folks” then they might opt out. He argued that if science is just taught in one way and students learning needs are not met that might cause them to be “pushed away from science especially if it appears to be difficult.” He also noted that the length of time one has to spend studying science and the job prospects can cause students to opt out. The failure of teachers to stimulate and motivate their students was also mentioned as a dropping out factor by Bob.

Jane also mentioned time investment as a reason why students give up on science. She said: “There are too many degrees to do, or there’s too much time invested to get to that career.” She explains that if they had someone in their life who somehow taught them that their science
skills aren’t strong then discouragement could set in and help them to opt out. In addition to the above reasons, Jane also commented:

But other factors that influence students to opt out of science have to do with the fact that some students will perceive it as being too difficult. The teaching style does not necessarily match their learning style. They do not understand the curriculum and therefore perceive it to be too hard for them. That’s discouraging, and it’s about feedback as well.

Jane also mentioned that students choose to opt out when they do not get answers to their questions. She believes that creating situations for them to ask good questions and explore the answer to those questions is absolutely vital. Another factor which she mentioned was the fear of making mistakes. She said: “Sometimes students have a misconception about what it is to be a scientist.” They do not realize that the process of science involves making mistakes. She explained: “when you make a mistake you learn more from that mistake than you do from doing something right the first time.” She described the process of science as a meandering river. It’s not about moving directly from point A to point B. She reiterates that “no one as a professional scientist gets directly from point A to B.” and that understanding that it’s all right to make mistakes is crucial.

From the teacher’s perspective, Greg outlined a number of issues that influence students to pursue alternate career paths instead of science. He strongly believes that failure is the single most important reason why many students opt out of science. He explained that for many students getting a lower mark than they expected could be the cause. Even if they are doing well, but their grades are slightly lower than what they achieve in other courses they may use that to conclude that science is not for them. He also cited perception as a factor. Students may have
the ability to do well in science but if they have the perception that they are not, they may opt out. Furthermore, he alluded to the fact that teaching strategies, background, *language skills*, *math skills and comprehension skills* could also prevent students from choosing science. Additionally, he explained that in some cases a student may have *competing interest*; they may be “passionate about something else.”
CHAPTER 5: Discussion

Introduction

Today, teacher-scientist partnerships are organized in an effort to nurture an interest in science and/or to motivate students to pursue careers in science. “How do these collaborations work?” “What are teachers’ and scientists experiences and perceptions of these partnerships?” and, “What are the outcomes for students involved in these partnerships?” These are the questions that this study set out to answer. As outlined in the last chapter, the results of this study indicate: a) Several factors influence the formation of these partnerships; b) Various partnership strategies are being employed by teachers and scientists, c) These partnerships result in a variety of outcomes; and d) A wide range of factors influence the engagement and persistence of students in high school. This final chapter will compare and contrast these findings with the themes found in the literature; and share the implications, significance, and limitations of this study. In addition, this chapter is also an evaluation and reflection on the research process as a whole.

How Findings relate to the literature

The four themes that resulted from this study were also found in the literature. However, there were some nuances discussed under each theme that were not necessarily found in the literature and vice versa. The fact that these themes keep reoccurring, points to their level of validity and suggests that this area of science education research should not be overlooked. More and more students are reporting that school science does not relate to their everyday life. In fact, as I consider various models of curriculum reform this may be the single most important issue that appears to influence major curriculum reform decisions. There are several differences between everyday life and school. Resnick (as cited by the National Research Council, 2000, p.74) discussed three of those
differences. The first major difference between schools and everyday settings that was noted was that the notion of collaboration is lost in schools and that schools place much more emphasis on individual work than most other environments. His reference to the study of navigation on U.S. Ships that found that no individual can pilot the ship alone definitely brought home the point that people need to work collaboratively and share their expertise. Moreover, scientists today work as teams and there is no reason why schools cannot adopt this strategy. The second major difference that was highlighted was that in everyday settings there is a heavy reliance on tools to solve problems whereas in schools mental activity is the primary means used to solve problems. Although tools allow people to work almost error free and new technologies allow students to use tools similar to those of professionals, schools are still reluctant to make use of this opportunity. The third difference that Resnick mentioned was that schools use abstract reasoning instead of contextualized reasoning. Most people solve their problems by thinking contextually, but schools insist on teaching students to use methods that are far removed from their daily experience. In order to develop a science curriculum that promises to bring about effective change these areas of contrast between the real world of students and the imposed world of school where they spend much of their time must be given serious consideration.

The above argument directly relates to the finding that teacher-scientist partnerships provide the opportunity for students, teachers and scientists to be immersed in each other’s environment. Students and teachers get to experience science in more authentic ways and scientists are exposed to the real world of students. As Houseal et al (2014) explain, “student-scientists partnerships employ authentic, inquiry-based learning to provide students and teachers with access to the scientific community and allow for their engagement with actual scientific research.” However, as they pointed out, the actual role that teachers play in these partnerships is seldom highlighted. This study, however, indicates some of the intermediary roles played by teachers in these partnerships. Apart from professional growth, it was evident that teachers’ pedagogical strategies are being influenced by these partnerships. They take the new ideas that they learn and bring them back to the classroom.
In relation to professional development, the literature speaks of the need for teachers to develop pedagogical content knowledge (PCK), this study shows that TSPs provide the opportunity for teachers to do that. The NRC (2007) stressed “the importance to provide teacher professional development that includes experiential learning opportunities with time to: a) generate answerable questions, b) think scientifically, c) analyse phenomena, d) interpret evidence, and e) engage in meaningful discourse about the validity of generated claims.” Again, the results showed that teacher-scientist partnerships provide the appropriate stage for these objectives to be reached. However, the fact that more of these partnerships are still not being seen in schools relates to another crucial outcome of this research – the availability of resources. The amount of resources (i.e., time, people, and money) available to teachers and scientists to develop partnerships is probably the most critical factor to consider when evaluating their success or failure. Most educational reform efforts will require these resources. Teachers may be willing to transform their classrooms by collaborating with scientists, but because most times they are not involved in the decision making process where resources are allocated; it becomes extremely challenging to implement the changes that they desire.

This brings us to the reason why it is so vital to receive institutional and administrative support in the establishment of teacher-scientist partnerships. Administrators play a pivotal role in ensuring that new initiatives get off the ground. Unlike teachers, they are the ones who make the key decisions regarding the allocation of resources. Therefore, if administrators do not sense the importance of providing students and teachers with the kind of authentic experiences that teacher-scientist partnerships offer, it will be very difficult to start these initiatives in schools. Moreover, the subversive role that institutional structures play in precluding change cannot be ignored. The way our institutions are set up is a significant barrier to implementing change. The time constraints place on teachers in schools, and the prescribed curriculum, together with the fact that science is not the only subject that students do in schools are all factors that hinder
experienced-based initiatives. Scientists also have their own challenges to face. Their main business is research. They are constantly looking for funding for their research projects and sometimes this takes up all of their time. For teacher-scientist partnerships to be successful they will have to be made a priority by policy makers. Institutions will have to be organized in ways that better support these collaborations.

The findings of this study indicate that most of the strategies used by teachers and scientists to collaborate are short-term strategies. This theme was also supported by the literature. There are few sustained relationships, except in cases where special projects are being undertaken and resources have already been assigned. Whereas there is value in having short-term relationships, teacher-scientists partnerships tend to be most effective as long-term arrangements. The establishment of secondment agreements, project-based partnerships, scholarship programs, and other cooperative relationships that extend over a longer period of time, seems to be a more sustainable approach to use when setting up teacher-scientist partnerships (TSPs). These extended relationships tend to provide more time for deeper learning of content knowledge and processes, and the acquisition of skills.

The factors influencing science engagement and persistence found in this study are also common themes found in the literature. Many studies have shown that experienced-based learning stimulates students thinking and gain their interest. Students need experiences that relate to their everyday lives. They need to feel connected to the content that is being presented to them. However, in relation to this finding it was the argument that humour must be used to keep students engaged that was most unique. The use of humour is often spoken of when dealing with other subjects like art, music and drama; rarely would you hear a reference to humour being given in relation to science. This may be a good argument for the use of science
jokes in class. Some teachers employ this technique without having any research evidence to support its use. This finding indicates that there might be some academic merit to using humour to engage students in science. The main idea here though is that providing students with the right experiences can excite their attention and keep them interested in science whether or not they plan to pursue science careers.

The influence of intrinsic motivators on students’ science persistence is not a prevalent theme in the literature. However, this study suggests that there are many personal characteristics that can increase the tendency of students to remain engaged in science. It may seem obvious that curiosity, internal drive, avoiding distractions, good time management skills, perseverance, open-mindedness, and communication skills are necessary to be successful as a science student, but these personal characteristics and skills are rarely mentioned as factors that influence science persistence. How can the influence of these personal traits on science persistence be determined? This is a question that I think needs further consideration.

The influence of family, background, social and cultural influences on science persistence was a theme that was found both in this research and the literature. This finding tends to suggest that students’ attitudes towards science are almost predetermined. How do influences outside of the school setting affect students’ choices related to science? This is also an important question for further study. Parents may encourage and even coerce their children to go into science, but what eventually determines their final choice? “Which factors have the most influence?” and “How do these factors relate to each other?”

As noted in the literature and in the findings of this study, students give up on science for a variety of reasons. Some perceive it as being too difficult; some are afraid to make mistakes and fail; and still others may have competing interest, or may not be willing to devote the time
required to prepare to obtain a career in science. Whatever the reason might be, I think it is reasonable to think that teacher-scientist partnerships may be able to address some of these challenges in a very practical way.

**Implications of this study**

This study has implications for all stakeholders in the science education enterprise (i.e., students, teachers, administrators, policy makers, parents and the community), and the education system as a whole. Students benefit from collaborations between scientists and teachers in a number of ways. They do not only obtain knowledge and skills from these relations; but they also get to meet mentors who can significantly alter their attitudes towards science. They are often motivated by the new innovations and developments that the scientists share with them, and they also gain a better understanding of the true nature of science. All of these benefits seem to suggest that giving students the opportunity to have these experiences should no longer be thought of as an optional part of the curriculum, but instead as the most vital part of it.

This study has a lot of significance implications for teachers. Drayton and Falk (2006) explain that in these collaborations teachers should be the ones deciding on the kind of knowledge that is acquired instead of scientists. They point out that teachers have a form of “tacit knowledge” (p. 739) available to them about the classroom and student learning that the scientists do not have. Therefore, they are in the best position to decide on the type of science knowledge that they would want to acquire, and on the way partnerships can be best organized to meet their needs and those of their students. The implication here therefore is that the role of teachers in these partnerships should not be passive. The teacher should play a dual role of student and teacher, where he/she becomes a learner at times and the instructional leader at other times.
This study has implications for administrators and policy makers also. As stated earlier, with no administrative and institutional support it is almost impossible for teacher-scientist partnerships to be successful in schools. Administrators and policy makers need to negotiate for the resources that are needed to support these relationships. This will require an essential change in the way in which they perceive the administering of the science agenda in schools. Students may have to be given more flexibility to choose the courses they select and when required the entire daily schedule of schools may have to be reworked.

Higher organizations such as school boards/districts and the ministry of education will have to be proactive in their planning to accommodate this paradigm shift. More funding will have to be made available to support these programs and special departments may need to be set up to assist schools in administering these partnerships. New policy documents may have to be written. Currently, only a few schools seem to be able to support these partnerships, and although the number of these arrangements are increasing all over the world there are still many challenges in relation to curriculum integration and effective functioning of these collaborations that need to be addressed (Wormstead, Becker & Congalton, 2002).

Limitations and Further study

This study is the first step in a series of studies that I intend to conduct on teacher-scientists partnerships. There are many areas still left to explore in this area of research. In subsequent studies, I intend to use a larger sample size to increase the generalizability of the data. More teachers and scientists will be interviewed, together with students, administrators and other stakeholders. As I mentioned in chapter 3, I will also include other sources of data in my data collection – records, observations, video recordings and so on – to ensure triangulation of my data. By using various sources of data I intend to gain further insight into the themes and
perspectives that emerged from this study. In this study only qualitative methods were used, but in the future a mixed method approach will be used. Quantitative approaches (i.e., surveys) will be employed in order to include a wider cross section of the population.

This study did not reveal a lot of the outcomes for students once they left high school. I would be interested in following up with students who were involved with teacher-scientist partnerships beyond university to see if any correlation could be made with their engagement in partnerships and their attitudes toward science regardless of career choice. In addition, as indicated earlier, I would also like to investigate the correlation between science persistence and personal attributes to gain insight into whether or not intrinsic/personal traits or extrinsic motivators are more effective in influencing science persistence.

Finally, further studies could also focus on the effectiveness of the various strategies being used by teachers and scientists to collaborate. Which strategies work best and why? This would help to inform teacher-scientist collaborators to improve the efficiency of their partnerships.
References


Appendix A: Informed Consent Document

Dear Participant:

I am currently a graduate student enrolled in the Master of Teaching Program at the Ontario Institute for Studies in Education of the University of Toronto (OISE/UT). As part of the requirements of this program, I am in the process of completing a Major Research Project on the topic: “Motivating High School Students to Persist in Science: A Collaborative Approach.” As an expert in your field of work, I believe that your knowledge, experience and insight would add great value to my research.

My data collection consists of approximately 30-45 minute interviews and will be conducted at a time and location that is suitable to you. The interviews will be audio recorded and transcribed for the purpose of analysis. The content of the interviews will be used for a final research paper, informal presentations to classmates, and potentially at a research conference or for publication. Your identity which includes your position and employer will remain anonymous and only my research supervisor and I will have access to this data.

Please be assured that your participation in this project is completely voluntary. In addition, you may decline to answer any question during the interview, stop the interview at any time and withdraw from the study for any reason. Should you have any questions or require further information, you may contact me or my research supervisor.
If you agree to be interviewed, please sign below and retain a copy of this letter for your records.

I appreciate your assistance in this endeavour.

Yours truly,

___________________________________
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CONSENT TO PARTICIPATE

I, ________________________________ wish to participate in the OISE/UT project as outlined above.

______________________________________
Participant’s Signature                                     Date                                     Participant’s Printed Name
Appendix B: Interview Questions

Primary Research Question:

*How do high school science teachers and practicing scientists collaborate to motivate and encourage high school students to remain engaged in science and/or pursue careers in science?*

1. What role, if any, should secondary school science play in encouraging students to remain engaged in science, and in the development of future scientists?

2. What role do you perceive for teacher-scientist partnerships in bringing about science curricula reform?

3. What strategies do scientists and teachers use to develop effective scientist-teacher partnerships in high schools?

4. What do you perceive to be the components/ingredients of an effective partnership program?

5. How can science teachers and scientists collaborate to plan and implement instructional strategies that work effectively to motivate students to remain engaged in science or pursue science as a career?

6. How can science teachers and scientists collaborate to plan high school science-related extracurricular activities (e.g., science fairs, clubs, and summer internships)?

7. What personal characteristics can be observed in students who eventually choose to become professionals in the field of science?

8. What influences students to remain engaged in science or choose to study science?

9. What factors influence students to opt out of science?

10. What factors do you perceive work as hindrances/barriers to the establishment of teacher-scientist partnerships in schools?

11. What are the overall outcomes for students involved in teacher-scientist partnerships?