The Implementation of Applied Science and Technology in Quebec:

A Descriptive Mixed-Methods Study

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Abstract

This mixed methods research study describes the implementation of Applied Science and Technology (AST) - a recently-implemented Secondary 3 and 4 program in Quebec. AST is part of the Math, Science and Technology Domain of the Quebec Education Program (QEP), a comprehensive reform of the K-11 Quebec curriculum. It is very different from the science programs of the past. AST teaches science by emphasizing the applications of science and technology in the real world of the students. The program uses the pedagogy of constructivism and integrates engineering technology into the science content.

This study examines the extent to which teachers follow the AST curriculum and use a constructivist/inquiry-based pedagogy. It also described the students' engagement with the program and their motivation and interest in learning science. Quantitative data were collected from online surveys of AST teachers and students as well as school board enrolment figures. Qualitative data came from extensive visits to AST classrooms in action and interviews with teachers, principals and science consultants. The data were triangulated to arrive at a comprehensive description of the implementation of AST.

The study examines the teachers' epistemology with relation to the AST curriculum. It found that many teachers, with support from consultants and new science teaching resources, are successfully incorporating applications of science and engineering technology as prescribed by AST. They are using some constructivist pedagogical practices – accessing prior knowledge, providing an

active learning environment and contextualizing the content within the students' reality. Some teachers, on the other hand, are finding it quite challenging to fully incorporate the technology aspect of the curriculum and the constructivist nature of the pedagogy. Students show strong motivation to learn science and express satisfaction with their experiences in AST when the AST activities are hands-on, have personal meaning and give them a measure of autonomy and challenge.

Résumé

Cette étude de méthodes mixtes décrit la mise en œuvre du programme d’applications technologiques et scientifiques (ATS) qui a été récemment mis en œuvre au Québec en Secondaire 3 et 4. ATS fait partie du domaine de la mathématique, de la science et de la technologie du Programme de formation de l’école québécoise, une réforme globale au Québec. Il est très différent des programmes scientifiques du passé. ATS enseigne la science en mettant l'accent sur les applications de la science et de la technologie dans le monde réel des élèves. Le programme utilise la pédagogie du constructivisme et intègre la technologie d'ingénierie dans le contenu scientifique.

L'étude a examiné l'épistémologie des enseignants par rapport au programme ATS. Elle a aussi examiné la mesure dans laquelle les enseignants et enseignantes suivaient le programme de l’ATS et utilisaient la pédagogie du constructivisme. Il a également décrit l'engagement des étudiants avec le programme et leur motivation et leur intérêt pour l'apprentissage des sciences. Les données quantitatives ont été recueillies à partir des sondages en ligne des enseignants et des étudiants de l’ATS ainsi que des chiffres d'inscription des commissions scolaires. Les données qualitatives proviennent de plusieurs visites dans les classes d’ATS en action et des entrevues avec des enseignants et enseignantes, des directeurs et directrices d’école et des conseillers et conseillères pédagogiques. Les données ont été triangulées pour arriver à une description exhaustive de la mise en œuvre de l'ATS.

L'étude a révélé que les enseignants, avec l'appui des conseillers pédagogiques et de nouvelles ressources d'enseignement des sciences, incorporent avec succès les applications de la technologie et de l'ingénierie tel que prescrit par l’ATS. Ils utilisent certaines pratiques pédagogiques constructivistes - accéder à la connaissance préalable, fournir un environnement d'apprentissage actif et mettre en contexte le contenu dans la réalité des élèves. Certains enseignants et enseignantes, d'autre part, trouvent qu'il est très difficile d'intégrer pleinement l'aspect technologique du programme et la nature constructiviste de la pédagogie. Les élèves montrent une forte motivation pour apprendre la science et se disent satisfaits de leur expérience dans l’ATS lorsque les activités sont pratiques, ont une signification personnelle et leur donnent un certain niveau d’autonomie et défi.

Acknowledgements

I began this quest as a late-career research study with the encouragement of Dr. Brian Alters who became my first supervisor. When I first approached him with my ideas, his initial response was, “You’ve got to have a PhD!” For the next few years he guided me and helped me plan my study of Applied Science and Technology.

My last three years working on this project were as a retired educator. During this time Dr. Anila Asghar became my co-supervisor, with Dr. Alters. As my research progressed, she spent countless hours with me reviewing my research and then my dissertation. Her insights enabled me to understand the need for clarity and rigor. She always reminded me that in my writing I had to make my case clear to the reader, who will not be as familiar as me with my subject matter. I could not have seen this project through without the support and encouragement of Dr. Alters and Dr. Asghar.

I am very grateful to the teachers who welcomed me into their classrooms. I am so impressed with their enthusiasm for science teaching, their professionalism and their insight into how teenagers learn. The science consultants, whom I had worked with for many years, were a great source of information and support to me as well during this study. They are the real experts in science education.

My wife Shirley has been a constant, unwavering supporter of my student endeavours. Luckily, as a retiree, I always had time for family. My children,

Lianne and Michael, well into their careers and marriages, were always proud and encouraging, if not a little amused with my continuing status as a student!

Chapter 1: Introduction to the Study

1.1 Foreword

Applied Science and Technology (AST) is part of the Quebec Education Program (QEP), a comprehensive curriculum, which has been implemented progressively over the past 12 years from elementary to high school. “Helping students construct their world-view, construct their identity and become empowered are the three aims of the Québec Education Program.”(Ministère de l’Éducation du Québec (MELS), 2004, p. 6 Ch 1). Commonly referred to as the Curriculum Reform, the QEP is a competency-based, student-centered curriculum that has changed the way all subjects are presented and evaluated. AST, the subject of this study, was implemented in most English high schools in the fall of 2008 in secondary 3 and, the following year, in secondary 4 – the year when all students must write exams to qualify them for a high school leaving diploma. The implementation of AST presented parents, teachers and school administrators with a brand new set of parameters for science education in high school. Parents and their children can now choose between equally-valued science courses, Science and Technology (ST) and AST in Secondary 3 and again in Secondary 4. The name “Applied” does not mean lower academically. Rather it refers to a different orientation from that of ST. AST focuses on scientific and technological applications where students “explore the different facets of the many applications of science and technology” (MELS, 2007, p. 5) Technology, meaning engineering technology, has become an integral part of the content and activities of both programs. Schools, with the support of school boards, had to equip the labs with new tools and equipment. These “tech labs” had to be up and running and teachers and lab technicians had to be trained to use them.

Schools and school boards scrambled to get ready. Training sessions began in 2006. School boards mobilized their consultants to give workshops and visit science teachers in their labs to advise them on how best to prepare themselves and outfit their labs. I was personally very involved with the implementation of the QEP. When it was first introduced in 2000, I was an elementary school principal and, as such, responsible for the introduction of the QEP in my school. By the time that the Science and Technology programs were being introduced to Cycle 2 high school (Secondary 3, 4 and 5), I held the position of Director of the Educational Services Department (ESD) for the largest English school board in Quebec. Implementation of the QEP was the main job of ESD. As director, I met regularly with school administrators to review the details of the new programs and discuss the many organizational and human issues involved with the implementation. When answers to the many questions didn’t seem clear and they could not determine the direction they needed to take, frustration was common. Teachers, used to the curriculum requirements of the previous curriculum changes, had a variety of reactions to the new reforms. Some thought it “would go away if we wait it out”; some wondered why it was necessary at all; and many embraced the ideas as positive advances in teaching and learning. But, as is the case with most educational change, teachers, administrators, consultants, and technicians all rolled up their sleeves and worked to make the implementation successful for their students.

This study is about the implementation of this new science program in high schools of Quebec. Throughout my career in education, much of which focused on science education, I have wondered how teenagers learn science best. As a retired educator, I am now in a position to pursue this question. The QEP has been fully implemented in high schools for 2 years now (Ministère de l'Éducation du Loisir et du Sport du Québec(MELS), 2007). I have chosen the Secondary 3 and 4 Applied Science and Technology program (AST), as the focus of my study because it offers a new and exciting approach to science teaching and learning. AST students learn science, in large part, by studying the applications of science in real life situations. (MELS , 2007, p. 3 Chapter 4) They spend a lot of time in the lab doing hands-on activities which integrate technology with science. The scientific content knowledge they need is developed in the context of the applications they study. Physical Sciences 416 is the program that AST replaces. Though hands-on in nature with many lab activities, it presented science to students in a more traditional way. Scientific principals were presented in the classroom and illustrated with lab activities, but much less attention was paid to the applications of science in the real world (MEQ, 1990).

I will use this study of the implementation of AST to pursue the following questions:

- What is the theoretical basis of AST?
- How is AST being implemented?

- Are AST students motivated to learn science?

1.2 Chapter Summary

Chapter 2: Theoretical Background and Literature Review – I describe three main aspects of AST:

- The Quebec Education Program (QEP) – its structure, content and philosophy.
- The philosophy of science and technology education – scientific literacy, constructivism and inquiry-based pedagogy and some of the educators and scholars who have influenced it.
- Applied Science and Technology itself – the curriculum and pedagogy.

Next I present a discussion of why this study is needed by the science education community. This includes the need for research into the implementation of the curriculum reform as it applies to science and technology, since none has been done up to this point. This includes the need to find out how teachers are being supported, to what extent AST is actually being applied as it is written and how AST motivates students to learn science and technology. I end the chapter with the presentation of the research questions which are directing the study.

Chapter 3: Methodology – I present my methodology for the study. I describe a mixed methods approach - how I use qualitative and quantitative approaches and triangulate them into a comprehensive study of the implementation of AST. The quantitative instruments include surveys of teachers and students and enrolment data. The qualitative data come from classroom visits and interviews with teachers, principals and consultants. In particular I describe:

- How I recruited the participants and decided on the research settings – the teachers and students for the surveys, the classes to visit, the people to interview, and the enrolment data from the school boards.
- The data collection instruments – what they are and how they were constructed.
- The collection of the data – how I went about generating the data from each of the instruments.
- How I analyzed the data – the processes I used to make sense of the quantitative and qualitative data.

Once I have described the data and instruments, I discuss validity concerns and how they are being addressed. Finally I describe the triangulation of the data and how this leads to an understanding of all aspects of the implementation of AST.

Chapter 4: The Teacher Surveys – This is the first chapter in which I describe data collection and analysis. I begin with the details of the teacher survey and how I built it – information about the teachers, the questions about teaching practices and student interest, the questions asking about the support they receive and the categories into which I divided the questions. Next I describe the participants, how I recruited them and the number of their responses retained for analysis. The analysis of the data from the responses to the survey is the major section of Chapter 4. Using the data from the survey, I establish quantitative statistics to link and compare the many aspects of the teacher survey. I use the findings from the survey to develop a first picture of the AST classroom according to the categories I established for the survey questions:

- Real World – The extent to which teachers contextualize their AST activities with the world that their students are familiar with.
- Constructivist Learning – The degree to which teachers use the pedagogy of constructivism and inquiry-based learning.
- AST Curriculum Content – How closely the teachers follow the AST curriculum as prescribed by the MELS.
- Student Motivation – The teachers' perception of the level of motivation of their students to learn science and technology in their AST classes.
- Support for teachers – The level of satisfaction of teachers for the support they receive from the school board, ministry, and teaching resources.
- Use of tools – The extent to which tools are used in AST activities.

<u>Chapter 5: The Student Survey</u> – This chapter is quite similar to that describing the teacher survey. Like Chapter 4, I describe the details of the questions, the categories of questions and the recruitment of participants. The big difference with this survey is that only students in the classes I visited were invited to participate, not students across the province.

Also I analyze the survey responses under two main categories:

- The nature of the activities done in class – Real world contextualization, constructivist pedagogy, AST curriculum content and use of tools (as described above).

- Student motivation - The students' feelings about AST, their motivation to learn science and their level of confidence in their ability to succeed in AST.

I use the results to establish links and come up with a picture of the classes I visited - this time from the students' point of view. Particular attention is paid to the analyses of the questions related to student motivation and engagement with the learning of science. Student gender is also investigated to see whether there are any significant differences between the responses of boys and girls.

<u>Chapter 6: Classroom Visits</u> –I describe my visits to AST classrooms. First I talk about what I was looking for, how I conducted myself in class, and how I recorded my observations. I described the selection of teachers and summarized the overall visit schedule and student and teacher demographics. Themes are developed from my observations of classroom activities. I present my descriptions and findings under the following three themes:

- The AST Curriculum - how the teachers use the activities to fulfill the requirements of the AST curriculum.
- Constructivist / Inquiry-based Pedagogy –teaching methodology in AST and how it fits in with constructivism and inquiry-based pedagogy.
- Student Motivation and Engagement – how teachers motivate their students to learn science and technology and engage them in the AST activities.

After a brief description of a selection of seven activities, I begin the theme-by-theme presentation of my findings. For each theme I summarize the theme-related aspects of each activity. I then illustrate that theme with a detailed vignette of one or two activities. I present each activity in detail, describing my observations from beginning to end, especially in relation to the theme highlighted for that activity. I conclude the chapter with a summary of the key findings from my observations.

Chapter 7: Interviews – I detail the processes and findings of the interviews I conducted with teachers, principals and consultants giving me three perspectives about what goes on in the classrooms of AST as well as what occurs behind the scenes affecting the progress of AST. I describe the questions I asked of each group as well as the themes that emerged from that group as follows:

- AST curriculum and approach
- Pedagogy - constructivism/Inquiry
- Student motivation and behavior
- Use of tools, labs and technicians
- Administrative/ Student selection

After presenting the detailed findings from each group separately, I put them together under the headings of each common theme and analyze the similarities and differences. Finally I discuss the implications for the implementation of AST of these findings.

Chapter 8: Synthesis – This is my concluding chapter. I synthesize what has been learned from this study of the implementation of AST. It has been written is such a way as to make it possible for a person to read only this chapter and still be able to understand nature of the project and its main findings. The chapter is divided into 3 sections, one for each of the sets of research questions: theory, description and outcomes.

The theory section reviews what is behind AST and summarizes the main issues: technology, pedagogy of constructivism and inquiry-based learning, and applications of science and technology. In both the description and outcomes sections I triangulate the findings of the quantitative and qualitative research to come up with the main conclusions of this study. I continue to use the same themes developed throughout this dissertation. Finally I make some recommendations from my personal point of view, taking into account what I have learned here and combining this with my experience in the school system, having been heavily involved in the implementation of AST as a senior administrator.

I hope you enjoy the ride!

Chapter 2: What's Behind AST and Why Study it?

In this chapter, I examine the theoretical background of AST. I begin by describing the QEP as a whole – its philosophy and content. Then I look at some of the major trends in the philosophy of science education - science literacy, constructivism and inquiry-based pedagogy - and how they have developed and changed the practice of science teaching over the last 20 years both in Quebec and elsewhere. Finally I discuss how these changes have influenced the writing of the Quebec Secondary Science and Technology programs, especially AST.

In Part 2, I describe why there is a need for research on the implementation of AST.   At the end of Part 2, I present my Research Questions for this study, resulting from the gaps in research which I identify.

2.1 Theoretical Background: The Quebec Education Programme (QEP)

The Educational Reform in Quebec is part of a world-wide trend to overhaul educational systems. It was implemented following several sets of hearings and reports involving the Ministry of Education and the Superior Council of Education. It began with extensive meetings of the Commission for the Estates-General on Education in 1997 and culminated in the Énoncé de politique (Ministerial Plan of Action for the Reform of the Education System) (Potvin & Dionne, 2007). As a result of these reports and consultations, the QEP was developed around a structure of competencies, subject domains and cycles (MEQ, 2004).

In this section I describe the fundamental changes brought on by the Curriculum Reform including:

- Structural changes to the way school is organized
- Pedagogical changes to both the content and organization of the curriculum

It is important to comprehend the overall structure of the QEP to understand the nature of AST. I will show how AST fits into the QEP and follows the QEP model: The written AST program provides the teachers with the overriding principles of the course, its three competencies, content, key features, outcomes and evaluation criteria.

2.1.1 School Organization

Under the QEP, the grade structure of schooling from K to 11 has been reorganized into cycles (MEQ, 2001).

- Elementary: 3 cycles of 2 years (Cycles 1, 2 and 3)
- Secondary: Cycle 1 – Secondary 1and 2
  Cycle 2 – Secondary 3, 4 and 5

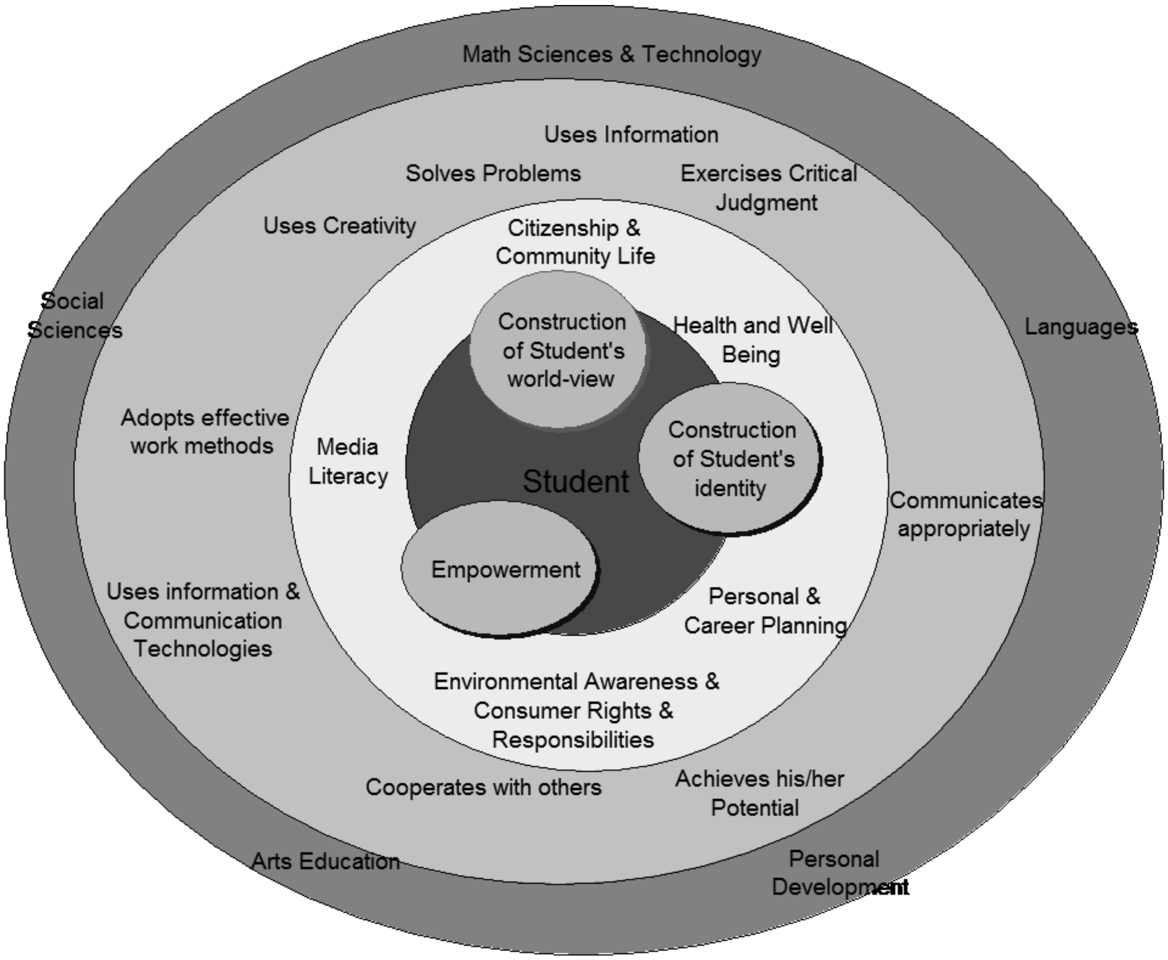
Student progress is evaluated at the end of each cycle at which time the decision is made to advance to the next cycle. In Secondary Cycle 2, the object of this study, each year of the cycle is separate. As in the past, a student is judged on the achievement of each year before proceeding to the next.

2.1.2 Pedagogical Changes

The Quebec Education Program is a competency-based curriculum divided into six Subject Domains - Mathematics, Science and Technology being one of them (MEQ , 2007). Each subject has competencies which must be developed by the students through Elementary and Secondary school. The content for each subject for each cycle is defined by the QEP and is used to develop the competencies.

Spanning all the subject domains are the Cross-Curricular Competencies (CCCs) and the Broad Areas of Learning (BALs). The CCCs are academic skills which must be developed in all subjects and are subject to evaluation at the end of cycle. The BALs, however, are life-skill-oriented. They address the student's personal development and his place in the world and are not subject to evaluation. See Appendix A for a list of the CCCs and BALs. Figure 2.1 illustrates the structure of the QEP.

Figure 2.1 The Quebec Education Program



Notes: Reproduced from The Quebec Education Program, Secondary School Education, Cycle One (MEQ, 2004)

At the center is the student. Immediately surrounding the student are the aims of the QEP. The light oval shows the Broad Areas of Learning. In the middle oval are the Cross Curricular Competencies. As shown in the outermost oval, the QEP was written with five Subject Domains. All students must take courses and be evaluated in the five Subject Domains according to the rules specified in the Basic School Regulation (MELS, 2011).

2.1.3 Philosophy of the QEP

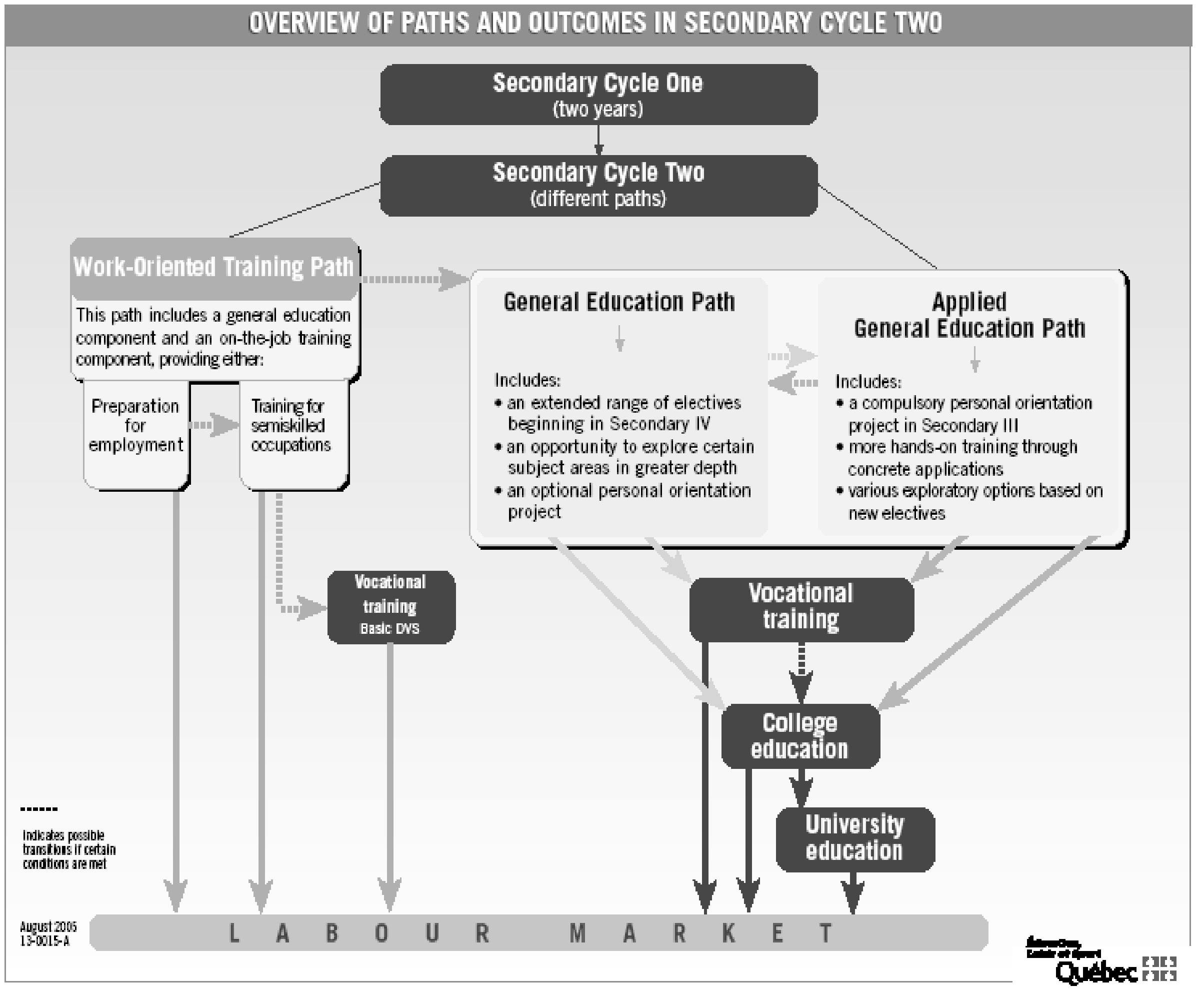
This change to a competency-based curriculum has required a profound shift in teaching and learning practices – a significant paradigm shift (Brassard, 2005; Louise Lafortune & Deaudelin, 2001). Among the required practices are a student-centered approach to learning, project-based learning, differentiated instruction to meet the needs of all learners, the introduction of information and communication technologies, a socio-constructivist approach to teaching (Louise Lafortune & Deaudelin, 2001) collegiality and cooperation among teachers, and continuous professional development (Brassard, 2005). These aspects will be described later in this chapter.

2.1.4 Content of the QEP

2.1.4.1 The Pathways

The QEP recognizes that not all students should follow the same pathways to high school certification. While all students follow the same program through Secondary Cycle 1, different pathways become open to them as they enter Cycle 2 (Secondary 3), as shown in Figure 2.2.

Figure 2.2 The Pathways



Notes: Reproduced from the Quebec Education Program, Secondary School Education, Cycle 2 (MELS, 2007)

The Work-Oriented Training Path, for students experiencing considerable academic difficulties, can lead to Vocational training or directly to the work place. The General Education Path and the Applied General Education Path, however, are equivalent pathways leading to Vocational or CEGEP education. Students are free to choose between these two directions for Secondary 3 and 4, and, in fact, can switch paths as they advance from Secondary 3 to Secondary 4. For the purposes of this study, the main difference between these two paths is the difference in the Science and Technology programs. Students in the Applied General Education Path take Applied Science and Technology (AST) while those in the General Education Path take Science and Technology (ST) (MELS, 2007).

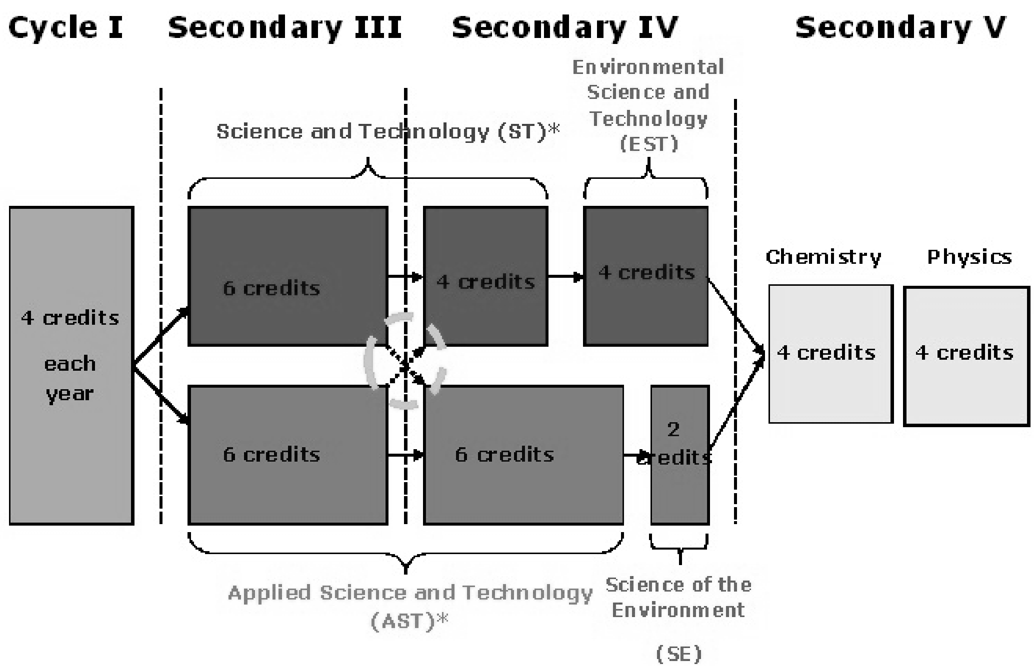
2.1.4.2 Mathematics Science and Technology Subject Domain (MST)

The QEP subject domain structure combines related subjects together. Mathematics is combined with Science and Technology in one subject domain. The logic of combining these two is simple. There is a great deal of mathematics needed for an understanding of science concepts. Students need to understand geometry, fractions and statistics, for example, in order to be able to solve problems of motion in Physics, or solutions in Chemistry, or populations in Ecology. In fact, teachers have long complained to me that there are not enough specific links between the mathematics and science curricula. Mathematics opens the door to the inclusion of authentic, contextual science-learning situations. (Davison, Miller, & Metheny, 1995; Samson, 2009).

2.1.4.3 The Cycle 2 Science and Technology programs

Beginning in Secondary 3 students must choose either AST or ST, a choice they can change in Secondary 4. At the end of Secondary 4, they must all write a compulsory exam in AST or ST from the Ministry of Education, Leisure and Sport (MELS), depending on their choice, and pass the course in order to receive a Diploma of Secondary Studies (MELS, 2011). Students who select AST in Secondary 4 have the option of adding a second Science and Technology course to their program of studies – Science of the Environment (SE), a program which is a prerequisite for Secondary 5 Chemistry and Physics.(MELS, 2011). Figure 2.3 illustrates the Secondary Cycle 2 Science and Technology programs.

Figure 2.3 Cycle 2 Science and Technology



Notes: Adapted from a PowerPoint presentation developed by the Educational Services Department, Lester B Pearson School Board, 2010.

2.1.5 Joining Science with Technology – Theoretical Directions

One of the major changes to the curriculum of the science program was the introduction of technology education - to prepare students for modern society (Charland, 2009). In fact all of the compulsory science programs from Secondary 1 through Secondary 4 are now named “Science and Technology”. The QEP emphasizes how science and technology are intertwined in the modern world.

“Science and technology are becoming increasingly interdependent, so much so that it is often difficult to draw a clear line between the two” (MEQ, 2004).

Incorporating technical education into general education was part of a world-wide trend through the 1980s and 90s, supported by UNESCO (UNESCO, 1983). Prior to this movement, students who pursued technical education were directed to the workplace and those in general education, to higher education (Charland, 2009). Using technology to teach science is well-researched - showing that technology-centered classrooms, can lead to effective science learning. (Council of Ministers of Education, 1997; Roth, 2001; Tala, 2009). Engineering design is a key theme of QEP technology content (MELS, 2007,ch. 26, p. 24).

Prior to the introduction of the QEP, all Secondary 3 students took Introduction to Technology (ITT) (MEQ, 1993). Students worked in a woodworking lab developing engineering designs and building models. The QEP Science and Technology programs specifically integrated the essentials of ITT (Barma, 2009).

Many science teachers are unfamiliar with how to integrate technology into the science curriculum (Capobianco, 2010). The successful implementation of the Science and Technology programs requires training and support for teachers so that they have the ability to use technology in the lab activities and present the content of the Technological World. The Centre de Developpement Pédagogique (CDP) provides teachers with activities to help them integrate technology. They focus on working with technological objects which are familiar and relevant to students (Loiselle, 2009).

The integration of science and technology is a new direction for the QEP. The writers of the Science and Technology programs have also incorporated other current trends in science education - scientific inquiry and constructivist pedagogy, for example. The next section will describe these recent trends and how they relate to the QEP programs.

2.2 Philosophy of the Science and Technology Programmes

This section will begin with a section on scientific literacy. I will then develop a case for the centrality of the pedagogy of constructivism as the main philosophical base for modern science teaching methodology. As I discuss constructivism, I will describe its broad base of support in science educational research and the influence of some of its main proponents (as well as some of its detractors). I will link this research on constructivism to some of the more recent work on inquiry-based learning in science education. Finally I will discuss some of the practical challenges to implementing a constructivist-based science curriculum – challenges to traditional teacher-centered behaviorist methodology and challenges involved with the need to cover the extensive content of AST.

2.2.1 Scientific Literacy

The QEP makes scientific and technological literacy a central theme of AST:

> It is important to help students gradually develop their scientific and technological literacy and to understand the role that such a literacy plays in their ability to make informed decisions and in their discovery of the pleasures of science and technology and their applications. (MELS, 2007, p. 2)

The National Research Council (NRC) describes scientific literacy as "the knowledge and understanding of scientific concepts and processes required to participate in a democracy" (National Research Council, 1996, p. 22).

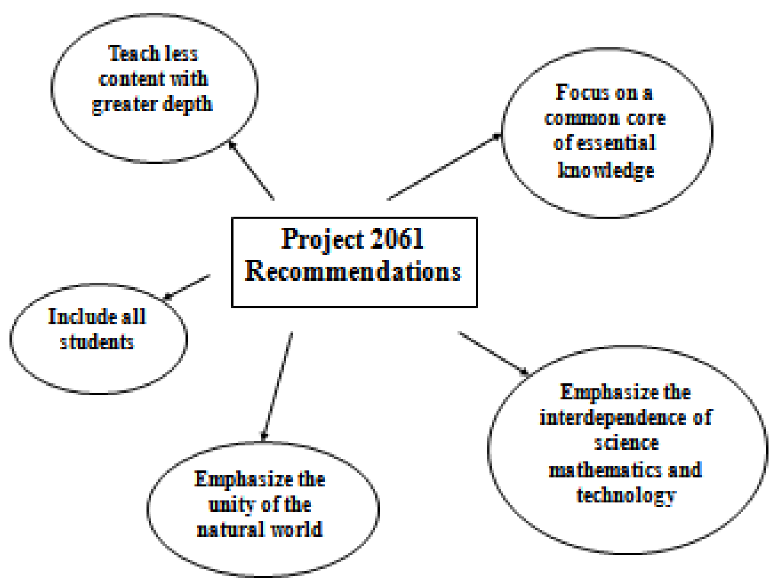
The writing of the QEP was influenced by ideas of scientific literacy from Canada and the USA (Bybee & Fuchs, 2006; Gengarelly & Abrams, 2009). These ideas include inquiry-based learning, context-based learning, constructivism, problem based-learning, and the Science, Technology, Engineering, Mathematics (STEM) movement (Barma & Guilbert, 2006; Potvin & Dionne, 2007). In 1995, the Council of Ministers of Education of Canada (CMEC) adopted the Common Framework of Science Learning Outcomes K to 12. This influential document was designed as a blueprint for scientific literacy for all Canadian students. It describes scientific literacy as follows:

> Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them. (Council of Ministers of Education, 1997)

The Framework speaks particularly to AST in this statement about real world applications of science and technology: "Students learn most effectively when their study of science is rooted in concrete learning experiences, related to a particular context or situation, and applied to their world where appropriate" (Council of Ministers of Education, 1997, p. 4.1).

Project 2061 from the American Association for the Advancement of Science (AAAS) similarly guided the updating of science education in America. It also recommends that the learning of science and technology be given a larger place in the education of students today. (American Association for the Advcancement of Science, 1993). Both the CMEC Framework and Project 2061 strongly influenced the writing of the Science and Technology programs of the QEP. Figure 2.4 shows the key recommendations Project 2061 made for science education, and which influenced the QEP Science and Technology programs.

Figure 2.4 Recommendations of Project 2061



Note: Reproduced from AAAS Project 2061

2.2.2 Curriculum Reform – From Behaviorism to Constructivism

During my career from 1968 to 2010, the science programs in Quebec progressed from the teacher-centered pedagogy of the mid-twentieth century to the explicitly student-centered Quebec Education Program (QEP) being implemented today. As a science teacher from 1968 to 1988, a science consultant from 1988 to 1996 and finally as a leader in the Educational Services Department of the Lester B Pearson School Board, I participated in the changes that were taking place in science pedagogy. It is my contention that during this period of time, the shift in science teaching methodology corresponds to the movement from behaviorism to constructivism.

Table 2.1 outlines the past 60 years of science in English Quebec schools in Secondary 4 (Grade 10). This table summarizes the science courses during my time as a student, teacher, consultant and administrator. Note that the times are not exact as there were not fixed implementation schedules prior to 1990. Also, schools and school boards had the flexibility to offer programs that best fit their needs prior to the implementation of Physical Sciences 416/436 in 1990. The term "behaviorist pedagogy" refers to the practice of presenting the accepted "scientific facts" based on the curriculum documents and textbooks, with little exploration or inquiry on the part of the students. *Behaviorism* was popularized by Pavlov, Watson and Skinner, among others, with their classical conditioning experiments on laboratory animals and the extension of their work to the study of the behavior of humans. In education, behaviorism postulates that students learn by absorbing knowledge, "the truth", from the teacher, reinforced by conditioning from extrinsic motivators – punishments, rewards, marks, and praise, for example (Boyanton, 2010; Kohn, 1999; Phillips & Soltis, 2009).

As is apparent from Table 2.1, the science programs in the 1950s and 60s were behaviorist in nature with the teacher and textbooks being the sources of all required science knowledge. In the 1970s and 80s the advanced programs of Chem Study, BSCS Biology and PSSC Physics, though very hands-on with some inquiry in its activities, were still teacher-centered (Biological Sciences Curriculum, 2002; Merrill & Ridgway, 1969).

Table 2.1 Years of Secondary 4 Science Programs in Quebec

Time Period	Science Programs Secondary 4	Students Served	Pedagogical Approach
50s and 60s	Chemistry, Physics and Biology	Optional for higher academic students only.	Behaviorist pedagogy – teacher/subject-centered. Limited hands-on. “Cookbook-style” labs.
70s and 80s	General Chemistry, Physics and Biology	Average students – compulsory to take one of the 3 courses	Behaviorist pedagogy – teacher/subject-centered Limited hands-on. “Cookbook-style” labs
	Advanced courses (First Year): Chem Study, PSSC Physics, and BSCS Biology	Optional for top students only Favoured by CEGEPS	Very hands-on. Behaviorist pedagogy with some inquiry in labs
90s to 2008	Physical Sciences 416	Compulsory for all students. 416 pass required for HS Diploma	Socioconstructivist pedagogy/student-centered prescribed in MEQ teacher’s guide
	Physical Sciences 436 advanced program	Required for Sec 5 sciences	
Present	General Science and Technology (ST) and Applied Science and Technology (AST)	Compulsory for all students to choose one and pass it	Competency-based, constructivist/inquiry-based pedagogy Student-centered
	Environmental Science and Technology (EST); Science of the Environment (SE)	Optional advanced courses - prerequisites for Secondary 5 Chemistry and Physics	

Constructivism has been a widely researched topic in science teaching since the 1990s. Many researchers take the position that the teaching of science is done most effectively, promoting deep understanding of science concepts, when the classroom practices are based on a constructivist model of learning (Bybee, 2002; Cobern, 1995; Linn & Burbules, 1992; Palincsar, 1998; Phillips, 2003;

Roth, 1993; Saunders, 1992; Taylor, Fraser, & Fisher, 1997; Tobin, 1993; von Glasersfeld, 1996; Windschitl, 1999; Yager, 1991). The CMEC Framework promotes constructivism as well:

> The ideas and understandings that students develop are progressively extended and reconstructed as students grow in their experiences and in their ability to conceptualize. Learning involves the process of linking newly constructed understandings with prior knowledge and adding new contexts and experiences to current understandings. (Council of Ministers of Education, 1997, p. 4.1)

What follows is a brief explanation of the constructivist learning model and its background.

2.2.3 The Constructivist – Behaviorist Continuum

Yager (Yager, 1991) advocated for a constructivist teaching approach in the science classroom. In a seminal article in The Science Teacher he made a strong case for science teachers to adopt his Constructivist Learning Model in their classrooms. As illustrated in Table 2.2, he compared this model with the traditional behaviorist model being practiced in science classrooms across America.

Table 2.2 The Constructivist - Behaviorist Continuum in Science Teaching

Source: Reproduced from Yager (1991)

Objectivist/Behaviorist	⟵⟶	Constructivist
Teacher	Identifies the issue / topic	Student
No	Issue seen as relevant	Yes
Teacher	Asks the questions	Student
Teacher	Identifies written and human resources	Student
Teacher	Locates written resources	Student
Teacher	Plans investigations and Activities	Student
No	Varied evaluation techniques used	Yes
No	Students Practice Self-evaluation	Yes
No	Concepts and skills applied to new situations	Yes
No	Students take actions	Yes
No	Science concepts and principles emerge because they are needed	Yes
No	Extensions in learning outside the school in evidence	Yes

2.2.4 Essentials of Constructivism

What follows is a summary of the main tenets of the pedagogy of constructivism. Though there are many interpretations of how constructivist pedagogy should be applied to the classroom, what follows is a summary of what it means to me and how it can be used in today's Quebec classrooms.

A. Active creation of Knowledge

Windschitl (1999) says that the basis of constructivism is that "learners actively create, interpret, and reorganize knowledge in individual ways." (Windschitl, 1999, p. 753) "Actively create" means take new knowledge and compare it to one's current or prior understanding to arrive at a new, revised understanding. Knowledge is constructed, not merely transmitted. This requires regular hands-on science activities (Stohr-Hunt, 1996; Tobin, 1993; Yager, 1991).

B. Based on Prior Knowledge

Prior knowledge is the foundation upon which new knowledge is built. In fact it is itself constructed and, once constructed, becomes foundational for the next level of construction. One of the concepts introduced in early high school, for example, is that of density. In order to construct their understanding of density students manipulate different materials (aluminum, steel and lead solids, for example). By comparing the masses of equal volumes of these materials they begin to understand the concept of density and its fundamental nature as a characteristic property of a given material. The prior knowledge they need is an understanding of mass and volume – concepts that they have constructed previously. Thus mass and volume are constructed concepts that become foundational to the concept of density.

C. Experientially-based

Von Glasersfeld (1995) explains the role of experience as follows: "It starts from the assumption that knowledge, no matter how it is defined, is in the heads of persons, and that the thinking subject has no alternative but to construct what he or she knows on the basis of his or her own experience. What we make of experience constitutes the only world we consciously live in." (von Glasersfeld, 1996, p. 1). Hands-on science activities provide an ideal opportunity for experientially-based learning. By using the senses to directly experience science, students can effectively construct deeper understanding.

D. Challenging cognitive structures

Saunders (1992) explains the cognitive processes which lead students to real understanding. When a student is confronted with observations which do not agree with his or her prior understanding (i.e. "disequilibrating experiences") he has choices to make: reject and ignore the observations or the observations and restructure his cognitive schemas. The teacher's job is to put the student into situations which will challenge his cognitive structures.

2.2.5 The Progressive School Movement/Student-Centered/Experiential Learning: Dewey's Influence

John Dewey has had a profound and long-lasting influence on teaching methodology (Bredo, 1998). Dewey (1963) emphasized that teaching must begin with an understanding of where students are – their previous knowledge, stating, "It is a cardinal precept of the newer school of education that the beginning of instruction shall be made with the experience that learners already have" (p. 74).

According to Walker (2002):

> Dewey challenged prevailing views of learning by suggesting that education is an internal process in which the learner uses prior knowledge and experience to shape meaning and to construct new knowledge. The debate was not new to Dewey's time, but rather reflected a continuing struggle to understand how students learn and how schools are capable of fostering learning (pp. 6,7).

In Democracy and Education, Dewey (1916) presents his philosophy of education. By simply receiving the facts, the child does not create any meaning for himself. Dewey asks a key question: “Why is it, in spite of the fact that teaching by pouring in, learning by passive absorption, are universally condemned, that they are still so entrenched in practice?” (p. 29). Though he wrote this in 1916, this question is still a concern of educators today, 96 years later. Many science teachers, faced with the pressures of heavy content-oriented subjects, continue to “pour in” the facts with little concern for or understanding of the need of the learner to construct understanding (Barrow, 2006). In my view, John Dewey can be seen as a father of constructivism with his ideas that teaching and learning should be based on the experiences of the learner. The learner must be at the center of the learning and must be active in the construction of his or her knowledge.

Teachers struggle with finding a balance between students constructing knowledge and the teacher providing it. Hall-Quest (1998) contrasts the basic operating principles of Dewey’s progressive schools to those of traditional schools.

> To imposition from above is opposed expression and cultivation of individuality; to external discipline is opposed free activity; to learning from texts and teachers, is opposed learning through experience; to acquisition of isolated skills and techniques by drill, is opposed acquisition of them as means of attaining ends which make direct vital appeal. (Hall-Quest, 1998, pp. 5,6)

These comparisons of progressive and traditional education are similar to comparisons between constructivist and behaviorist pedagogies in today’s classrooms. In my view the struggle between these two pedagogies is the core problem in the reform initiatives both here in Quebec and elsewhere.

2.2.6 Von Glasersfeld's Influence

Von Glasersfeld (1996) describes his approach to pedagogy as radical constructivism. He considered his version of constructivism to be radical because it went farther than the prevailing constructivist thought in the direction of relativism – that "knowledge is not passively received but built up by the cognizing subject and that the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality" (von Glasersfeld, 1996, p. 18).

Acknowledging that science teachers are preoccupied with the transmission of facts, he points out that "ten or 15 years ago… educators were concerned with getting knowledge into the heads of their students and educational researchers were concerned with finding better ways of doing it" (von Glasersfeld, Larochelle, & Ackermann, 2007).

This is reflected in the writings of other radical constructivists as well (Bettencourt, 1993). While some critics of constructivism would say that constructivists deny the existence of facts (Matthews, 2002) what constructivists really say is, as learners, we can only understand facts in our own way – that we all construct our own understanding of the facts - that "Understanding is personally constructed."(Tobin, 1993).

Von Glasersfeld was greatly influenced by the writings of Piaget and, like Piaget, believed that a person constructs his own knowledge based on his own experiences and interpretation of these experiences. "Piaget was unquestionably the pioneer of the constructivist approach to cognition in this century" (von

Glasersfeld, 1996, p. 54), though behaviorism was all the rage in American classrooms (Gallagher, 1993; Good, Wandersee, & St. Julien, 1993; von Glasersfeld, 1996).

2.2.7 Social Constructivist Perspectives on Teaching and Learning

Those advocating a social constructivist approach to learning maintain that real learning is based on the interdependence of social and individual processes in the co-construction of knowledge (Palincsar, 1998). In other words children learn better if they can exchange ideas and learn from each other, though Linn and Burbules (1992) caution that group learning isn't necessarily always constructivist.

In describing the role of the teacher in a social constructivist classroom, Driver (1994) insists that science concepts are illustrated and investigated by students in a social context whereby students' different ideas are explored, negotiated and shared.

2.2.8 Inquiry-Based Learning

Inquiry-based learning in science education is closely linked to constructivism and often discussed interchangeably with it. While discussing inquiry-based learning, Sharma & Anderson (2009) state "It has been almost a century since inquiry, in its various guises, was advocated as the prime pedagogical device as well as an object of study in science classrooms by educators and reform movements" (p. 1262).

A great deal of research has being done in recent years showing the benefits and drawbacks of the inquiry-based science classroom (Anderson, 2002; Furtak, 2006; Martin-Hansen, 2010; Minner, Levy, & Century, 2010; Park Rogers & Abell, 2008; Wilson, Taylor, Kowalski, & Carlson, 2010).

In the inquiry model, students are given the opportunity to conduct real science inquiries in an age-appropriate and pedagogically sound way to mimic the work of practicing scientists (Furtak, 2006). As advocated by constructivists, students solve meaningful problems in the lab by exploring relationships between variables, creating models for scientific phenomena, and building technological objects for example. As in constructivist classrooms, students access prior knowledge, face cognitive dilemmas, cooperate with one another to wrestle with real problems and construct their knowledge and understanding of the scientific world. The literature emphasizes the key role played by professional development in successfully implementing inquiry-based learning and obtaining positive outcomes for science learning (Akkus, Gunel, & Hand, 2007; Buczynski & Hansen, 2010; Crawford, 2007; Wallace & Kang, 2004).

Although research points to many positive effects of inquiry-based learning, mixed results are found regarding its effects on student outcomes (Kirschner, Sweller, & Clark, 2006; Mayer, 2004). Similar to the debate between constructivists on the one hand and these cognitive psychologists and behaviorists on the other hand, there continues to be disagreement as to which science teaching methodology results in the best student outcomes as reflected on student achievement instruments – standardized tests, end-of-year exams and provincial assessments, for example. In a recent large study, however, Blanchard (2010) compared traditional to inquiry-based laboratory instruction and found significantly higher posttest scores for the inquiry-based instruction over a wide range of schools and demographics (Blanchard et al., 2010).

2.2.9 The Constructivist Dilemma

As a science educator, I often had discussions with other teachers around the question of which methodology to use when presenting science topics. Should I present the known "scientific facts" about the topic to my students? Should I put the students into a situation where they will discover them as the result of a guided (or less guided) lab activity? Seldom is the conclusion clear. Each situation is different: the topic, the nature of the class, the materials available. This is the constructivist's dilemma. It forces the teacher to situate himself somewhere in the constructivist vs behaviorist continuum – between having the students discover/construct the "facts" and receive the "facts" from the teacher.

Behaviorists convinced us that rote learning made real thinking unnecessary and this is reflected in our tests and exams today. In fact Skinner (1978) characterized understanding as a "pre-scientific mentalist fiction". Von Glasersfeld (1996), however, describes the limits of the behaviorist explanation of behavior – the stimulus-response mechanism of learning. He points to the fact that each individual perceives and attaches importance to a given stimulus in his or her own way. "All too frequently a 'fact' or a relation that seems perfectly obvious to the teacher is not even seen by the student." (von Glasersfeld, 1996, p. 179).

Behaviorist teachers do not see the need to relate understandings to the students' experiential base. The patterns of behavior that they promote "discourage questions, conversation and individual reflection." (p182).

The implication of a constructivist-based pedagogy for science learning is that students must think their own way through problems in order to be able to solve more. The implication for science teaching is that teachers must have in their repertoire of strategies ways to encourage and promote high motivation for problem solving - to make problem solving into a satisfying activity that students want to do.

While constructivism in its different interpretations is now becoming the methodology of choice among curriculum developers in school districts and provincial education ministries in Canada, this trend is not always supported by teachers and parents who, with few exceptions, were schooled in the traditions of behaviorist instruction.

> Unfortunately, the signs and symbols of teacher-centered education and learning by transmission persist in classrooms today. In this environment, it is assumed that the more quiet and orderly the classrooms are, the more likely it is that learning is taking place. Individual desks face the front of the room, where the teacher occupies a privileged space of knowing authority; students work individually on identical, skill-based assignments to ensure uniformity of learning. (Windschitl, 1999, p. 751)

The result is the traditional classroom with the teacher in control of the learning. In science class the teacher gives the facts, shows demonstrations to illustrate them and has students do experiments to verify what they have been taught. This behaviorist pedagogy may be expedient in that factual knowledge is transmitted efficiently, but real understanding is often missed by the students.

This is the dilemma faced by science teachers who must, on the one hand, cover the onerous content of their programs and on the other hand are told to use constructivist methodology in their classrooms.

This constructivism vs behaviorism dilemma presents an interesting perspective for my study. Observing if and how the teachers bounce between constructivist and behaviorist approaches as they implement AST has provided me with valuable data.

2.2.10 Constructivism and Psychology

Though constructivism as a learning model fits well with the philosophical positions described above, cognitive psychologists present a different view – that unguided discovery, as advocated by constructivists, does not lead to effective learning. Mayer (2004) found that "a dispassionate review of the relevant research literature shows that discovery-based practice is not as effective as guided discovery" (p. 18). Kirschner et al (2006) disagree with constructivist teaching methodology. "Controlled experiments almost uniformly indicate that when dealing with novel information, learners should be explicitly shown what to do and how to do it." (p. 79). "Not only is unguided instruction normally less effective: there is also evidence that it may have negative results when students acquire misconceptions or incomplete or disorganized results."(p. 84). They maintain that current research on learning for novices supports direct teaching and the use of minimal guidance methods results in frustration and misconceptions.

Contrary to what these studies indicate, in my experience as a science educator, supporters of constructivist science teaching do not advocate a free-for-all approach to learning. Constructivist teachers do not send their students into the lab without instructions or directions. Good teachers carefully craft their activities with the students' abilities, knowledge and experiences in mind. They know that they must guide their students toward the construction of knowledge and understanding. They know that a fully unguided approach is a recipe for chaos resulting in little learning. It is unrealistic to think that an individual can come up with the scientific concepts just from making his own observations (Driver, 1994).

2.2.11 Constructivism and Student Motivation

The question of what makes students want to learn science has intrigued me throughout my educational career. It seems to me that learning about the natural world that surrounds us should be of intrinsic interest to everyone, and learning about it in school should be fascinating for all students. But this is not the case. Enrolment in high school optional science courses around the world is declining and students increasingly drop science courses as soon as they can. They find it difficult and boring and, surprisingly, they find it unrelated to their lives. (Lyons, 2006; Skamp & Logan, 2005)

Intrinsic vs Extrinsic Behavior - Flow Theory: The APA Dictionary defines intrinsic motivation as "an incentive to engage in a specific activity that derives from the activity itself (e.g., a genuine interest in a subject studied), rather than because of any external benefits that might be obtained" (e.g., course credits) (APA, 2006).

One explanation of the intrinsic motivation for students to learn science can be found in the ideas of Flow Theory. Flow describes people's state of "complete absorption in the present moment" when they are intrinsically motivated to engage in an activity (Czikszentmihalyi & Nakamura, 2005). They are in control of their actions and pursue the activity for its own sake, not in pursuit of a reward or to avoid a punishment. Some of the conditions for flow are: "perceived challenges, or opportunities for action, that stretch but do not overmatch existing skills", "clear proximal goals and immediate feedback about the progress being made."(p. 195). People "in flow" would be observed to be focused on an active task, unselfconscious and in control. They may comment about the surprisingly fast passage of time while doing the activity. Pink (2011) describes "flow" as Type I behavior. By this he refers to intrinsic motivation characterized by autonomy (control over the project), mastery (the desire to continually improve it), and purpose (doing something that has personal meaning). The opposite of Flow or Type I behavior is motivation by punishment and reward, often referred to as extrinsic behavior. Though this is a common practice in education, this behavior more often undermines motivation and engagement on the part of students and tends to reduce learning and understanding (Czikszentmihalyi & Nakamura, 2005; Deci, Koestner, & Ryan, 1999; Kohn, 1999; Pink, 2011).

AST addresses the issue of student intrinsic motivation. By studying the applications of science before learning about the theory of science, students can connect their learning to the world around them – the world that has personal meaning to them. In terms of Flow Theory, the constructivist approach gives students autonomy and control over their learning. The challenge of constructing knowledge through hands-on work satisfies their need for mastery. Seeing how the learning is related to their personal life gives them purpose for learning. According to Bergin (1999) Flow Theory helps to explain the interest that students have in learning and adds other AST-relevant factors which also contribute to student engagement, some of which are: competence, relevance, background knowledge, hands-on, novelty, content, and social interaction.

2.2.12 The Constructivist Dilemma in Quebec Science Teaching

Although the case is very strong for constructivist pedagogy in the science classroom, in my discussions with teachers, I have found that they often feel that the outcomes that they seek cannot be delivered. Many teachers feel that the constructivist approach goes against their claim of the objective truth they teach. They worry that, if the learning must be constructed by the learner, they, the teachers, will lose control of the knowledge and students will not acquire the facts as prescribed by the curriculum. Quebec teachers, for example, face a particular dilemma. How do they teach their courses using the government-recommended constructivist approach (as stipulated in the new Quebec Education Program and the recently-replaced Physical Science 416 programs for example)(MEQ, 1990;

MELS, 2007) and then prepare students for a largely fact-based, knowledge-oriented final, high-stakes exam? There are many anecdotal reports that teachers in Quebec classrooms abandon the constructivist approach and use instead a teacher-centered, behaviorist methodology to prepare their students for the exams. In an initial research project, done in 2007, I surveyed Quebec science teachers to identify their classroom practices to see to what extent they use constructivist teaching practices. I adapted the Constructivist Learning Environment Scale (Taylor, Fraser, & Fisher, 1997) to the Quebec teaching situation. In a summary submitted to the Quebec English school boards and presented at the annual QPAT Teachers' Convention in November, 2007 I reported that the majority of teachers who took the survey report using constructivist teaching methodology regularly in their science classes (Elliott, 2007).

The concern is however still very much present in the minds of teachers. In June 2012 Secondary 4 AST students had to write a compulsory ministry AST exam for the first time. Though the analysis of this exam and the student results are beyond the scope of this study, the preparation for this exam has become a concern for teachers and administrators. Having been told that the exam would have significant numbers of questions related to content knowledge, teachers reported that they had to decrease or even abandon their emphasis on constructivist pedagogy. They had to divert a lot of time planned for scientific inquiry to transmission of knowledge to prepare the students for the high-stakes exam.

2.3 Applied Science and Technology

I will conclude Chapter 2 with a description of the AST program. I will first link AST to the pedagogical issues I have just explored regarding constructivism and inquiry in science learning and teaching. Then I will briefly describe the AST program content and competencies.

2.3.1 AST and Constructivist and Inquiry-based Pedagogy

Socioconstructivist pedagogy was explicitly prescribed in the last writing of the Physical Sciences programs of the 90s science program and the teacher's guide and MEQ workshops gave directions to the teachers as to how to manage a constructivist learning environment (MEQ, 1990). In the current ST and AST programs, both socioconstructivist pedagogy as well as inquiry-based learning is fundamental to the teaching of AST (Louise Lafortune & Deaudelin, 2001; Larochelle & Désautels, 2011; Ministère de l'Éducation du Loisir et du Sport du Québec, 2007; Potvin & Dionne, 2007). The QEP explains that students are the architects of their own knowledge:

> The program is based on the premise that knowledge should be constructed by students rather than transmitted by teachers, because no one can learn for another person. Although it is not based on one particular approach, it draws on several theories [constructivism, social constructivism, cognitivism] that share a recognition that learners are the main architects of their competencies and knowledge. (MEQ, 2004, p. 9)

<u>Learning and Evaluation Situations</u>: The QEP with its focus on the development of competencies requires an evaluation system which assesses not

only the acquisition of content knowledge but also the level of a student's attainment of the competencies for each subject. Teachers are encouraged to use Learning and Evaluation Situations (LESs) for this purpose. An LES puts the students into a problem-solving situation in which they integrate different concepts and content knowledge in order to solve a real-world problem related to the curriculum topics being covered at that time. The Ministry of Education at the time described this aspect of evaluation:

> In the case of evaluation to recognize competencies, formal instruments must be used. The learning and evaluation situations include complex tasks that generally involve elaborate productions. The tasks can relate to one or more competencies, and make it possible to verify the level at which students have developed subject-specific competencies. (MEQ, 2003)

AST specifies the competencies that students must develop, the science and technology content they must become familiar with, and the evaluation criteria that must be used. The QEP is not a teachers' guide. In a section titled "Role of the Teacher", teachers are encouraged to guide their students using appropriate strategies for problem solving and providing them with levels of support as needed "providing the necessary explanations, answering questions, proposing ideas for solving problems, providing less independent students with additional support…". Though it does specify that when solving problems "These situations require a hands-on approach", and that "each student is responsible for his or her learning", it does not give detailed instructions to the teachers as to how to teach specific science and technology topics (MELS, 2007, p. 14). Each competency lists End-of-Cycle Outcomes which specify the particular skills which students must have developed in order to have attained the competency.

The particular teaching strategies however are left to the textbook publishers, science consultants and teacher teams in the schools and boards.

Teachers were however greatly helped by the publication of the Progression of Learning (PoL). This document, published for all QEP subjects, lists all the concepts which AST teachers must cover and when they must be covered. According to the PoL document for AST (together with all high school Science and Technology programs),

> This document provides additional information about the learning prescribed in the compulsory secondary-level Science and Technology programs and its progression from year to year and from cycle to cycle. This document is intended to help teachers with their lesson planning. (MELS, 2011b, p. 5)

Using the QEP, PoL and the textbooks and other teaching resources available, it is assumed that the constructivist approach is the pedagogy of choice as it had been prescribed in the previous science reforms. Potvin & Dionne (2007) agree. They state that teachers must "abandon their ingrained habits of transmitting knowledge to the students and instead embrace new approaches based on social constructivist theories of learning." (p. 395).

2.3.2 The AST Program

All students must choose between General Science and Technology (ST) and Applied Science and Technology (AST) in Secondary 4. MELS requires that students must pass either ST or AST in order to receive a Diploma of Secondary Studies (DSS) (Ministère de l'Éducation du Loisir et du Sport du Québec, 2011). The evaluation includes both a MELS compulsory exam (50%), both written and laboratory, and a class mark generated by the teacher (50%). Both AST and ST have a common basis in science as well as technology. AST however differs from ST in that is intended to offer students a more practical approach to learning science. AST places particular emphasis on the applications of science and technology and explains the applications as “practical achievements (objects, systems, products or processes), which are characterized by their operation, the materials of which they are made, the associated scientific and technological principles and the way in which they are built or manufactured” (MELS, 2007, p. 22).

2.3.3 The Competencies

The QEP is a competency-based curriculum in which all subjects are evaluated based on the attainment of competencies. Each subject has 3 or 4 competencies which students must develop, and these competencies are the same throughout secondary school for that subject. The three competencies for secondary Science and Technology (MELS, 2007) are the following:

<u>Competency 1</u>*: Seeks answers or solutions to scientific or technological problems.* The focus is on hands-on methods used in science. Students experiment, design and construct in the lab, workshop or elsewhere to solve problems. Examples include performing scientific experiments, designing, building and repairing technological objects.

<u>Competency 2</u>*: Makes the most of his/her knowledge of science and technology*. Students focus on scientific knowledge related to issues in real life

and analyze phenomena from a scientific and technological point of view. Examples include learning conventional topics related to the 4 Worlds, understanding how technological objects work, identifying the effects of science and technology.

Competency 3: *Communicates in the languages used in science and technology*. Students exchange information and communicate their scientific and technological findings. Examples include oral and written reports of lab and workshop activities, exchanges of information on analyses of impacts of scientific discoveries and other natural phenomena, research into current scientific and technological issues.

2.3.4 AST Content

AST divides the program into seven different technological fields: "medical, agricultural and agri-food, energy, information and communications, transportation, manufacturing and construction technologies." (MELS, 2007, p. 23). Both AST and ST recommend methodologies involving modeling, observation, experimentation, empiricism, and technological analysis. AST, however, adds the design process and industrial processes to make it different from ST as shown in Table 2.3.

Table 2.3 Focus of ST and AST

General Science and Technology (ST)	Applied Science and Technology (AST)
Scientific Method	Technical Design Process
Forming Opinions	Understanding How Things Work

Like ST, the content of AST is divided into the 4 Worlds: The Technological World, The Material World, The Living World, and Earth and Space (MELS, 2007, 2011b) as follows:

The Technological World: In the first year of Cycle 2 (Secondary 3), AST covers concepts of graphical language, engineering, materials, manufacturing and biotechnology. In Secondary 4 mechanical linking and electricity are added. A much greater emphasis is placed on the Technological World in AST than in ST. All topics in this world are done in much greater depth than in ST especially in the analysis, repair and manufacture of technological objects.

The Living World: In Secondary 3, the content focus of AST is the human body, namely the digestive, respiratory, circulatory, excretory and reproductive systems. The Secondary 4 content looks at ecosystems and how living organisms relate to their environment, including the effects of human endeavours – manufacturing, energy use, transportation, etc. - on the environment.

The Material World: Secondary 3 AST content is divided into five general areas: properties of matter, changes in matter, organization of matter, fluids and waves. Whenever possible this content is presented as it relates to the human body. In Secondary 4, like in ST, chemical changes, electricity and electromagnetism, the transformation of energy, fluids, and force and motion are the 5 main content areas.

Earth and Space: According to the Progression of Learning, Cycle 2 content for Earth and Space is left to Secondary 4 only.(MELS, 2011b) The content topics covered are the lithosphere (minerals), hydrosphere (waterways and catchment areas), atmosphere (air masses and weather) and space (the moon and solar energy)

Table 2.4 illustrates the uniqueness of AST.

Table 2.4 Uniqueness of the AST Content: Secondary 4

World	Applied Science and Technology (AST)
The Material World	Emphasis on the technological applications of the following topics Electricity and electromagnetism: Fluids, forces and motion
The Living World	The emphasis on technological applications related to the human body and ecosystems
Earth and Space	The emphasis is on applications including engineering accomplishments, manufacturing and energy
The Technological World	Graphical language, Mechanical engineering, Electrical engineering, Materials, Manufacturing

2.4 The Need for a Study of the Implementation of AST

In this study I describe the state of implementation of AST in English schools of Quebec. I look at how teachers teach AST and the support that they receive. I look at how motivated students are to learn science. The discussion below will illustrate the need for this study.

2.4.1 The Implementation of the QEP and Especially AST

Since 2005 a limited amount of writing has been done, mostly in French, by Université du Québec à Montréal (UQAM) and Université de Montréal (UdeM) professors and practicing teachers about their experiences and theories regarding the implementation of the Science and Technology programs in the QEP (Brassard, 2005; Charland, 2009; Potvin & Dionne, 2007). Professeur Pierre

Potvin hosts an active blog, ReDEST, at UQAM in which he invites teachers and other educators to participate in online exchanges regarding their experiences with Science and Technology (Potvin, 2010). In the English sector there are active exchanges of Science and Technology ideas (including AST) through school board portals. These are initiated and maintained by the science consultants of the respective boards. MaST, the coordinating committee of Science Consultants of all English boards of Quebec, actively encourages and facilitates the sharing of ideas through regular monthly meetings and an active ongoing SAKAI® space. These examples of exchanges however are not research. Other than an article in the McGill Journal of Education in 2007(Potvin & Dionne, 2007), there has been, to my knowledge, no research published about the implementation of QEP Science and Technology (and AST) programs.

There were many obstacles to the implementation of the QEP due to a number of factors. According to Pelletier (2005), changes in curriculum in Quebec have come in waves and have often contradicted the reforms which preceded them. Ministers of Education have historically changed frequently (approx. every 16 – 18 months) and each one has wanted to leave his or her mark on the history of education. There have been many restructurings included new school boards, school success plans and governing boards. They have also conducted large defining events, for example, the Estates General in 1996 resulting in the Inschauspé Report “Reaffirming the Mission of Our Schools - Report of the Task Force on Curriculum Reform”(MEQ, 1997). Throughout my career, the impression among teachers and school board administrators is that the reforms and structural changes are imposed but rarely completed, resulting in confusion and anger among the people and organizations most directly affected. It then falls on the school boards and the schools themselves to translate the reforms into action with inadequate guidance from the Ministry of Education. Resistance often comes from the competent, conscientious teachers and administrators who find it hard to abandon their own tried and true methods in order to embark on the unknown. The change process is complex and fraught with potential conflicts and obstacles (Brassard, 2005; Fullan, 1993; Pelletier, 2005). It can be tough and exhausting.

Therefore, research is needed on how teachers have adapted their teaching methods as a result of the Curriculum Reform in the Science and Technology (and especially AST) curriculum.

2.4.2 Support for Teachers

The need for and nature of the professional development required to implement inquiry-based science curriculum is widely researched (Jeanpierre, Oberhauser, & Freeman, 2005; Khourey-Bowers, Dinko, & Hart, 2005; Shymansky, Yore, & Anderson, 2004). Researchers emphasize, among many factors, the need for improved deep understanding of science concepts, collegiality among teachers, understanding of the inquiry processes, and the considerable amount of time required for professional development (PD). In my role as Director of Educational Services, I oversaw the delivery of PD to all school personnel in all subject domains. Schools, boards and MELS spent the implementation years offering workshops to teachers and administrators and producing teaching materials and ideas to support them. In one particularly effective initiative, for example, MELS undertook a multi-year training program for Science and Technology teachers at all cycle levels, both high school and elementary in the English school boards. They formed the Science and Technology Implementation Committee (STIC). The STIC team consists of four retired science teachers/consultants hired to deliver the training to teachers across the province. Since 2006 they have been giving workshops to all high school Science and Technology teachers. This has taken place both at a centralized training center in a high school in Montreal and directly in schools according to the needs of the local teachers. They have focused on the aspects of the programs with which teachers are most likely to be unfamiliar, especially inquiry-based hands-on activities in technology and design.

At the local school board level, the support for teachers is coordinated by the science consultants whose job it is to make sure that science teachers have the means necessary to deliver the QEP Science and Technology programs. Science consultants present workshops on professional development days, visit teachers in their schools to give training sessions and discuss implementation progress and problems. They also maintain active online portal communities to disseminate information and share activities and other teaching ideas. (Elliott, K., & Asghar, A. Forthcoming)

Therefore, research is needed to gauge the effects of the training of teachers on the implementation of Science and Technology (and especially AST).

2.4.3 The Implementation level of AST in schools

Once the training is done, the materials are available in the school classes, labs and workshops and the textbooks are in the hands of the students, it is up to the individual teachers to deliver the program to the students. The implementation of reforms in curriculum is a difficult task for teachers. Not only do they have to learn new curriculum content, but they often have to change their style of teaching to meet new philosophical requirements (Brown & Melear, 2006; Bybee & Fuchs, 2006; Fullan, 1993; Jeanpierre, et al., 2005; Wallace & Kang, 2004). Successful implementation depends on the concordance between the curriculum as it is written and what actually takes place in the classroom.

Therefore, research is needed to understand the level of the implementation in AST classrooms in English schools: to what extent teachers are following QEP – use of technology, use of tools, use of LESs, evaluation processes, constructivist teaching methods.

2.4.4 The Outcomes of AST

The outcomes of inquiry-based/constructivist science programs have been widely studied both in terms of student results on tests and exams and student motivation to learn science. Results are mixed. Many studies show that, in comparison to a behaviorist approach where the teacher is the source of information, active science inquiry in the classroom and construction of one's own knowledge and understanding create increased interest in learning science (Bergin, 1999; Deci, et al., 1999; Tai, Sadler, & Loehr, 2005). Others show that increased conceptual learning among students (Minner, et al., 2010). Some show improved student performance (Akkus, et al., 2007; Anderson, 2002; Fouad, 2004; Stohr-Hunt, 1996). Still others, however, show that students perform no better or even worse when instructed with an inquiry-based approach (Wood, Lawrenz, Huffman, & Schultz, 2006). The use of inquiry/constructivist methodology is also found to increase teacher enthusiasm and motivation (Brown & Melear, 2006; Liu, Lee, & Linn, 2010)

The fact that the research on outcomes for inquiry-based/constructivist science teaching is so mixed and varied suggests the need for locally-based research to understand specifically the outcomes of AST. AST is also very different from the programs described in the research literature and therefore drawing conclusions from the literature would be questionable. I realized that conducting research into the performance of AST students was beyond the scope of this study. AST students wrote a compulsory MELS AST exam for the first time in June 2012. Analyzing the results would not be possible in the time frame of this study and, moreover, drawing any conclusions from this first set of results would be premature. In my experience it has always taken a few years of compulsory ministry exams in any subject before it can be determined that the exams are a valid reflection of the students' understanding. Therefore the analysis of student results has been eliminated from this study.

Therefore, research in AST is needed to understand the level of engagement and motivation among AST students in a constructivist, inquiry-based learning environment.

2.5 Research Questions

In order to address some of the gaps in knowledge regarding the implementation of AST, I have developed the following research questions for my study of the implementation of Applied Science and Technology:

Theory: How do various theories of learning underpin Quebec's Applied Science and Technology (AST) program?

1. What are the theories of learning underpinning the AST program?
2. How are these theories used within the programs?
3. What theoretical links exist between the AST program and the immediate previous science programs of Quebec?

Description: How is AST being taught in Quebec schools?

1. Who takes AST in secondary 3 and 4 – overall and by gender?
2. What teaching practices, specific to AST, do teachers use in the classroom and lab?
3. What is the relationship between the teachers' epistemology and practice especially as evidenced by their approach to the AST curriculum?
4. What tools, and other scientific equipment are being used specifically for AST?

Outcomes: What are the outcomes of the AST program on student motivation to learn science?

1. To what extent are students positively engaged in the learning of science in AST?

2.6 Summary

This chapter presented the AST program and its historical and philosophical underpinnings. Its purpose is to set the stage for an in-depth study of the implementation of AST in the English high schools of Quebec. Applied Science and Technology (AST) is a Secondary 4 program introduced under the Quebec Education Program (QEP) and implemented over the past 3 years in all high schools in Quebec. Based on a constructivist philosophy of learning and relying on an inquiry-based pedagogy, students learn science and technology through real-life applications. AST represents the culmination of a process of change in the pedagogy of science education in Quebec – from the teacher-centered behaviorism of the 60s and 70s to a more student-centered constructivist methodology today. The success of the implementation of AST depends on the teacher preparation and application of the inquiry/constructivist approach – the subject of this study.

Chapter 3: Methodology

In this chapter, I will describe the following aspects of my study:

- Research setting and Recruitment of participants – criteria and procedures
- Instruments for data collection
- Processes for data collection
- Methods of data analysis

This will be a Mixed Methods Research (MMR) study drawing on quantitative and qualitative approaches to research (Creswell & Plano Clark, 2007). Qualitative and quantitative components will be triangulated into a comprehensive examination of the implementation of AST. Both types of data will be given equal emphasis and, depending on the matter being studied, will supplement each other to varying degrees. This will be described in greater detail later in this paper. The quantitative aspects will include enrolment data from school boards and online surveys of teachers and students. Qualitative data will be obtained from extensive field studies in some Secondary 3 and, mostly, Secondary 4 classes in action, and interviews with teachers, principals and science consultants – all of whom are involved in the delivery of the program. The data from all these varied sources will be triangulated into a comprehensive study. Data triangulation is described by Hales (2010) as follows:

> Data triangulation is the use of a variety of data sources, including time, space and persons, in a study. Findings can be corroborated and any weaknesses in the data can be compensated for by the strengths of other data, thereby increasing the validity and reliability of the results. The approach has been used in many sectors to strengthen conclusions about findings and to reduce the risk of false interpretations. (p. 15)

3.1 Research Setting and Recruitment of Participants

The implementation of the Science and Technology programs required a great deal of my attention in the final years of my career as Director of Educational Services. I was directly and closely involved with the implementation of the QEP in all subject areas and at all high school grade levels from Secondary 1 to 5. I oversaw the professional development workshops and other activities for teachers and supervised the subject consultants who organized and provided the training and resources for teachers

The programs had changed dramatically. Technology had become a major new area of study. Labs had to be upgraded and renovated to include new tools and equipment. Teachers had to be prepared to teach new content involving engineering technology as well as the newly-integrated Four Worlds. My career background prepared me well to lead the Reform implementation in the science and technology area. I had taught science and mathematics for 20 years. I had spent seven and one-half years as a science consultant for a school board in Montreal before becoming a school administrator in elementary and high schools. The study of the implementation of AST, therefore, was something of natural interest to me. I felt that I could be both a researcher in the study as well as a subject of the research. I could be a source of information as well as researcher in search of the insights of current participants.

To answer my research questions, I worked with high school science teachers, students, science consultants, and administrators in the public English school system in Quebec. I gathered data through online surveys, interviews and classroom observations and discussions to examine and understand (a) the philosophy and goals of the new AST program, (b) how it is being implemented in practice in high schools today, and (c) how the program affects student motivation to learn science. This diverse group of educators and learners enriched my data collection with many points of view regarding the implementation of AST in English schools of Quebec. Teachers described their first-hand experiences. Their administrators informed me of the programming and parental concerns and experiences. Consultants informed me from their deep understanding of the program and the "big picture" about its implementation across their school board. The Secondary 3 and 4 students helped me understand how they are learning science and their level of motivation and enthusiasm for learning.

With McGill Research Ethics Board authorization, data were collected from the various populations over two school years: 2010-11 and 2011-12. AST teachers from the province of Quebec responded to an online survey (described later) over these two years. In-school observations and interviews began in 2010-11 in Montreal schools and in two schools in two boards outside Montreal in 2011-12. Over the two years I conducted interviews with the AST teachers I observed, their school administrators and their consultants.

3.1.1 Recruitment of Participants

This section describes the recruitment procedures for participants for online surveys, interviews, and classroom observations.

Online Surveys:

AST Teachers Survey: All AST teachers in English school boards in Quebec were invited to participate by email. The email addresses were provided by all nine English School boards in Quebec after they agreed to participate in my research study. Consent was implied by the teachers' voluntary completion of the survey. The teachers were invited to participate in 2010-11 and again in 2011-12. See Appendix B for the letter of invitation to teachers and Appendix C for the survey questions.

AST Student Survey: Students in the classes that I observed were invited to do the survey in class time in the school computer lab. Written consent was obtained from them and their parent(s). See Appendix D for the survey questions.

Classroom Observations

I worked in two schools of the Lester B Pearson School Board (LBPSB) in 2010-11. In 2011-12, I visited one school in the Riverside School Board and one school in the Sir Wilfred Laurier School Board for an total of four schools. To gain an understanding of the program and its implementation, I observed AST classes in action, interviewed teachers and administrators, and observed and talked to students while they were engaged in AST activities. I observed five AST classes in two on-island schools in 2010-11. In 2011-12 I visited three classes in two different off-island schools.

The choice of teachers was based on recommendations by the school board science consultant (with the enthusiastic approval of the school principal) on the basis of their strong science teaching skills and their positive attitude to the

AST program. These teachers voluntarily accepted to participate after I invited them. I obtained written permission from the school principal, the teachers, the students and the school board. I also held informal conversations with the students, teachers and lab technicians during the activities. In all I carried out 44 classroom observations in nine different classes in four different schools.

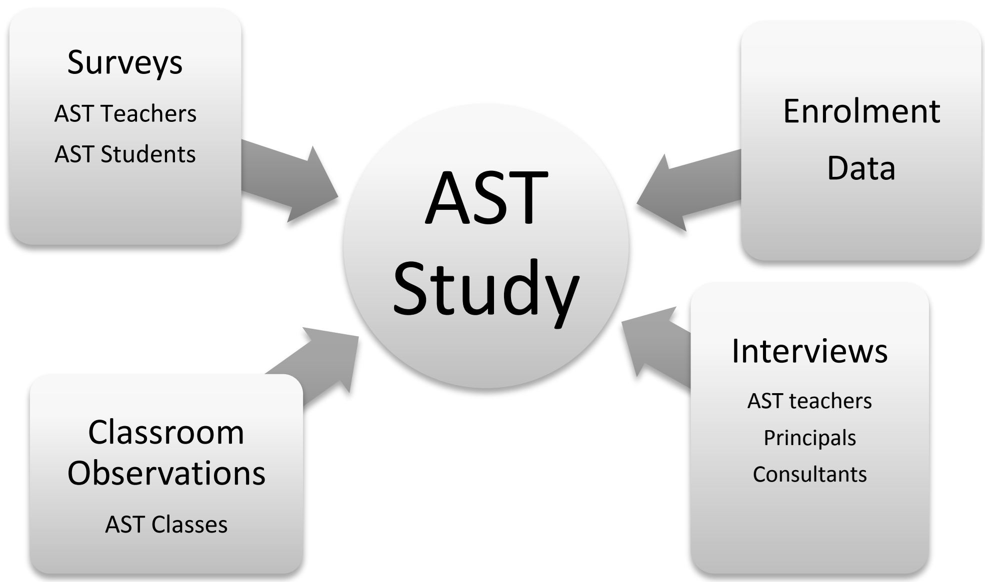
Interviews:

Teachers and Principals: I conducted interviews with six teachers, four administrators and four consultants (the interviews are described in detail in the following section). The interviews were conducted in 2010-11 and 2011-12 with the teachers in the classroom observations and their Principals. They all signed consent forms and were assigned aliases to protect their privacy.

Consultants: Science Consultants from the English school boards were invited to be interviewed. I interviewed three from the boards where I conducted classroom visits and one other from a large board not visited. I am in regular contact with the science consultants through their organization MaST (Math and Science and Technology), an official provincial subcommittee of DEEN (Directors of English Education Network) to which I belonged from 2007-2010 (K. Elliott & Asghar, Forthcoming). In fact I supervised MaST during that time.

Figure 3.1 shows the participants and data sources for the study.

Figure 3.1 The AST Study



3.2 The Research Tools – Qualitative Research

The qualitative research aspect of this study required me to be a part of the process being observed. Information gathering was both informal – chats, observations - and more formal - interviews and discussions with pre-determined topics (Maxwell, 2005). Though all data gathering methods were feasible, it was important to guard against keeping this inductive design too loose (Miles & Huberman, 1994, p. 17). I used observation checklists and interview protocols to keep the process structured, to a certain extent, and on track. In the quantitative research, on the other hand, my role as a researcher was much more in the background as I was more concerned with threats to internal validity and reductions to subjective bias (Creswell & Plano Clark, 2007).

3.2.1 Observations of AST classes

My classroom observations can be described as ethnographic field research since they involved the study of groups of students going about their everyday lives in the AST classes and labs (Emerson, 1995). As the researcher I got to know the research subjects and their activities by involving myself in their daily classroom activities as much as possible. Rist (1982) points out that "research posits that the most powerful and parsimonious way to understand human beings is to watch, talk, listen, and participate with them in their own natural settings." (p. 440). Ethnography involves the use of observational field notes, videotaped lessons, dialogue between teachers and students, interviews with teachers and students and online internet forums to obtain data (Roth & Tobin, 2010). The study of classroom discourse provided valuable data about the implementation challenges and issues (Hellermann, Cole, & Zuengler, 2001) and was part of my study. I took fieldnotes to record the actions of the teachers and their students. I used direct quotations as well as detailed descriptions of episodes when these helped with the understanding of the classroom processes. I did not video- or audio-tape any of the activities as I was not looking for detailed nuances of speech and body language to inform the study (Roth & Tobin, 2010). Qualitative research, like this ethnographic study, allowed theories to emerge from the observations (Emerson, 1995, p. 151). This is particularly important in this study, since no research has yet been done on the implementation of AST (Charland, 2011). The factors which influence the implementation emerged from this field study.

From December to May in the 2010-11 school year I visited the classes of three teachers of Secondary 4 AST at Howland HS and one teacher of both Secondary 3 and 4 AST at Lake HS. Both schools are in western Montreal. The studies involved visits timed to coincide with hands-on activities. 33 visits were conducted between December 2010 and May 2011. Each visit lasted one class period (50 minutes in the case of Howland HS and 75 minutes at Lake HS). In the 2011-12 school year, I extended this to two schools outside Montreal for visits of three to five class periods each. The purpose of this extension was to compare and contrast the implementation processes and progress in different school boards.

During the school visits I observed the activities as well as their preparation and follow-up presentations and discussions. The following aspects received particular attention:

- Nature of the activities / link to the AST program
- Evidence of student motivation to learn and engagement in the activities
- Evidence of student learning
- Classroom atmosphere
- Student-teacher relationships
- Gender differences

During my visits, I circulated among the students to observe their actions and behavior and I discussed their progress and their thinking with them. I took note of their actions, their interactions with each other and the teacher, their behavior, and their level of motivation. I observed the nature of the activities and related them to the AST curriculum. I also observed the presentation and guidance offered by the teacher and other adults working with the classes – lab technicians and integration aides. The observation checklist is appended. (See Appendix E)

After each class had finished, I categorized the fieldnotes according to themes which emerged from the observation checklist. This checklist was linked directly to the research questions. The fieldnotes were used to write the ethnography - a "thematic narrative… (which) begins by stating a main idea or thesis (and) progresses toward fuller elaboration of this idea throughout the paper." (Emerson, 1995, p. 171). The fieldnotes were used to inform my writing about the real-life classroom conditions which enabled or impeded the progress of the implementation of AST. These conditions included, among many others, the way AST was programmed into the school schedule, the lab facilities available to the students, and the relationship between teacher and students. These fieldnotes became the building blocks of the story which developed towards a concluding thesis.

3.2.2 Interviews

I conducted interviews with teachers, principals (and vice principals where appropriate) and school board science consultants. During these interviews, I discussed my own classroom observations in order to get their perspectives from their different points of view and probe other aspects of the implementation of AST with them as well. What follows is a brief description of these interviewees and their roles in this study.

Principals: Principals are responsible for organizing the school and ensuring that all programs are implemented according to the parameters set by the school board. These parameters follow the directives of the MELS. Principals have to take their school realities into account when making organizational decisions. For the organization of AST, some of these realities include: the lab facilities available to them, the teachers and their expertise and preferences, the program choices made by students and their parents, the attitudes of the school community to the programs. Though MELS has made it clear that AST and ST are of equal status, for example, some school communities have the attitude that AST is a program designed for the less able students and principals may program it accordingly. Interviews with the principals focused on the following: (See Appendix F)

- Their point of view on the implementation of AST
- Feedback on AST from their school community
- School organization issues involving AST

Consultants: Science consultants have a special supporting and organizational role in the implementation of AST. All of the English school boards in Quebec have an educational consultant whose job it is to train and support teachers in their teaching of the sciences in high school. While larger boards have a dedicated science consultant, others have consultants who may have other subjects (often mathematics) assigned to them as well. Interviewing them was important to this study because they are deeply involved in the support of all their teachers across the board and therefore are in the best position to be able to convey the details of the implementation process in their board. They are the experts! Interviews with the consultants focused on the following: (See Appendix G)

- The selection of students for AST
- Support for AST teachers
- Curriculum issues with AST
- Feedback from AST teachers

Teachers: The teachers of course are the ones who make or break the program implementation. Once the training is done and the classes are assigned, the teachers deliver the program to the best of their understanding and with the best interests of their students in mind. Each teacher has their own unique style of teaching and relating to students. Each has their own understanding of the program and their own ideas as to the best ways students learn science. While conducting the field studies in their classes, I carried on an informal dialogue with them. I asked them how their students are learning, what their ideas are for presenting their lessons, how they are feeling about their progress and anything else that seems appropriate and pertinent to the activities in particular and the program in general. Interviews with the teachers focused on the following: (See Appendix H)

- Their teaching and educational background
- Student selection and motivation to learn
- Their approach to teaching and evaluation of AST

3.2.3 Qualitative research summary

Table 3.1 summarizes the qualitative data collection. Details of the instruments and participants are provided in the appropriate sections of this paper.

Table 3.1 Qualitative Research

Table 3.1 – Qualitative ResearchInstrument	Participants	Timing and Progress
Classroom Observations Regular visits to observe AST classes in different schools	One secondary 3 and seven secondary 4 AST classes in four high schools: two inside and two outside Montreal	33 observations from December 2010 to May 2011 in five classes in Montreal 11 observations from September 2011 to January 2012 in three classes outside Montreal
Interviews with school board employees: Teachers, Principals, Consultants	AST teachers along with Principals and Guidance Counselors of the schools in the field studies. Science Consultants in 3 school boards	The teachers and principals from Lake HS and Howland HS and four consultants were interviewed in 2010-11. Two teachers from Maple HS and Trudeau HS and their principals were interviewed in fall 2011.

3.2.4. Validity and limitations – qualitative research

Identifying how the researcher may be mistaken in the findings being reported on is the key to establishing the validity of this study. In this section I show how I dealt with validity issues in the classroom visits and interviews.

3.2.4.1 Classroom observations.

The qualitative data sources provided me with a varied and rich source of information for this research. However I am aware of the limitations and validity threats pertaining to the qualitative component of the study. In this section I will describe the validity issues and how I have addressed them.

Maxwell (2005) refers to validity in qualitative research as "the correctness or credibility of a description, conclusion, explanation, interpretation, or other sort of account." (p. 106). Kirk (1986) states that "Loosely speaking…'validity' is the extent to which it (a measurement procedure) gives the correct answer." (p. 19). Rigor and trustworthiness are terms sometimes substituted for validity especially in discussions of validity of qualitative research (Morse, 2002). One threat to validity could be seen as the selection of the classes to observe. The observations are being carried out in classes where there are teachers identified as strong and enthusiastic about AST. Though the number of classes is limited, the choice of teacher will ensure that the implementation of AST is carried out in settings which are as ideal as possible. The purpose is to discover not only the average conditions across the system, but also to describe the implementation at its maximum potential.

Another potential threat is researcher bias or subjectivity. Since the beginning of the implementation of the QEP, I have been particularly interested in the approach to science teaching taken by AST. Different types of data from different groups of participants have helped to address the issue of my expressed subjectivity and bias towards AST. Perspectives from teachers, principals, consultants, and students help to compare and contrast trends from the data. Conversations with teachers and students as well as classroom observations help me to cross-check findings and patterns. I was alone in my role of observer and wrote my observations with some occasional use of photographs. However, with repeat visits throughout the winter and spring and a consistent observation protocol, the classroom observations were more likely to present an authentic picture of the reality of the AST classroom situation. I have attempted to use a consistent methodology for conducting classroom observations to be able to meaningfully compare data collected from different classrooms.

The following pattern of observation and interaction was used in each classroom activity:

- During the early stages of an activity I visited all groups of students and asked them about the nature of their project.
- As the project continued, I asked the students about their thinking in the design or experimentation process.
- At the end, I asked them about their attitude towards their accomplishment and an explanation of the science behind their work.

To address researcher effect - how my presence in the class might alter the interactions and processes - I visited the classes frequently and asked the same pattern of questions consistently to become a natural part of the classroom operations and thus have minimal effect on both students' and teachers' behaviors.

3.2.4.2 Interviews

Interviews of non-teaching personnel (principals and consultants) strengthened the validity of the classroom observations by informing the background conditions to the AST implementation. Each of the interviewees added information specific to their expertise in the selection of students, the programming of the school, facilities available, staffing limitations and parental pressures.

The interviews, however, impose some limitations on validity. The principals may have limited knowledge of AST and the ministry regulations governing the implementation conditions required for each school. Because of the nature of their administrative workload, they have little time to spend on the finer details of the program implementation. On the other hand, the consultants, though they are very expert in their knowledge and understanding of the AST program, do not have the knowledge and understanding of each school's programming limitations.

The effect of the researcher was certainly a potential source of validity threat in the case of interviews. I know all of the interviewees personally and, though there is a high degree of trust in the researcher-interviewee relationships, the risk exists that they have coloured their responses towards what they felt I want to hear. For this reason it was vital to have the same information from many different sources. For example principals and consultants were all asked about the issues of the programming of students in AST. All have the information, but they all have a slightly different point of view about it.

External validity or generalizations about the research findings were another possible source of threats to validity. To generalize from the activities of one classroom to the implementation of AST as a whole would be a questionable practice. In this study there were observations in eight different classrooms with six different teachers. These observations were triangulated with the interview data, as described above, as well as with quantitative data from surveys and enrolment data from school boards. This allowed for multiple viewpoints and comparisons and further increased the study's validity. Although findings from qualitative interviews and observations are generalized to the participants only, they generate useful insights about the effective implementation of AST curriculum in other schools and school boards.

3.3 The Research Tools – Quantitative Research

3.3.1 AST Teachers' Survey

This survey examines science teaching methodology, but is much more specific. Only Secondary 3 and 4 AST teachers were invited to participate. They all received an invitation by email to participate in the online survey (See Appendix B for the email invitation). Teachers identified themselves and their school affiliation. This was done so that I will be able to survey them a second time after a year. Confidentiality was guaranteed to them in that email. Unlike most of the other survey questions, the identification question was not made compulsory so as to encourage maximum participation. The survey was hosted by Google® and used the Google Docs® survey instrument. Its web address, http://bit.ly/astsurvey, is easily accessible. Google Docs® stores the data and provides a user-friendly summary including graphs of the response frequencies as well. 37 AST teachers responded to the survey in the winter of 2011 and a further 38 took it in the winter of 2012. They were asked to identify their teaching practices in the following categories:

- The extent to which teachers introduce the real world in classroom activities
- The extent to which teachers use constructivist teaching methodology
- The extent to which teachers use AST-specific content and activities
- The extent to which teachers perceive student attitudes to AST as positive
- The extent to which students use tools in their AST activities
- The extent to which teachers teach the content of the Four Worlds (MELS, 2007)

The full teacher survey can be found in Appendix D.

In addition to questions regarding their teaching practices, participants were also asked to identify the professional development training they received to enable them to teach the course, their sources of material and human support and their level of satisfaction with the support they received. A comment section was available to them if they wanted to make comments about any aspect of AST.

3.3.2 AST Student Survey

This survey was done by the students in the classes involved in the field studies. With the written permission of their parents, Secondary 4 AST students were invited to take the online survey during school time in the school's computer lab. They logged in to Google Docs® at http://bit.ly/aststudent. Their survey was based on topics similar to those in the teachers' AST survey, with more emphasis on their interest in and motivation for studying science. They took the survey anonymously and identified only their gender and their school. They were asked to identify how AST is presented to them, how they participate, and how they feel about the course. 28 Secondary 4 AST students responded to the survey in 2010-11. 71 more students took the survey in 2011-12 in the classes visited. They responded to questions in the following categories:

- The extent to which **the real world** is part of classroom activities
- The extent to which **constructivist teaching methodology** is used
- The extent to which **AST-specific** content and activities are used
- The extent to which they **use tools** in their AST activities
- The extent to which they have positive **attitudes to learning** science and AST
- The extent to which they feel **capable of achieving** well in AST
- Their aspirations for **future studies** in science

A comment section was also available to them. The full student survey can be found in Appendix F.

3.3.3 Enrolment Data

In order to get a sense of who takes AST in the different schools and school boards, enrolment data was requested from eight school boards. Three boards gave complete data for the years 2009-10, 2010-11, and 2011-12. One board gave data for 2009-10 and 2010-11 only. Two boards indicated that they have no classes in Secondary 4 AST. The remaining two boards did not respond, but represent less than 20% of student provincial enrolment in English education. These data representing more than 80% of Secondary 4 science enrolment, gave a picture of the number and percentage of students taking AST in Secondary 3 and 4 and the gender of AST students.

3.3.4 Quantitative Research Summary

Table 3.2 summarizes the quantitative research – the instruments, participants and progress.

Table 3.2 Quantitative Research

Instrument	Participants	Timing and Progress
AST Teachers' Survey: Online survey of AST teachers across Quebec	Secondary 3 and 4 AST teachers (n=75) in English high schools in Quebec	Two data collections: Once in winter 2010-11and again in winter 2011-12
AST Students' Survey: Online survey of AST students involved in field studies	Secondary 4 AST students in field studies	One data collection: 3 classes done in winter 2011-12. Three others in winter 2011-12
Student Enrolment Data Numbers of students in AST in Secondary 3 and 4	6 school boards	Three boards' data received for three years. One board for two years only. Two boards with no data because of no students in Secondary 4 AST.

3.3.5 Validity and Limitations – Quantitative Research

There are a number of concerns regarding the validity of the online AST surveys. The first concern is for content validity - whether the survey questions accurately reflect the content and methodology of the program (Creswell & Plano Clark, 2007, p. 134). This was addressed for the AST teacher and student surveys by the researcher by having the survey pilot-tested by two AST teachers and three science consultants – professionals who have been closely involved with the implementation of AST from the beginning.

Another concern is self-reporting bias - whether the respondents answer the questions truthfully for their situations. Will they report accurately on the situation in their classroom, or will they respond according to how they think the researcher thinks they should be teaching? To address this concern, it was important to get as wide a sample as possible of AST teachers. I administered the same survey to all AST teachers a second time in the fall/winter of 2011-12 to increase the sample, and to validate the data from the first administration of the survey.

Sample size is important when analyzing the responses for correlations which may link teaching practices with other factors like gender, years of experience, school board and many others. Triangulation with qualitative data, described above, helps to increase the credibility of the survey data. Sue and Ritter (2007) caution against sample sizes less than 30. This can limit the ability of the researcher to generalize from the data and reduces the reliability of the sample (Sue and Ritter, 2007). This survey with a sample size of 75 is well above this limit. Too small a sample size can result in coverage error – not representing the AST teachers adequately, nonresponse error – teachers choosing not to respond, and inaccurate estimates of their practices by AST teachers. It is my position that this survey data has helped build an overall picture triangulated with the other sources of quantitative and qualitative data.

3.4 Mixed Methods Research and Triangulation

As explained earlier this is a mixed methods research (MMR) study which "focuses on collecting, analyzing and mixing both quantitative and qualitative data in a single study or series of studies."(Creswell & Plano Clark, 2007, p5). MMR is one of three major research paradigms along with qualitative and quantitative research (Johnson, Onwuegbuzie, & Turner, 2007). In their study of the history of MMR, Johnson et. al. (2007) state that "a three-paradigm methodological world might be healthy because each approach has its strengths and weaknesses and times and places of need." (p117). Synthesizing the definitions of MMR of 18 leading MMR methodologists gathered in response to an email invitation by the authors, they came up with:

> Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration (p. 123).

Cresswell and Plano Clark (2007) identify 4 types of MMR designs – Triangulation, Embedded, Explanatory and Exploratory. I will use the triangulation design, which they identify as the most common. "This design is used when a researcher wants to directly compare and contrast quantitative statistical results with qualitative findings or to validate or expand quantitative results with with qualitative data." (p. 62). According to Green et al (1989), "The core premise of triangulation as a design strategy is that all methods have inherent biases and limitations, so use of only one method to assess a given phenomenon will inevitably yield biased and limited results."(Greene, Caracelli, & Graham, 1989). There are many examples of the use of triangulation in educational studies in general and science education in particular (Bleicher & Lindgren, 2005; Seifert, Goodman, King, & Baxter, 2010). Bryman (2007) states that "Bringing quantitative and qualitative findings together has the potential to offer insights that could not otherwise be gleaned." (p. 9). In this research, for example, the data from the online surveys of teaching practices in AST classes is compared and integrated with direct observations of classroom practices. The observed differences enrich the analysis of the implementation situation and to help explain some of the complexities of the implementation process.

3.4.1 The triangulation Process – Some examples

What follows are some examples of the triangulation process being used. In the online survey of AST teaching practices, teachers were asked to what extent they use constructivist teaching practices in the classroom and labs. The data from the classroom observations bring clarity to the nature and extent of these practices. In question 16, for example, teachers indicate on a 5-point Likert scale the extent to which the following occurs in their classes: "Students develop their own procedures to solve science and technology problems in the laboratory". While 17 out of 37 respondents answered "sometimes" to this question, a better understanding of this situation comes from direct observations of classes doing the AST activities. The instructions to students are examined to see to what extent the procedures are student-driven or teacher-directed.

Another example regards the extent to which AST is offered in the high schools. The school boards furnish enrolment data for their schools. This tells only part of the story. It is in the interviewing of principals, teachers and guidance counselors that enrolment is understood. They explain how choices are made, how the school programming works, the staffing considerations and all the other background concerns that the quantitative data don't bring out.

3.5 Data Analysis

3.5.1 Data Analysis - Qualitative

As described above, the qualitative data are made up of interview transcripts, observation notes, and comments on the surveys. Qualitative data analysis was ongoing and began with an effort to understand the overall picture that the data present. This involved my reading of the classroom observation notes and listening to and transcribing the interview tapes. I did this throughout the data collection process so as to be able to capture ideas and patterns as they emerged. I wrote memos to myself to help me understand the data as I went through the initial reading and listening (Maxwell, 2005, pp. 95-99). The data were coded and analyzed for the themes which emerged. Fade & Swift (2010) explained the use of codes as follows:

> A code (sometimes referred to as an index or a node) is simply a label that the researcher attaches to piece of data. When working with transcripts, a piece of data might be a single word, a group of words, a complete sentence or a whole paragraph. (p. 107)

Codes become the basis for broader themes which emerge. Some of these themes include for example: the use of tools and other technology, the use of constructivist pedagogy, student behavior in different types of activity, and the adherence to the program content.

The classroom observations give rich data. Watching the program in action – the students as they carry out their activities, the teachers guiding them and the progress of the curriculum content – gave me direct evidence of the implementation of the program. I read the observation notes immediately after the class, edited and adjusted them according to my recollections and impressions, and wrote myself memos for future reference. Once I had observed a number of related classes (a multi-day activity of one teacher or a single activity conducted by different teachers, for example), I reread the transcripts and coded them. These codes emerged as the reading of the transcripts progressed (Fade & Swift, 2010). In one class period for example, I noted and created codes for the following:

- the use of floor-mounted tools
- the level of student collaboration
- the teachers' linking of application to theory
- students' off-task behavior during teacher explanations (Adams & Krockover, 1999)

While classroom observations gave direct evidence about what actually happened in the AST classroom, interview transcripts and survey comments furnished valuable, indirect insights which shed light on the implementation of

AST. They explained the circumstances affecting the classroom by detailing the background to, for example, the preparation of the teacher, the choice of the student clientele, programming considerations and the facilities in the school. They helped also with what Rist (1982) describes as role and network analyses – the study of the roles of the teacher, principal, guidance counselor and students and their linkages both formal and informal in the organization (p. 446). These data were given coding and thematic analysis similar to that of the classroom observations.

3.5.2 Data Analysis - Quantitative

I used appropriate statistical analyses to help answer the different categories of research questions. In the research questions dealing with the description of the implementation of AST, I analyzed the data regarding the AST student population using simple descriptive statistics. I described the nature of the AST population: its gender, proportion of the overall science student population and academic background.

The extent to which the AST program is being implemented is explored under the question: "What teaching practices, specific to AST, do teachers use in the classroom and lab?" I searched for the answer to this question first by analyzing the individual questions related to the program implementation on the teacher survey and then by creating an "AST Implementation Index" score (AI) for each teacher. This AI score was generated by averaging the Likert Scale results for all related questions for each teacher. This will be fully explained in

Chapter 4. The results from this compilation provided a useful tool for analyzing the implementation of AST across the province. It also provided a means for eventually describing the factors involved in student engagement outcomes.

One of the key components of this study for example is the question: "To what extent are students engaged/motivated in learning of science in AST?" First the responses to the survey questions related to student engagement in both the teacher and student surveys were compiled and analyzed. Frequency distributions and graphs were created for each question. Correlations were calculated to see how closely these question responses are related both internally in each survey type and then across the teacher and student surveys to compare the student with the teacher responses. Other advanced statistical tests were used (e.g., t-tests and one-way ANOVA) to compare any differences in the trends within and across teacher and student populations (Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2010).

3.6 Summary: Research Questions and Research Instruments and Analytic Techniques

The following three tables summarize the research questions and the related research instruments for each question. The techniques listed will be used for the appropriate statistical analyses (Welkowitz, Ewen, & Cohen, 2000). Each table corresponds to one of the three categories of research questions: Theory, Description and Outcomes.

Table 3.3 Theory: How do various theories of learning underpin Quebec's Applied Science and Technology (AST) and Science and Technology (ST) programs?

Research Question	Data	Analytic Techniques
1. What are the theories of learning underpinning the AST (and ST) programs?	Study of the QEP and related documents Study of academic literature – books, journals, etc	Coding, developing themes, comparing and contrasting salient themes emerging from the documents
2. How are these theories used within the programs?	Linking of academic literature and QEP Interviews with program writers	
3. What theoretical links exist between the AST and ST programs and the immediate previous science programs of Quebec?	Study of the QEP and related documents Study of academic literature – books, journals, etc Study of previous programs. Linking with QEP	

Table 3.4 Description: How is AST being taught in Quebec schools?

Research Question	Data	Analytic Techniques
1. What proportion of secondary cycle 2 students take AST in secondary 3 and 4 – overall and by gender and academic ability?	Interview transcripts with principals and guidance counselors Enrolment data	Percent calculations Coding, developing themes, comparing and contrasting salient themes
2. What teaching practices, specific to AST, do teachers use in the classroom and lab?	Field studies Interviews with teachers AST teachers' survey AST students' survey	AST teachers and student survey: % calculations; frequency distributions; graphical representations; measures of central tendency; standard deviation; t-tests; correlations, ANOVA Coding, developing themes, comparing and contrasting salient themes
5. What is the relationship between the teachers' epistemology and practice especially as evidenced by their approach to the AST curriculum?		
3. What tools, scientific equipment and consumable materials are being used specifically for AST?	Field studies Interview transcripts with teachers AST teachers' survey and AST students' survey:	Analysis of field study data Analysis of survey data % calculations; frequency distributions; graphical representations; measures of central tendency Coding, developing themes, comparing and contrasting salient themes

Table 3.5 Outcomes: What are the outcomes of the AST program on students' motivation to learn science?

Research Question	Data	Analytic Techniques
To what extent are students and teachers engaged/motivated in the teaching and learning of science in AST?	Field studies Interview transcripts with teachers AST teachers' survey and AST students' survey	Analysis of field study data Analysis of survey data Surveys: % calculations; frequency distributions; measures of central tendency Coding, developing themes, comparing and contrasting salient themes

The next four chapters will be about the research. Each chapter will describe one research instrument, the details of the data produced and an analysis of the findings.

Chapter 4: The Teacher Survey

Chapter 5: The Student Survey

Chapter 6: The Classroom Visits

Chapter 7: The Interviews

In Chapter 8 I will synthesize the findings of the research instruments and triangulate them into a comprehensive story of the implementation of AST.

Chapter 4: Teacher Surveys

What they say about the Applied Science and Technology Reality

I invited AST teachers from English high schools across the Province of Quebec to participate in an online survey of their teaching practices and their students' attitudes. Students from the classes which I visited took a student-oriented version of the survey as well. In this chapter, I describe what I learned from the teacher surveys. The findings from the student survey will be presented and analyzed in Chapter 5.

In the first section, I give the details of the surveys and the participants. This includes the number and categories of questions and the nominative information about the participants as well as the survey processes: creating the survey, recruiting the participants and accessing the data. In the second section I describe how I analyze the data. Here I outline the kinds of information about the AST classes that the data produced and the statistical processes which I use to analyze them. In the third section, I detail the findings – what the surveys tell me about the teaching and learning and student motivation in AST classes in Quebec. The comment section provided the teachers with the opportunity to say whatever they wanted regarding any aspect of their experience with teaching AST. The comments will be summarized toward the end of the chapter.

4.1 The Survey

The teacher survey was launched twice - in late November 2010 and again in December 2011. All AST teachers in the nine public English school boards were invited to participate both times. Though the survey was done twice, I will treat it as one survey for analysis purposes. As I will show later in this chapter, the results of the 2 surveys were very similar, thus allowing for the single analysis. The teacher survey consisted of the following sections:

- Information about the teacher: name (first survey only), gender, number of years teaching science, school name, school board name, science courses they teach. All names have been eliminated from the data to ensure confidentiality.
- 25 questions about their teaching practices and student interest – responses on a 5-point Likert scale from “never or almost never” to “almost always”
- Questions about the support they receive and the resources they use
- A comment section open for anything the participants wish to say (or not)

I built the 25 questions about the classroom teaching practices and student attitudes based on the issues which I identified from the AST program of the QEP (MELS, 2007). I had to create the survey “from scratch” since no QEP/Science survey instrument exists in the literature. The inspiration for these questions came from the Constructivist Learning Environment Scale (Taylor, Fraser, & Fisher, 1997).

The categories of questions are based on the content of the AST program, the teaching methodology recommended by the program and supporters of the program in the science teaching community, the teaching resources recommended and the perceptions of student attitudes to the program. (Charland, 2011; Potvin & Dionne, 2007) As a result, the survey asked teachers to identify their AST experiences in the following categories:

4.1.1 Categories of Questions

Category 1: The extent to which teachers introduce the real world in classroom activities (four questions). As described in the Chapter 2 discussion of scientific literacy, the AST curriculum was written with an emphasis on learning science and technology as it relates to the world that students live in. The following four questions ask the teacher to what extent the real world is part of the curriculum they teach.

Question 1: I include applications of science and technology in the real world as part of classroom activities.

Question 2: When beginning a new topic I introduce the topic by discussing a real life application before discussing the scientific theory.

Question 3: In my class students learn how science relates to their lives inside and outside of school.

Question 6: In my class new learning relates to experiences or questions about the world inside and outside of school.

Category 2: The extent to which teachers use constructivist teaching methodology (six questions). In Chapter 2, I made the case for the introduction of constructivist teaching methodology as a major component of the teaching practices in AST. The answers to these questions show to what extent teachers center their classroom activities on accessing students' prior knowledge and having students develop their own plans and procedures in order to construct their knowledge and understanding.

Question 4: Students help me plan what they are going to learn.

Question 10: I find out what students already know about a topic before an activity or discussion of a new topic begins.

Question 15: I closely follow the teacher's guide and textbook to direct classroom activities and lab exercises.

Question 16: Students develop their own procedures to solve science and technology problems in the laboratory.

Question 20: Students decide what materials to use when solving a science and technology problem in the laboratory.

Question 25: I give students detailed, step-by-step instructions for laboratory activities.

Category 3: The extent to which teachers use AST-specific content and activities (nine questions). These questions explore how closely teachers follow the AST curriculum as written in the QEP. The questions ask them about their laboratory practices that are exclusive to AST as well as content questions common to all science and technology programs.

Question 5: I include applications of science and technology in the assessment of students.

Question 7: I include diagnosis of the operation of technological objects in the activities in my class.

Question 8: I include repair of technological objects in the activities in my class.

Question 9: I include activities in which students take apart and/or (re)assemble technological objects in my class.

Question 11: Students do activities regarding the applications of science and technology when studying the MATERIAL WORLD.

Question 12: Students do activities regarding the applications of science and technology when studying EARTH AND SPACE.

Question 13: Students do activities regarding the applications of science and technology when studying the LIVING WORLD.

Question 14: Students do activities regarding the applications of science and technology when studying the TECHNOLOGICAL WORLD.

Question 21: Students do activities in the lab at least once a week.

Category 4: The extent to which students use tools in their AST activities (three questions). The use of tools greatly enhances students' ability to construct their knowledge in AST. These questions ask about teachers' use of three categories of tools: floor-mounted power tools, hand-held power tools and ordinary hand tools.

Question 17: Students use FLOOR-MOUNTED POWER TOOLS (drill press, mitre saw, table saw, belt sander, etc) when carrying out activities.

Question 18: Students use HAND-HELD POWER TOOLS (drill, circular saw, hand-held sander, etc) when carrying out activities.

Question 19: Students use HAND TOOLS (hammer, saw, sander, chisel, cutter, etc) when carrying out activities.

Category 5: The extent to which teachers perceive student motivation to learn AST as positive (three questions). These are teacher perceptions based on observations of their students' reactions to AST activities.

Question 22: Students react positively when hands-on activities on applications of science and technology are proposed.

Question 23: Students participate enthusiastically in discussions of applications of science and technology.

Question 24: Students seem to prefer activities involving applications of science and technology to those involving scientific theory.

The full survey questionnaire along with the question categories can be found in Appendix D.

The survey was hosted by Google® and used the Google Docs® survey instrument. Google assigned a web address and I used the services of Bitly® to reduce its length to the more "friendly" web address, http://bit.ly/astsurvey. Google Docs® stored the data and provided a user-friendly summary including graphs of the response frequencies as well.

4.1.2 Recruitment of Participants for the Teacher Survey

In the fall of 2010, I asked all English school boards in Quebec for the email addresses of all their AST teachers and permission to contact them to take the survey. I repeated this one year later so that I could do a second survey of the teachers. I wanted to see if there was a noticeable difference in responses after 1 year, as the implementation was in its early stages. While six of the nine school boards gave me the email addresses quickly, two boards required me to contact each school individually. One board had no one teaching AST.

On November 18, 2010, I sent the first email invitation to all AST teachers. Two and one-half weeks later, on December 7th, I sent a reminder to those who hadn't responded to the first invitation. I repeated this procedure one year later with an initial email on Dec 8, 2011 and a reminder follow-up a month later on January 4th. Examples of the first email letter and the follow-up reminder can be found in Appendix B.

Table 4.1 shows the number of email invitations and the response rates for both surveys.

Table 4.1 Teacher Surveys - Response Rates

Survey	Number Invited	Responses after 1st email	Responses after 2nd email	Total Responses	Response Rate
First Survey: Nov / Dec 2010	100	25	12	37	**37.0%**
Second Survey: Dec / Jan 2011-12	83	13	25	38	**45.8%**
Overall	**183**	**38**	**37**	**75**	**41.0%**

The total of 183 teachers includes 46 teachers who were asked to do the survey twice – once each year. This leaves 91 teachers who were invited once. The reason that 91 teachers were asked only once is that teacher assignments change from year to year. Therefore it is not always the same ones who teach AST from one year to the next at a given school. The list of AST teachers is thus very different from one year to the next. These data indicate that almost half of the AST teachers taught the program for only one of the two years covered by this survey. This could affect the AST classroom. For example if a teacher taught AST in 2010-11, but not in 2011-12, his or her valuable AST experience was lost to the system after only one year. On the other hand, for those who taught it for the first time in 2011-12, it is unlikely that they had the benefit of the training which had been offered in the first year or two of the implementation.

Teachers Retained: I eliminated 12 of the total of 75 teacher responses in order to ensure that I counted the results of a given teacher only once. I searched the results for teachers who had responded for the same grade level twice – over the two years. I found them by logical deduction looking at their survey input for school, gender and years of experience. I matched these responses with the list of teachers I had invited. I eliminated their 2010-11 response in all cases.[1] The number retained for analysis was 63.

Accessing the Data: The responses to the teacher survey were stored by Google® "in the cloud" in a password-protected site and readily accessible in an

[1] This decision to eliminate teachers from the analysis was taken after consulting a professor of statistics in the social sciences at McGill University.

account I created. Google® maintained a spreadsheet which was continually updated in real time as the teachers submitted their responses. I then transferred them to an Excel® spreadsheet for my own analysis. Excel® offers some basic statistical analyses, but I felt it was necessary to dig deeper into the data to draw more information from the results of the surveys. I used a combination of Excel® and SPSS 20® software from IBM® to conduct the analyses.

4.2 Data Analysis – Teacher Survey

In this section I describe the development of the overall Applied Index (AI) Score and the AI scores by categories. I then test the data for differences in means of categories and subcategories according to the date administered. Next I examine the scores of each category question by question - looking for patterns and correlations between questions and categories. This leads to the subsequent section which relates the AI scores to characteristics of the teachers and grade levels.

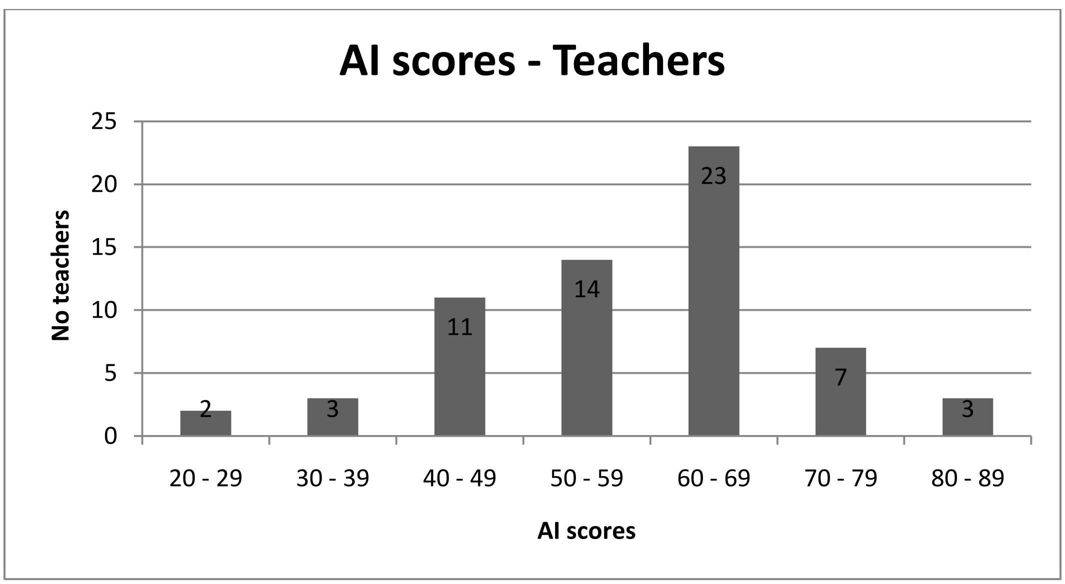
The Applied Index Score (AI): The descriptive statistics of the categories of questions give an initial picture of the level of implementation of AST in secondary 3 and 4 in Quebec high schools. This data is based on the Applied Index (AI) score for all teachers. I developed this statistic by assigning a score of 0 to 4 for each response based on the 5-point Likert scale according to Table 4.2.

Table 4.2 Applied Index Score Developer

Likert Scale	Raw AI score	AI score (%)
Never (or almost never)	0	0
Seldom	1	25
Sometimes	2	50
Often	3	75
Almost always	4	100

Each teacher received an overall AI index score - the average of that teacher's AI for all questions. Figure 4.1 shows the distribution of the scores of the 63 teachers retained for analysis. The mean AI score is 57.7.

Figure 4.1 AI Scores – All Teachers



4.3 Comparison of AI Scores by Date of Administration

In order to test whether the means for Surveys 1 and 2 (2010/11 and 2011/12, respectively) are significantly different the data for the two surveys were subjected to an independent samples t-test. The *t*-test failed to reveal a statistically reliable difference between the AI scores of those surveyed in 2010/11 (M = 59.8, s = 12.16) and those surveyed in 2011/12 (M = 57.6, s = 15.12), $t(61) = .718$, $p = .475$, $\alpha = .05$. Since a significant difference between the 2 surveys cannot be detected, I will treat them as one data set and analyze relationships among variables based on this assumption. A second independent samples t-test was performed comparing the means of all questions in the survey. The only question found to have significantly different means between session 1 and 2 was Q25 with $p=.030$ at $\alpha=.05$. Since a significant difference between the 2 surveys can be detected in only 1 question, I will treat them as one data set and analyze relationships among variables based on this assumption.

The implications of almost no differences in the survey responses are that the overall picture of practices in the AST classroom, as reported by AST teachers, did not change from one year to the next.

4.4 AI Scores by Category

An AI score was also generated for each of the five categories identified above: real world, student attitude, constructivism, AST curriculum and tool use. For the category "real world", for example, the average AI score for the four questions in that category was calculated for each teacher and then the scores for all teachers were averaged. The result was 71.74. Table 4.3 lists the means of the AI overall and category scores along with accompanying information on the range and standard deviation. Figure 4.2 illustrates these data graphically.

Comparison of means of AI Score categories: One-sample t-tests were performed on the AI category scores for teachers to see if there were significant differences between the means. This was done to find out whether or not teachers perform differently in the different categories of their AST teaching. The mean AI scores were found to be significantly different from each other at the $p \leq .05$ level.

4.4.1 Interpretation of the Individual Question Scores by Question and Question Category

The following chart shows the raw mean scores for the 25 questions on teacher practices and student attitudes as reported by all AST teachers who responded to either or both of the teacher surveys in 2010-11 and 2011-12. See Appendix D for the wording of the questions by question number.

Figure 4.2 Raw Scores – Teacher Survey

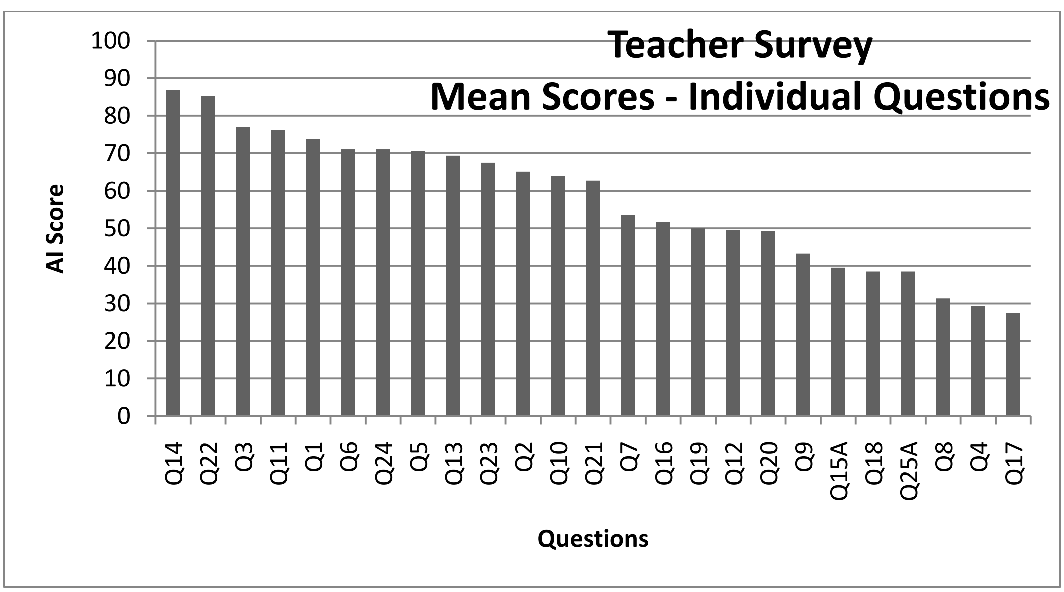


Table 4.3 – AI Scores by Category

		Minimum	Maximum	Mean	Std. Deviation
AI - Overall	63	25	87	57.74	13.37
Categories					
AI – Student attitude	63	33	100	74.60	16.36
AI - Real World	63	38	100	71.74	15.35
AI – AST Curriculum	63	15	88	55.05	16.64
AI- Constructivism	63	8	83	45.41	16.45
AI – Tool use	63	0	100	38.62	28.14

Figures 4.3 breaks down the means by category.

Figure 4.3 Mean Scores by Category

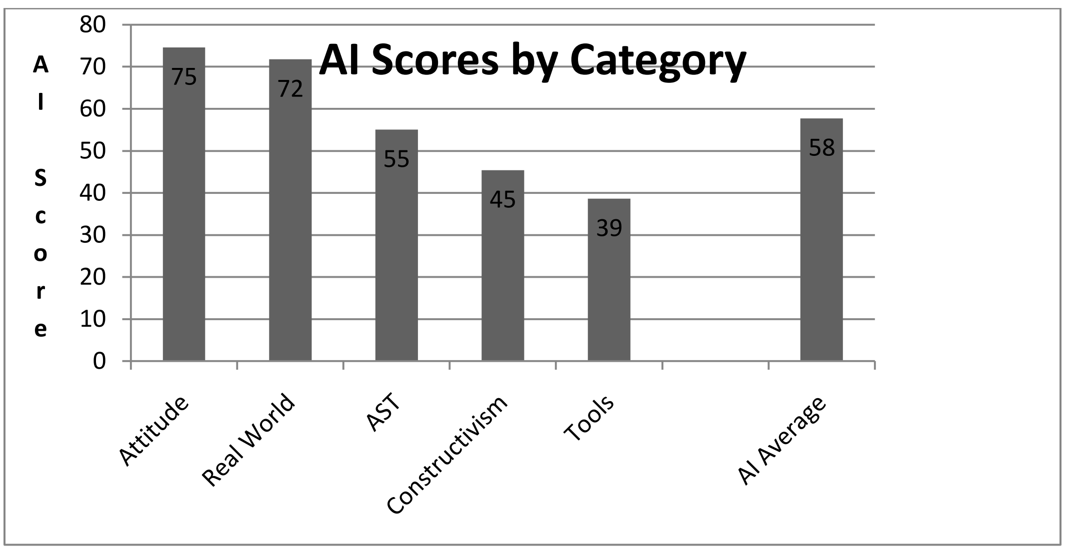
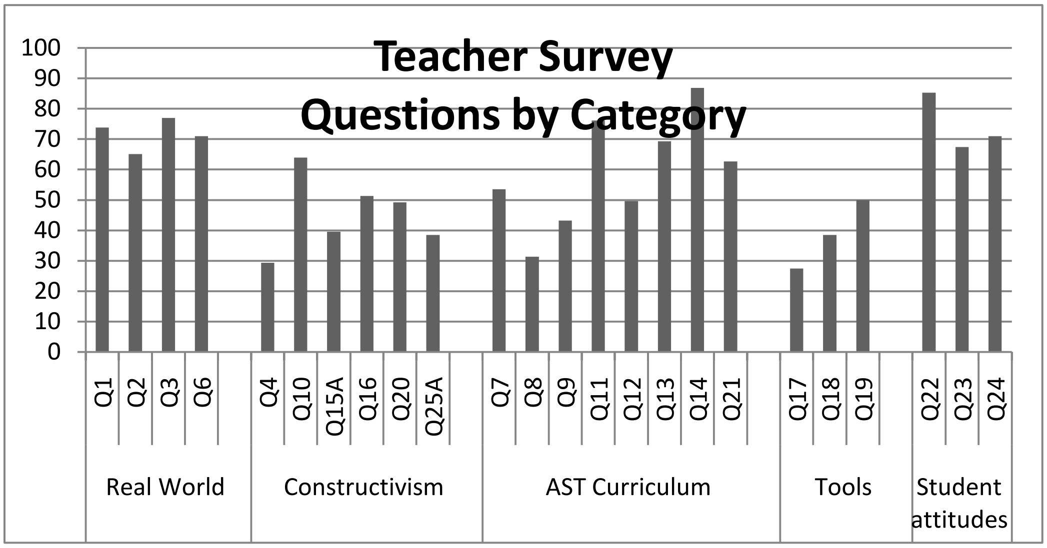


Figure 4.4 shows the categories from Figure 4.3 broken down into their constituent questions. It shows that the Real World and Student Attitude questions do not vary much from their respective means. The other three categories, Constructivism, AST Curriculum and Tools, have AI responses which vary greatly from their respective means.

Figure 4.4 Raw Scores by Question Category



A picture of the AST classroom across Quebec begins to emerge from an examination of Figures 4.2, 4.3 and 4.4. The mean AI index scores vary from category to category.

Student Attitudes: A large number of teachers believed that student attitudes and motivation toward learning science are positive (75 out of 100).

Real World: Teachers report that they regularly relate the real world to their classroom activities (72 out of 100).

Constructivism: The reported use of constructivist teaching methodology gets only an average of 45 out of 100. The AI scores of four of the six questions in this category are close to the 45 average. Of the remaining two, the lowest score shows that teachers seldom have their students plan their learning. The highest is for teachers' accessing students' prior knowledge.

AST Curriculum: The average AI score of 55 is made up of high scores for teachers' coverage of the Four Worlds, balanced by lower scores for operations with technical objects, especially repairing.

Tools: The use of tools in AST activities receives the lowest score. At 39 out of a possible 100, this shows that tools are used from "seldom" to "sometimes" on a weekly basis. This average comes from AI scores which range from 25 to 50 – the lowest for large floor-mounted tools and the highest for regular hand-held tools.

4.4.2 AI Index Scores and Correlations

In this section I will focus on correlations between the overall teacher AI scores with AI scores of teachers' categories and with those of individual questions. In this study, a teacher's overall AI score is the average of their scores on the 25 individual questions. The higher the a teacher's AI score, the more closely their practices conform to those prescribed by MELS in terms of their pedagogy, coverage of the curriculum, use of tools, contextualization in the real world and student motivation. I decided to run Pearson r correlations on all pairings of the questions for two reasons:

- To see if a teacher's AI score is a consistent predictor of the AI scores in the different categories.
- To look for expected and unexpected relationships between different aspects of AST teaching practices.

A study of the correlations of AI Index score for teachers with the scores of individual questions shows positive correlations ranging from r = .356 to r = .702 for 23 of the 25 questions in the survey. In other words, the higher the overall AI scores for a teacher, the higher were the AI scores for individual questions for that teacher in general. For example, comparing the teacher overall AI score to the AI scores for Q17 – use of floor-mounted tools – the correlation was r = .599, indicating that the higher the teacher's AI overall score, the higher was the use of floor-mounted tools. The only exceptions are questions 15 and 25:

> Question 15: I closely follow the teacher's guide and textbook to direct classroom activities and lab exercises. (r = -.079)
>
> Question 25: I give students detailed, step-by-step instructions for laboratory activities. (r=.-.114)

Question 15 addresses how creative teachers are in their preparation of their AST activities and Question 25 the extent to which they give their students control of the activities. There seems to be no relationship between these aspects of AST and the AI scores.

In the following section I examine relationships of each category with questions outside the category to look for correlations which might reveal how teachers teach AST. For example I look at the correlations between the Real World AI category scores for teachers and whether they diagnose the operation of technical objects as asked in Q7. This study will reveal important connections among teaching practices.

4.4.3 Category 1: Real World

The answers to the 4 questions in this category show a strong consistency. In general, teachers report that they "often" (AI = 71.74) contextualize their classroom activities with what is happening in the world outside the classroom when introducing them, carrying them out and analyzing the results.

Correlations: Real World Index scores: Real World AI correlates with the questions dealing with technical objects – diagnosis, repairing, taking apart and reassembling Q7($r=.481$; $p<.05$); Q8 ($r=.369$; $p<.05$); Q9($r=.451$; $p<.05$). This indicates that those who teach AST in a real world context tend also to be more inclined to include the activities with technical objects in their activities.

Real World Index scores also correlate with Q24 ($r=.432$; $p<.05$) which deals with students preference for applications over theory and the availability of tools in the classroom or lab($r=.433$; $p<.05$). In other words, teachers tend to teach in a real world context when their students prefer applications to theory or when they have tools available to them.

4.4.4 Category 2: Student Attitudes and Motivation

This category of questions receives the highest average score from the AST teachers. They report that their students "often" (AI = 77.6) look forward to AST activities, are enthusiastic in their participation in discussions, and that they prefer AST activities to studying about scientific theory. This means that they perceive that their students have very positive attitudes to their AST studies.

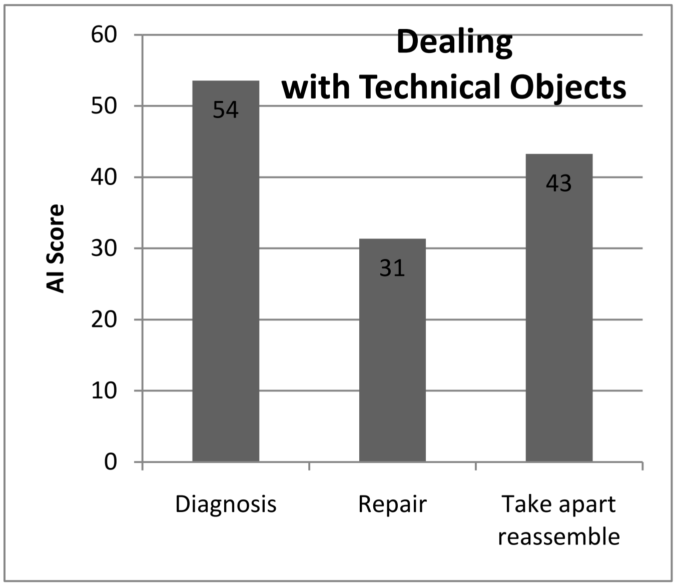
Student Attitudes and Motivation AI scores - Correlations: The teachers' perceptions of student positive attitudes to AST are positively correlated with how closely the AST curriculum is followed ($r = .532$; $p<.05$), the constructivist nature of the methodology ($r = .422$; $p<.05$) and how frequently the learning is contextualized in the Real World ($r = .393$; $p<.05$). Students' positive attitudes also strongly correlate with the frequency of students helping plan their learning ($r = .529$; $p<.05$), doing activities in the Technological World ($r = .510$; $p<.05$) and the frequency of doing lab activities ($r = .483$; $p<.05$). In other words positive student attitudes seem to be related to overall active constructivist learning.

Student positive attitudes are also correlated with the satisfaction teachers have toward the support they receive ($r = .584$; $p<.05$). It seems that the better teachers feel supported, the more they feel that their students are positive about their learning.

4.4.5 Category 3: AST Curriculum

This category can be divided into 2 sections – AST-specific lab activities and AST curriculum content. The former consists of questions about how teachers deal with technological objects in the lab. An important difference between ST and AST is that AST has a focus on the use and understanding of objects in common usage in our daily lives.

Figure 4.5 Dealing with Technical Objects



The teachers reported that, in their AST activities, they “sometimes” diagnose the operations of (AI = 54) and take apart/reassemble these objects (AI = 43), but that they “seldom” repair them (AI = 31). In practical terms, however, this should not be considered as a lack of following the AST curriculum. In fact it would be unrealistic to expect that these activities could be done more frequently considering the amount of time required by other aspects of the program. Further research is needed to quantify the time and effort which ideally satisfy the curriculum needs of AST in this area of study of technological objects.

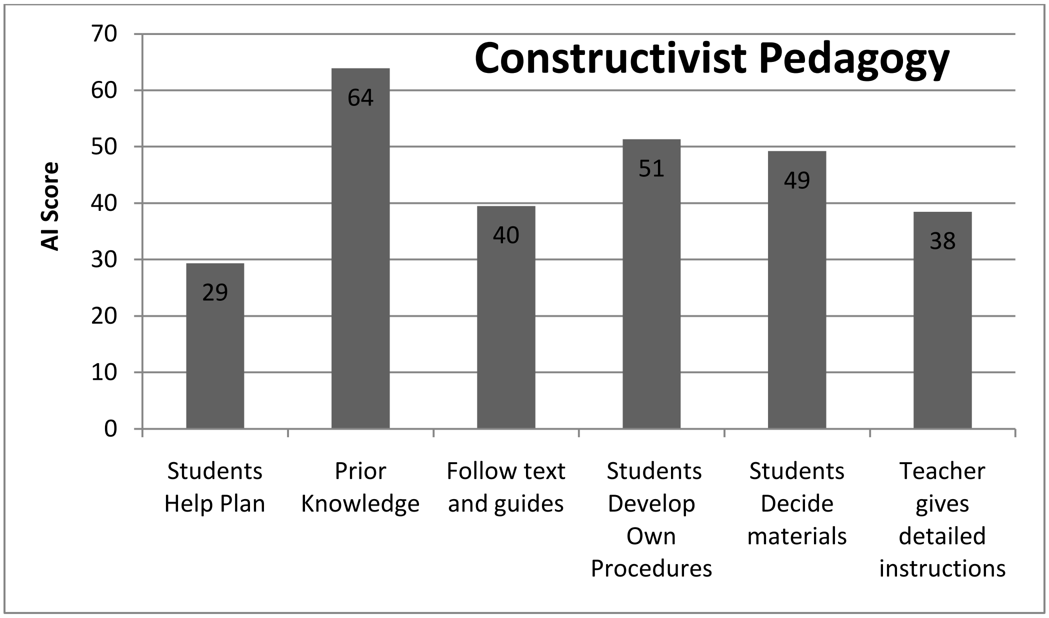
Questions dealing with the curriculum content areas of AST – the 4 Worlds – understandably receive higher ratings since this is the curriculum content they must cover for their students to receive credit for the AST program. The Technological World receives the most attention of AST teachers with teachers responding that they include activities from this World “often to almost always” (AI = 87). This makes sense as this is the main emphasis of AST and a strong aspect of the final MELS evaluation at the end of Secondary 4. The Material World (AI = 76) and the Living World (AI = 69) receive high scores as well. The Living World is higher among Secondary 3 (AI = 78) than Secondary 4 teachers (AI = 64) since Human Biology is the central theme in Secondary 3. Among the Four Worlds, Earth and Space receives the least attention of AST teachers. Here, a difference exists between Secondary 3 and 4 teachers. The reported rate of doing activities in Earth and Space is a little more than "seldom" in Secondary 3 (AI = 39) and "sometimes" in Secondary 4 (AI = 57). This is a reflection of the emphasis in this content area at the two levels. The Progression of Learning specifies that Earth and Space should be covered only as a Secondary 4 topic (MELS, 2011b).

AST Curriculum - Correlations: How closely teachers follow the AST curriculum correlates with all categories of the AI index – again with the exception of Questions 15 and 25. The levels of correlation range from $r = .532$; $p<.05$ for student attitude and motivation to $r = .762$; $p<.05$ for the frequency of tool use. In other words, the more teachers follow the AST curriculum, the higher they tend to rate in their performance on the AI sub-indices.

4.4.6 Category 4: Constructivism

As described in Chapter 2, a constructivist classroom is a student-centered class where the teacher builds on the students' prior knowledge and provides them with active learning opportunities. Students are given the opportunity to construct their own knowledge by developing their own procedures for solving scientific problems. Figure 4.3 shows the wide differences in the means of the AI scores of some of the constructivism question responses.

Figure 4.6 Constructivist Pedagogy



Teachers report that they “sometimes” to “often” (AI = 64) access their students’ prior knowledge about a topic which they are about to begin in class. The survey shows that teachers are hesitant to embrace constructivist teaching practices especially in the area of student control of their own learning. Rather than let their students develop their own ways of solving scientific problems, teachers “sometimes” to “often” (AI = 40) follow the teacher’s guide and text book and give their students step-by-step instructions for activities (AI = 38). This is supported by their reporting that they “seldom” (AI = 29) let their students plan what they will learn. However teachers do report giving some independence within activities. They report “sometimes” letting their students develop their own procedures (AI = 51) and select their own materials (AI = 49) for these activities. In Chapter 6 I will describe the extent to which teachers use constructivist practices in the selected classes I visited during the course of this study. It becomes clear that they carefully choose the teaching methodology that fits the activity at hand and adjust according to their interpretation of what is best for maximum student learning in that situation.

Constructivism - Correlations: The strongest correlation with the Constructivism AI is the AST curriculum index ($r=.600$; $p<.05$). In other words, the more constructivist their pedagogy, the more teachers follow the AST curriculum. Other strong correlations involve dealing with technical objects especially taking apart and reassembling them ($r=.458$; $p<.05$); the use of power hand held tools ($r=.417$; $p<.05$) and students enthusiastic participation in discussions ($r=.429$; $p<.05$). A high constructivist AI seems to correlate with doing activities strongly in line with the AST philosophy.

4.4.7 Category 5: The Use of Tools

The AST program includes many activities in which students design and build technical objects out of wood, plastic and other materials (MELS, 2007). In the survey, teachers were asked how frequently they use each of the three categories of tools in AST activities. These are the tools that high schools in the past used for woodworking and Introduction to Technology classes prior to the implementation of the QEP (though in many cases purchased new or upgraded for the QEP with Ministry funding) (MEQ, 1993).

Figure 4.7 Use of Tools

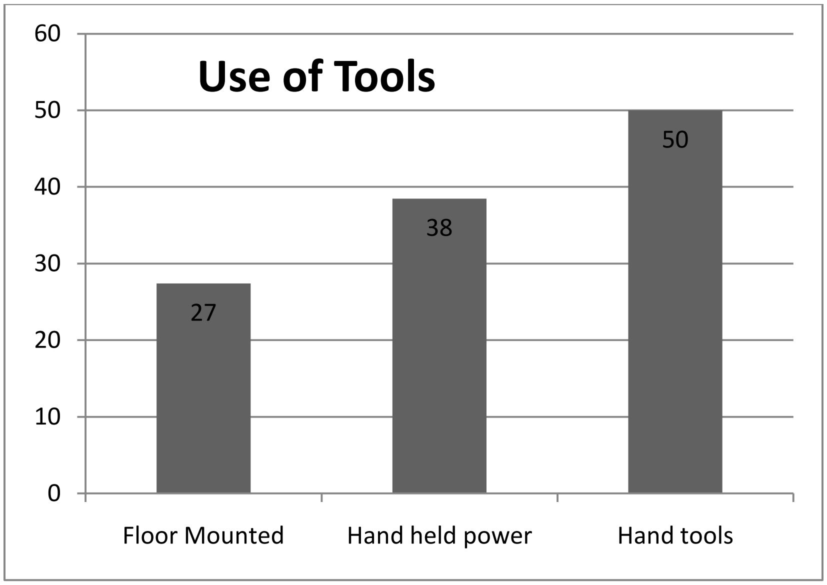


Figure 4.7 shows that, on average, teachers report “seldom” using floor-mounted tools (AI = 27). They report “seldom” to “sometimes” using electric hand-held tools (eg. Drill, glue gun) (AI = 38) and “sometimes” using non-power hand-held tools (eg. hammer, screw driver, saw) (AI = 50). Not surprisingly, the extent to which teachers use tools correlates significantly with the tools that they have at their disposal as reported on the survey, as shown in Table 4.8 below. In other words, if they have the tools they are more likely to use them!

<u>Use of Tools - Correlations</u>

The first question is whether the availability of tools correlates with the teachers’ reported use of tools for AST activities. Table 4.5 shows this strong correlation showing that the more available the tools are, the more teachers tend to use them.

Table 4.3 Tool Use vs Tool Availability Index[2]

	Q17 Floor-mounted tools	Q18 Hand-held electrical tools	Q19 Manual tools
Mean AI score	27.4	38.5	50.0
Pearson r correlation with Tool availability index	.532	.560	.296
Correlation significance level (p)	0.01	0.01	0.05

However, despite this positive correlation, among those reporting having the floor-mounted tools (N=43 or 68%), the use of these tools is still only in the range of "seldom" (AI = 27.4).

Other aspects of the AI scores also correlate with tool use. How frequently teachers use tools correlates strongly with the Constructivism AI (r=.455; p=.01) and the AST Curriculum AI (r=.762; p=.01). Tool use also correlates with the following "hands-on" aspects of AST:

- the study of technical objects, especially taking apart and reassembling them (r=.448; p=.01)
- students' developing their own procedures (r=.436; p=.01)
- students' deciding what materials to use in solving AST problems (r=.508; p=.01)

This indicates that the more constructivist a teacher's pedagogy, the more likely they are to use tools in AST.

[2] The Tool Availability Index is assigned to all teachers according to the tools they report to be available to them as follows: 4 = floor-mounted power tools; 3 = hand-held power tools; 2 = hand-held manual tools; 1 = equipment used in previous science programs

4.4.8 The Highest Correlations between questions

Apart from the correlations listed above, there are other very strong correlations (r>.550) between certain individual questions. Though the links seem obvious in these situations, it shows that the teachers were consistent in their self-reporting regarding their AST practices.

- Teachers who include applications in the real world also introduce new topics with real world applications (r=.602).
- Teachers who include diagnosis of the operations of technological objects also include their repair (r=.624) and those that repair them also take apart and reassemble them (r=.685).
- Teachers report that when students use floor mounted tools, they also use hand-held power tools (r=.717). Students who use hand-held power tools also use hand tools (r=.787).
- Teachers report that students who help plan what they will learn also are involved with the repair of technical objects (r=.590).
- Teachers report that students who react positively when hands-on applications are proposed also participate enthusiastically in discussions of applications. (r=.568).

4.4.9 Summary – AI Index and the 25 Questions

An analysis of the results of the 25 questions helps us understand what goes on in AST classrooms. Teachers have told us what they and their students do in class, the materials they use, and how their students react. The correlations among the question responses informs us of the commonalities and consistencies which exist in AST classes across the province. From this first look at the AI Index scores and the questions which constitute it, a picture is beginning to emerge of the AST classroom.

- Teachers make a big effort to contextualize their presentation of AST topics – to ground their teaching in the real world that their students experience, respecting their prior knowledge of it.
- Teachers engage their students in active learning processes, but are tentative in ceding control over the activities to their students.
- Teachers are thorough in their “coverage” of the compulsory AST content, but have not yet embarked to a large degree in the use of the tools available to them.

4.5 AI Scores and Teacher-related Characteristics

Are there certain teachers who are best suited to teach AST? Since AST is a new program with a heavy technological, hands-on component, should the ideal teacher have certain characteristics? Does it make a difference, for example, whether they are male or female, or whether they are new to science teaching or experienced? Do teachers of Secondary 3 AST teach differently from those teaching Secondary 4 AST? Does the support that teachers feel they get from the MELS, their school board and their schools make a difference in how they teach? The answers to these questions may be able to help guide schools and boards in how they organize, staff, train for and support their Science and Technology programs.

This section examines the relationships of the AI scores (overall and by category) with the characteristics and conditions of the AST teachers that took the survey. It will look at gender differences, years of science experience, AST grade level, and teachers' satisfaction with the level of support they receive.

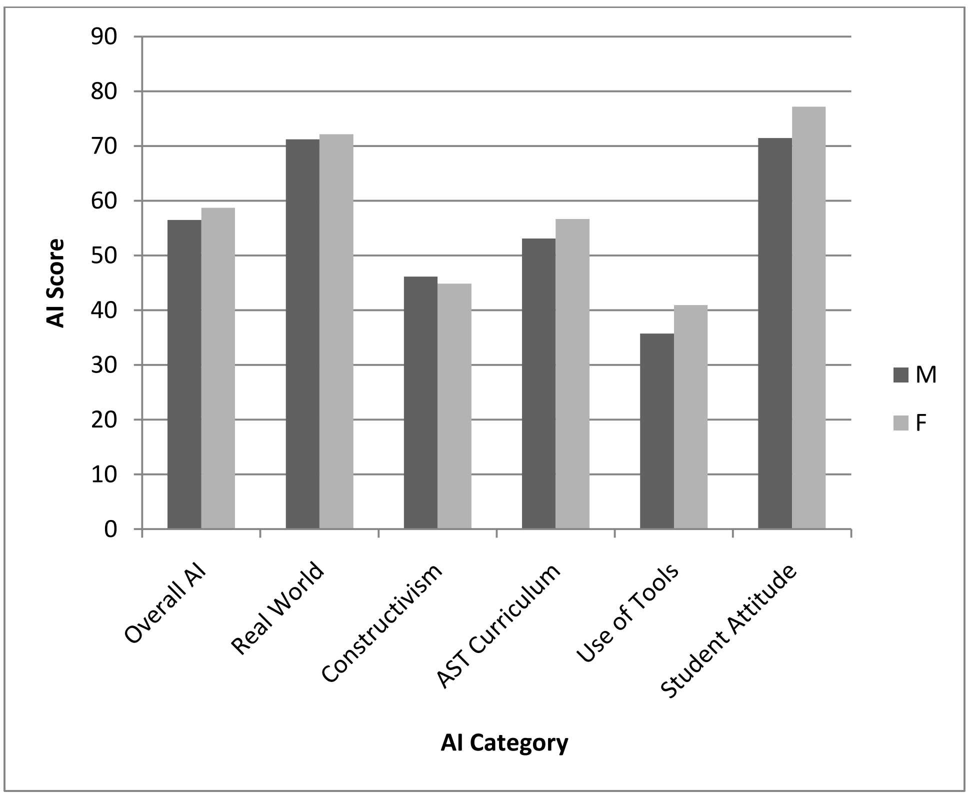
4.5.1 Comparison of AI Scores by Gender

In most categories, Female teachers have higher AI scores than their male counterparts as illustrated in Table 4.4 and Figure 4.6.

Table 4.4 AI Scores by Teacher Gender

Teacher Gender	Overall AI	Real World AI	Constructivism AI	AST Curriculum AI	Tool Use AI	Student Attitude AI
Male	56.5	71.2	46.1	53.1	35.7	71.4
Female	58.7	72.2	44.8	56.6	41.0	77.1
Total	57.7	71.7	45.4	55.1	38.6	74.6

Figure 4.8 Comparison of AI Scores by Gender



Independent Samples t-tests were performed on all AI score categories to determine whether or not there was any significant difference between the scores of men and women respondents. The results showed no significant differences by gender at the p =.05 level. Thus the gender of the teacher makes no significant difference to the way that AST is taught.

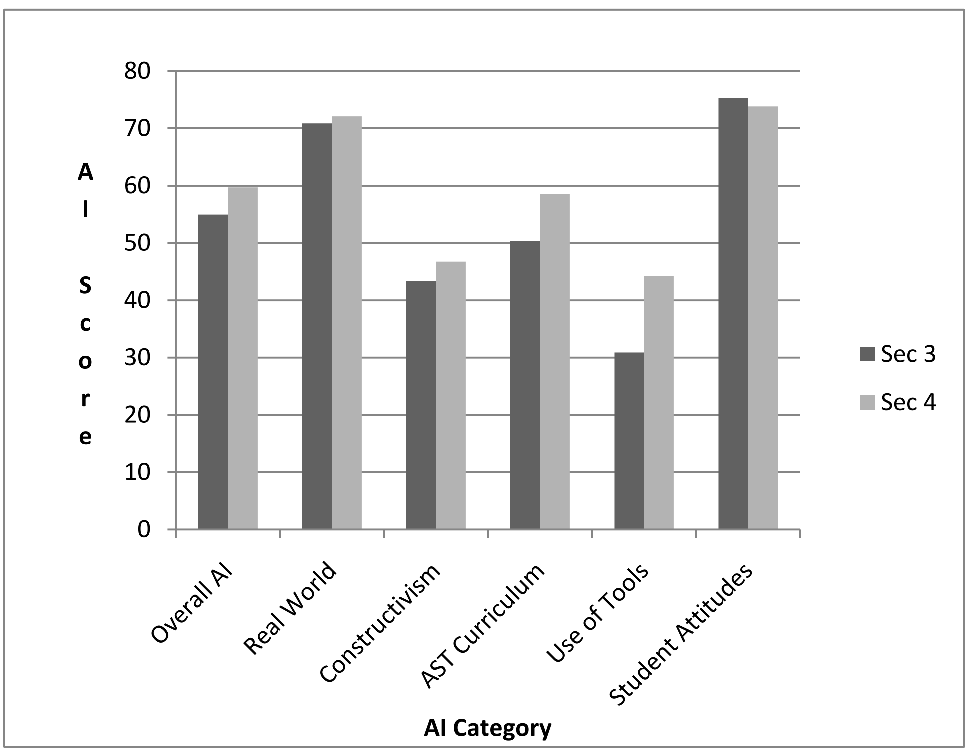
4.5.2 Comparison of AI Scores by Grade Level

When the data are broken down by grade level, it becomes clear that the classroom practices are different from Secondary 3 to Secondary 4. In all categories the AI scores are lower in Secondary 3. The difference is most apparent in the use of tools and the curriculum of AST.

Table 4.5 AI Scores by Grade Level

Grade Level	Overall AI	Real World AI	Constructivism AI	AST Curriculum AI	Tool Use AI	Student Attitude AI
Sec 3	55.0	70.9	43.4	50.4	30.9	75.4
Sec 4	59.7	72.1	46.7	58.6	44.2	73.8
Total	57.8	71.6	45.4	55.3	38.9	74.4

Figure 4.9 Comparison of AI Scores by Grade Level



The Overall AI scores as well as the AI subcategory scores by grade level were not significantly different at p = .05 level. However there were significant differences at p = .10 level in two categories: AST curriculum (p(58) = .065) and Use of Tools (p(58) = .070). This means that Secondary 4 teachers report following the AST curriculum and using tools more than their Secondary 3 counterparts. These two differences can be explained by the fact that the Secondary 3 and 4 AST programs have different curriculum themes. While Secondary 3 emphasizes the human body and the Living World, Secondary 4 concentrates on the Technological World (MELS, 2007, 2011b). Considering these themes, teachers tend to use tools less frequently in Secondary 3 as there is less emphasis on tool use in the Living World. There are, however, many technology-oriented possibilities in Secondary 3. When I present the classroom visits in Chapter 6, I will describe an example of a very effective Secondary 3 activity from the Technological World. The challenge for teachers and planners is to support an increased presence of technology in Secondary 3.

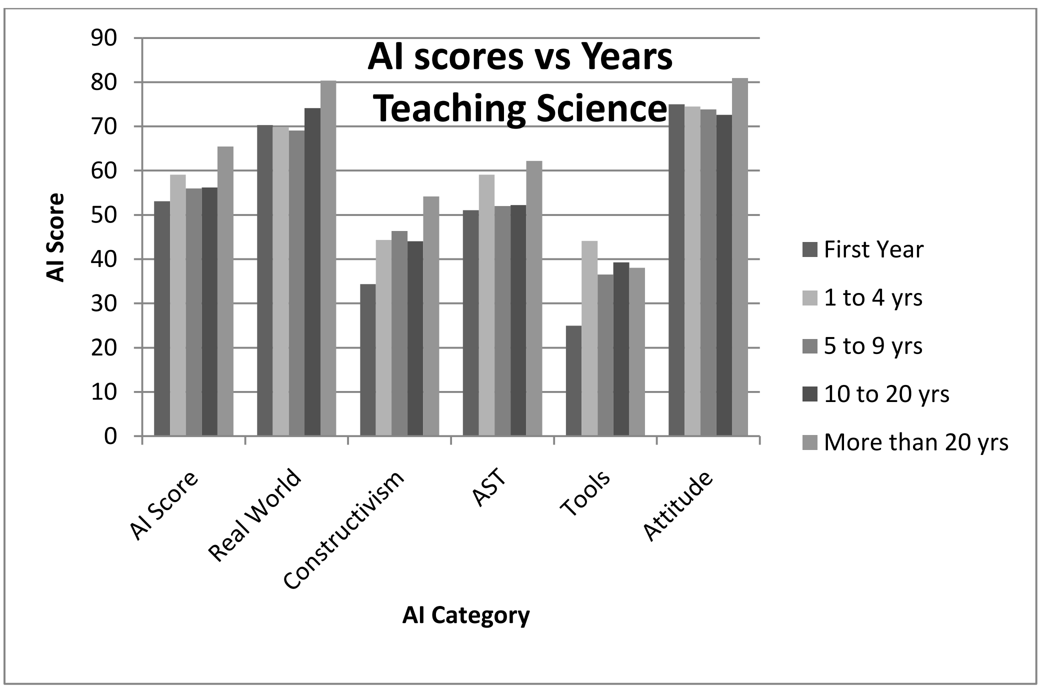
4.5.3 Comparison of AI scores by Years of Experience Teaching Science

Analyzing the AI scores with respect to the number of years that the teachers have been teaching science shows minor differences among the years experience and the AI categories. Though at first glance, those in their first year have much lower scores, it must be realized that since their number is very low (n = 4) little can be concluded from these data.

Table 4.6 AI Scores by Years of Experience Teaching Science

Years experience	n	Overall AI	Real World AI	Constructivism AI	AST Curriculum AI	Tool Use AI	Student Attitude AI
First year	4	53.1	70.3	34.4	51.1	25.0	75.0
1 to4 yrs	17	59.1	69.9	44.4	59.1	44.1	74.5
5 to 9 yrs	21	56.0	69.1	46.3	52.0	36.5	73.8
10 to 20 yrs	14	56.2	74.1	44.1	52.2	39.3	72.6
More than 20 yrs	7	65.4	80.3	54.2	62.2	38.1	81.0
All teachers	63	57.7	71.7	45.4	55.1	38.6	74.6

Figure 4.10 Comparison AI Scores and Years Teaching Science



From the Figure 4.8 above, it is seems that the teachers with more than 20 years of experience have the highest AI scores in almost all categories. However a one-way ANOVA test shows no significant differences between groups. These results do not point towards using the experience of teachers in science teaching as a factor in assigning AST classes to a teacher's workload. A larger sample size would be needed to determine whether those with less experience are less effective in the AST classroom. I would speculate that those with less experience might benefit from extra support services from the boards and schools. I will look closer at the question of support for AST teachers in this next section.

4.6. Support for AST Teachers

Overall, teachers expressed the opinion that they have received the support they need to teach AST. Question 28 on the Teacher Survey asked to what extent the support they received from the various professional development and training activities was sufficient to allow them to deliver the program effectively. The mean AI score of 65.8 is strongly positive and is equivalent to "sometimes" to "often".

Figure 4.9 shows that 57.1% of respondents deem that the support they have received is "often" or "always" (3 or 4) satisfactory to allow them to carry out AST activities to their satisfaction. On the other hand, only 11.1% of them feel that is it either "almost never" or "seldom" (0 or 1) satisfactory enough.

Figure 4.11 Level of Teachers' Support Satisfaction

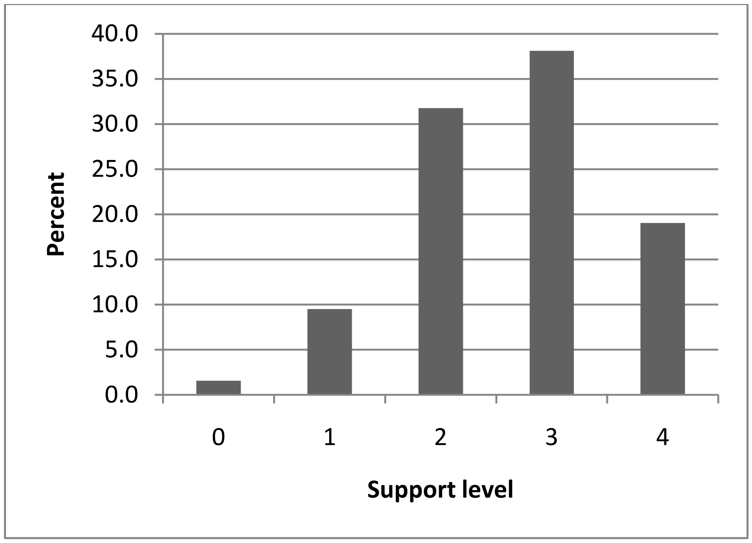
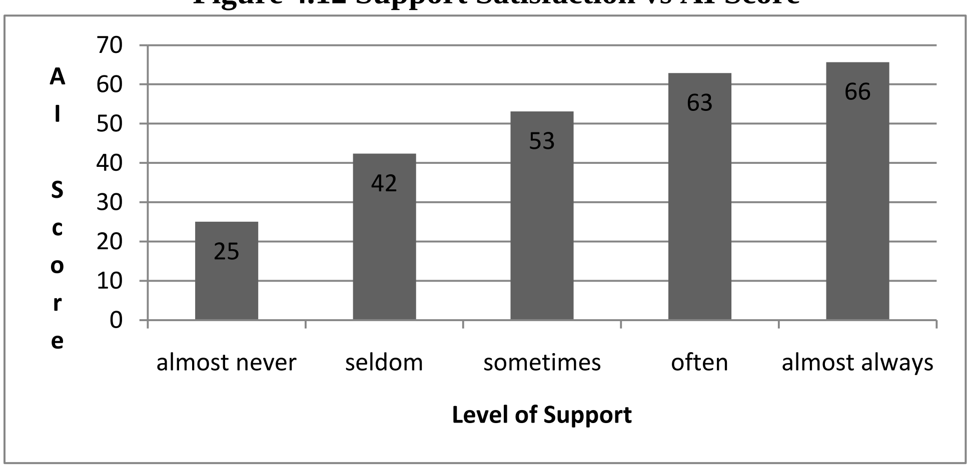


Figure 4.10 below illustrates a positive relationship between the overall AI index scores and the responses to Q28 – the level of satisfaction with the support teachers receive. The average AI score is shown for each level of response. This shows that the more positively they see their support, the greater is their AI score.

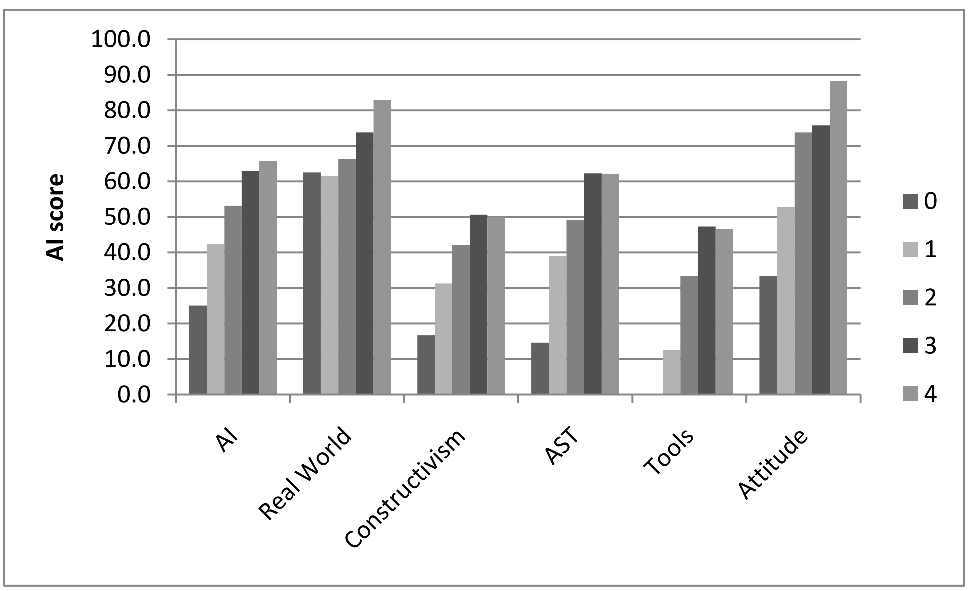
Figure 4.12 Support Satisfaction vs AI Score



When the AI scores were matched with the responses to Q28 there is a positive correlation ($r = .596$; $p \leq .05$) between the satisfaction with their support and their AI scores. This relationship between AI score and level of support satisfaction is also reflected in all of the categories that make up the AI scores as shown in Figure 4.11. This shows that the more that teachers feel the support that they received is sufficient; the greater is their AI score in each category. This implies that the greater the support given to a teacher, the more likely he or she is to teach AST the way it is intended. Conversely, teachers who feel that they have not received sufficient support are less likely (and able) to teach AST as prescribed.

Figure 4.11 shows clearly the positive relationship between teacher feelings of support and their AI scores. It shows that in all AI categories, the more that teachers felt supported, the greater was their AI score.

Figure 4.13 Support Satisfaction vs AI Categories



The implication of this comparison is that support makes a big difference to a teacher's ability to teach AST properly. While in general teachers are well supported, added support will always be necessary for those who are newly switched into AST teaching as a result of the annual changes in teacher assignments

4.7 The Availability of Tools vs AI Scores

As part of the survey, teachers listed the tools which they had available to them for teaching the AST program. As previously noted, a Tool Availability Index (TAI) was assigned to each teacher according to the tools they report to have as follows: 4 = floor-mounted power tools; 3 = hand-held power tools; 2 = hand-held manual tools; 1 = equipment used in previous science programs

A positive correlation was found between the TAI and the AI score for all teachers ($r=.551$; $p=.00$). In other words, the more they have the tools available to them the better they deliver the AST program.

One-Way ANOVA tests can be used to test for significant differences among three or more samples as opposed to t-tests which compare the means of two samples only. In this study an ANOVA test confirmed that there are significant differences when the TAI – the type of tools available - is factored into the AI Score responses. In particular, there is a significant difference between the AI scores of those with floor-mounted tools and/or electric hand tools and those with only equipment from old courses. Though the One-Way ANOVA test showed that there are some significant differences between those with different TAIs, it doesn't specify which TAIs are different from which others. The ANOVA Tukey Post Hoc Multiple Comparisons test identifies those differences. The TAIs of 1 and 2 (old equipment or hand-held tools only) give significantly different AI scores from TAI of 4 (floor-mounted tools). This means that teachers who had either floor-mounted tools or hand-held electric tools available to them had significantly higher AI scores (p = .05) than those with only the equipment from the old courses. In my tenure as Director of Educational Services, the school boards received considerable funding from the MELS to upgrade the schools' labs and equip them with floor-mounted and/or hand-held electric tools so that they could teach the technology components of AST. The results of this teacher survey show that the availability of these tools makes a significant difference in their ability to teach AST.

4.8 Teachers' Open Comment Section

Teachers were invited to comment on any aspect of AST and 33 responded. Eight teachers who responded stated that they were very much in favour of the program and its approach while three said that they were not. One teacher gushed, "Students always enjoy my lesson because of varieties of activities included and especially when we start the workshop. They enjoy every single minute and they don't feel the time." Another teacher took the opposite stance, "I feel that it is totally inappropriate to include technology in the science program. While I do feel that it is very important to teach students manual skill such as woodworking, it should not be part of the science program."

The greatest area of concern, expressed by 11 teachers, was the technology aspect of the curriculum. Their concerns included not having the right tools or the training to use them, and not having the time to complete the technology-oriented activities. Three teachers, on the other hand, said that the technology aspect was a very positive part of AST. Five teachers bemoaned the fact that their workload had significantly increased now that they were teaching AST with the added time needed to prepare the new activities and the difficulty coming to grips with the changes required of them. As on teacher put it, "even a hard working teacher has difficulty finding the time to set up hands-on activities. They are labour intensive to set up and plan."

4.9 Summary of Findings – Teacher Survey

From a first look at the AI Index scores and the questions which constitute it, a picture begins to emerge of the AST classroom.

- <u>Real World</u>: Teachers make a big effort to contextualize their presentation of AST topics – to ground their teaching in the real world that their students experience, respecting their prior knowledge of it. They tend to begin new topics by first referring to real world applications and problems.
- <u>Constructivist Learning:</u> Teachers engage their students in active learning processes by doing a lot of hands-on activities and problem solving. They are however less likely to give control over the activities to their students. They prefer to give detailed instructions to the students, often from the textbook, rather than letting students control the problem solving processes themselves.
- <u>AST Curriculum Content</u>: Teachers are thorough in their "coverage" of the compulsory AST content. They concentrate their efforts, especially in Secondary 4, on the Technological World. Earth and Space, the area least

familiar to them and not part of the Secondary 3 AST curriculum, receives the least attention of the 4 Worlds. Most teachers have the new tools available to them but have not yet embarked to a large degree in their use. Use of tools contributes positively to the AST curriculum. Some teachers have difficulty incorporating the technology aspect of the program.

- Student Motivation: Students are overwhelmingly positive about doing hands-on application activities in AST. They enjoy discussing real life applications of science and technology and they prefer AST activities to those involving scientific theory. AST is a positive experience for them.
- Support for teachers: The support that teachers receive seems to be a very positive factor in their teaching practices. Teachers who receive the support that they feel they need are significantly more able to teach AST than those who are not adequately supported. This support comes in the form of professional development help from the school board consultant and MELS, textbooks and teacher guides, resources from LEARN, MELS and the QEP, other online resources, and collaboration with teacher colleagues.
- AI Scores by Category**:** There are 5 categories of AI scores which make up the overall AI score for each teacher – student attitude to AST, contextualization with the real world, AST curriculum content, constructivist pedagogy and use of tools. These category scores are significantly different from each other. This indicates that teachers may embrace certain aspects of AST in their teaching practices more than others. For example they tend to contextualize

their teaching in the real world more than they use constructivist pedagogical practices, as shown in 4.3.

- AI Scores by Date of Administration The teacher surveys were done twice, about a year apart – during the 2010-11 and 2011-12 school years. However, the scores from the 2 years were not significantly different.
- AI Scores by Gender: The gender of AST teachers doesn't seem to matter. Men and women have similar AST teaching practices. As shown in Figure 4.6, the AI scores per category of questions in the survey showed no significant difference between male and female teachers.
- AI Scores by Grade Level: In all categories Secondary 4 teachers had higher AI scores than Secondary 3 teachers. These differences were significant for the overall AI score as well as for the AST curriculum and Use of Tools categories.
- AI Scores by Years of Experience Teaching Science: Teachers with varying numbers of years of science teaching experience took the survey. There were no statistically significant differences among them in any of the AI categories.
- Reliability of the Teacher Survey Questions: After the study was completed, I subjected both the teacher and student surveys to a series of Alpha Cronbach tests and found a very high level of reliability. The Alpha Cronbach score for the 25 questions of the teacher survey was .890.

The teacher survey has provided an interesting first look at the implementation of AST across Quebec. This is only one part of the study. In subsequent chapters I will look at AST from different perspectives. In Chapter 5, I present the results of the student survey to get a better picture of how they see

AST. Then, in Chapter 6, I describe my visits to AST classes. I elaborate on their classroom practices, the classroom atmosphere, the gender differences, the AST activities and the relationships among, students and teachers. Finally, I complete the description of AST by summarizing the interviews I conducted with teachers, principals and consultants in Chapter 7.

Chapter 5: The Student Survey

What the students have to say about AST

Unlike the teacher survey which was offered to all AST teachers across the English public school system across Quebec, the student survey was taken only by students in selected classes. The students surveyed are therefore not a representative sample of Quebec students. They are only from classes I visited during the course of this research. The teachers of these classes were selected based on recommendations from their science consultants and their principals. In these classes the students do frequent, active hands-on AST activities.

The purpose of the student survey was to add to the data I collected visiting AST classes during the 2010-11 and 2011-12 school years. During these visits, which will be described in detail in Chapter 6, I observed the students in action and discussed their work and attitudes with them on an individual basis. The student survey gave me more information about their classroom and lab activities as well as their attitudes to AST. These data added further to my understanding of the implementation of AST.

I asked the teachers of these classes how best to administer the online survey and five of them offered to have their students take it during class time after I had completed my visits. In fact only 4 of them had their students do the survey. The survey consisted of the following sections:

- Information about the student: gender, school name, and their overall academic performance

- 25 question about their classroom activities and their motivation to learn science – responses on a 5-point Likert scale from “never or almost never” to “almost always”
- Questions about the textbook and their future in science education
- A comment section open for anything the participants wish to say (or not)

As I did with the teacher survey, I constructed the survey with categories of questions – this time only two: the nature of the activities they do in class and their feelings about AST and their motivation for learning science. There were 17 questions about the nature of the AST activities. They reflected the questions asked of the teachers. There were questions about the real world, the constructivist nature of their learning, the AST curriculum and their use of tools. There were 9 questions about their feelings and their motivation to learn science. What follows are some examples of these questions by category

1. I learn about applications of science and technology in the real world as part of classroom activities. (Real World)

4. We help the teacher plan what we are going to learn. (Constructivist Learning Environment)

8. In class we do activities in which we take apart, study, and/or (re)assemble technological objects. (AST Curriculum)

20. I enjoy working with tools while doing activities (Students’ Motivation Level)

22. I feel I am able to solve problems presented in AST. (Students’ Confidence Level)

The full survey questionnaire can be found in Appendix F. Like the teacher survey, it was hosted by Google® and used the Google Docs® survey instrument. Google® assigned a web address and I used the services of Bitly® to reduce its length to the more "friendly" web address, http://bit.ly/aststudent. Google Docs® stored the data and provided a user-friendly summary including graphs of the response frequencies as well.

I first analyze the student responses to find out what AST – specific activities they do in their classes and how motivated they are to learn science and technology in AST. Then I see if there are other factors which affect their responses to the survey – the class they're in, their overall academic performance, and their gender. I use extensive tables and graphs to describe the data and to help in the analysis.

5.1 Participants

In all, students from 6 different classes participated in the survey from three different schools. Despite repeated efforts on my part, I could not get any student participation in the survey from the 4th school. Classes #1 and # 2 were from one school - with 2 different teachers. Classes #3, #4, and #5 were all from another school - all three with the same teacher. Class #6 was from a third school. Its results will be counted in the analysis of student results, but will be excluded from all school-by-school analyses. The numbers of participating students are shown in Table 5.1.

Table 5.1 Participating Students

Class	Grade Level	School	Number of respondents
1	Sec 4	Howland HS	17
2	Sec 4	Howland HS	11
3	Sec 4	Trudeau HS	23
4	Sec 4	Trudeau HS	20
5	Sec 4	Trudeau HS	27
6	Sec 4	Maple HS	1
Total			99

5.2 Student Survey Category A– The Nature of the AST Classroom Activities

Each student was assigned an AI score corresponding to the mean of the responses for questions 1 to 17 – their description of their classroom activities.

Figure 5.1 Students' AI Scores – AST Activities

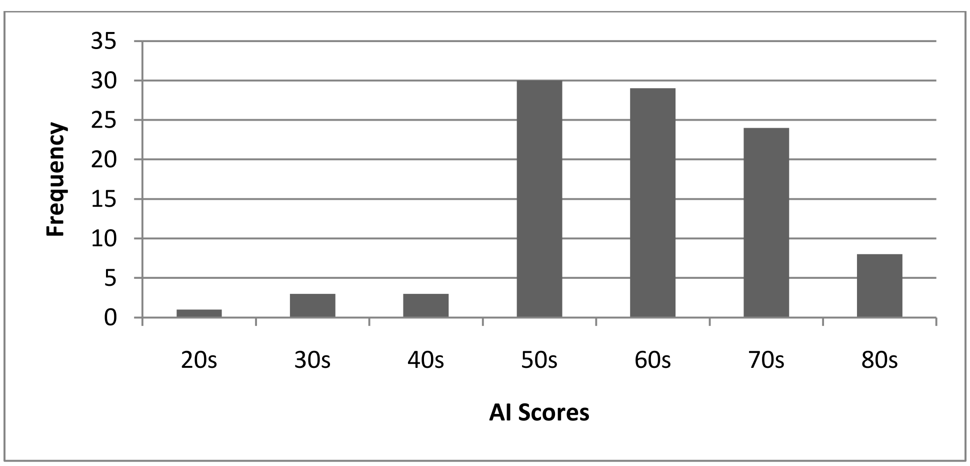


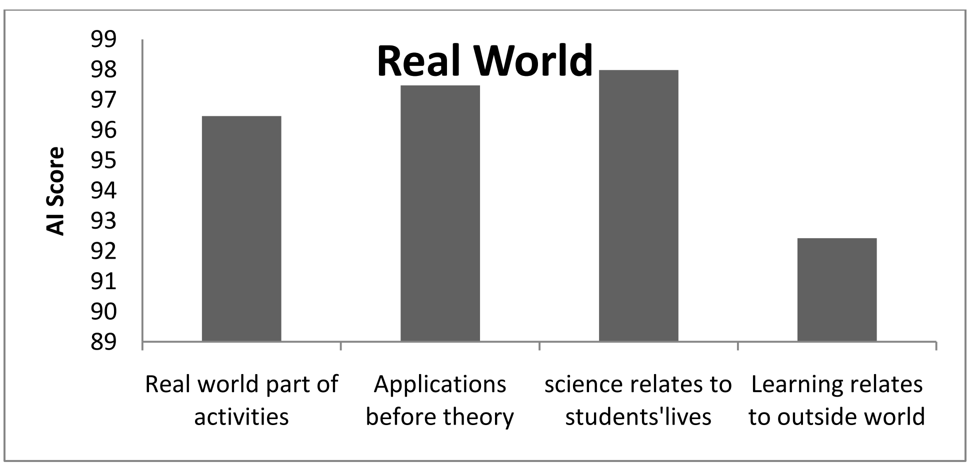
Figure 5.1 shows quite a positive picture of the AST activities. The mean AI score of 63.7 indicates that the average response was in the range of

"sometimes" to "often" on the 5-point Likert scale described in Chapter 3. A much clearer picture emerges with a closer examination of different groups of questions. In the following sections I show graphs of the breakdown of activities by category of question. I also interpret the graphs showing how they relate to the reality of the AST classroom.

5.2.1 Real World Questions

Questions 1, 2, 3 and 6 ask students to what extent the AST activities have to do with the world that they know. Figure 5.2 shows a very high level of AI scores. It shows that most students responded "always" to these questions. Their AST teachers make sure to link what they do in class to the reality of their students.

Figure 5.2 Real World Student AI Scores

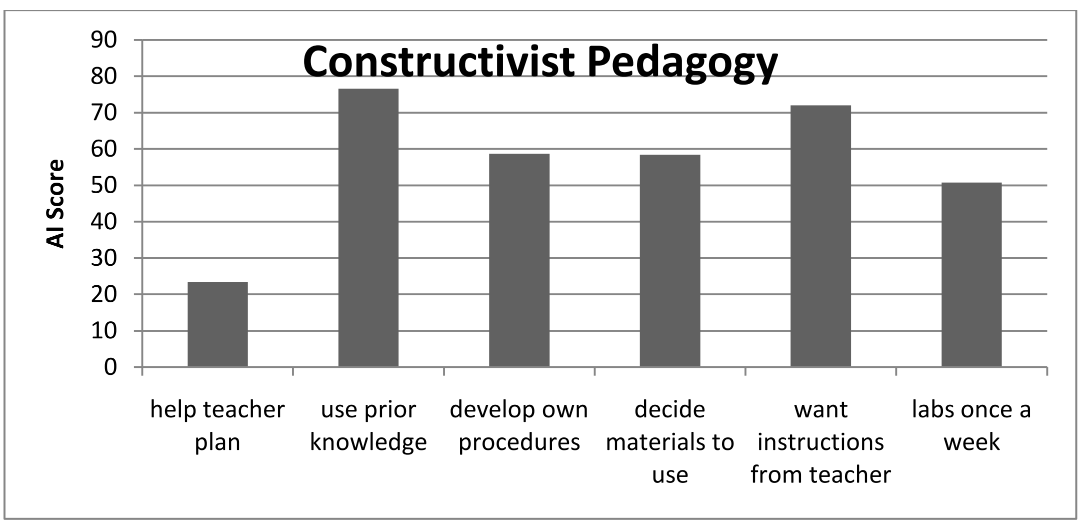


5.2.2 Constructivist Learning Environment

Students describe a learning environment which can be characterized as partly constructivist. As Figure 5.3 shows, they feel that their teacher regularly accesses their prior knowledge when introducing a subject. They report that they "sometimes" go to the lab at least once a week. From my observations of the demands of the AST curriculum, using the lab at least once a week can be difficult to organize. In fact when they are doing AST activities, they usually go to the lab for a number of periods in a row - up to 6 or 7 days. After that, they may not go back for a few weeks.

While they are doing or preparing activities, they say that their teacher "sometimes' to "often" has them develop their own procedures and decide on the materials to use. It is interesting to note that they say that they would "often" prefer that the teacher decide on the instructions for them. It seems that their teacher may want a constructivist environment more than they do!

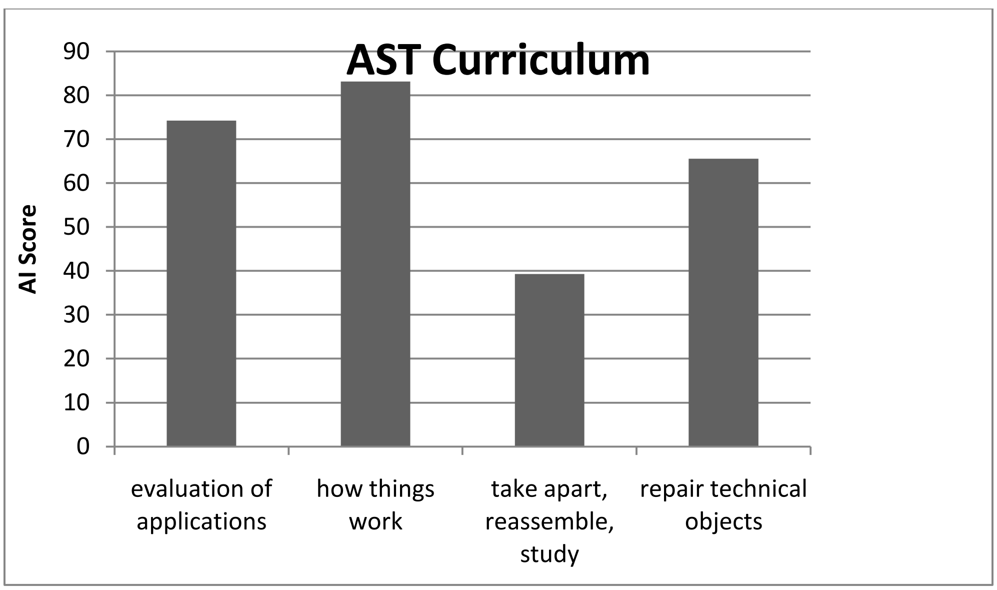
Figure 5.3 Constructivism Student AI Scores



5.2.3 AST Curriculum

Unlike the teacher survey, the students were not asked about the extent to which they studied the curriculum content – The Four Worlds. I felt that they would not be familiar with the terminology of the content areas enough to be able to identify which areas of the curriculum they were studying.   I did, however, still want to find out about students' experiences with AST-specific hands-on activities. They reported that they "often" investigate how things work. They "sometimes" to "often" repair technical objects, but only "seldom" to "sometimes" take apart, study and reassemble them (See Figure 5.4) This indicates a high level of AST-specific lab activity. In fact the technical objects they report working with are usually objects that they have designed and constructed themselves as part of their AST activities.

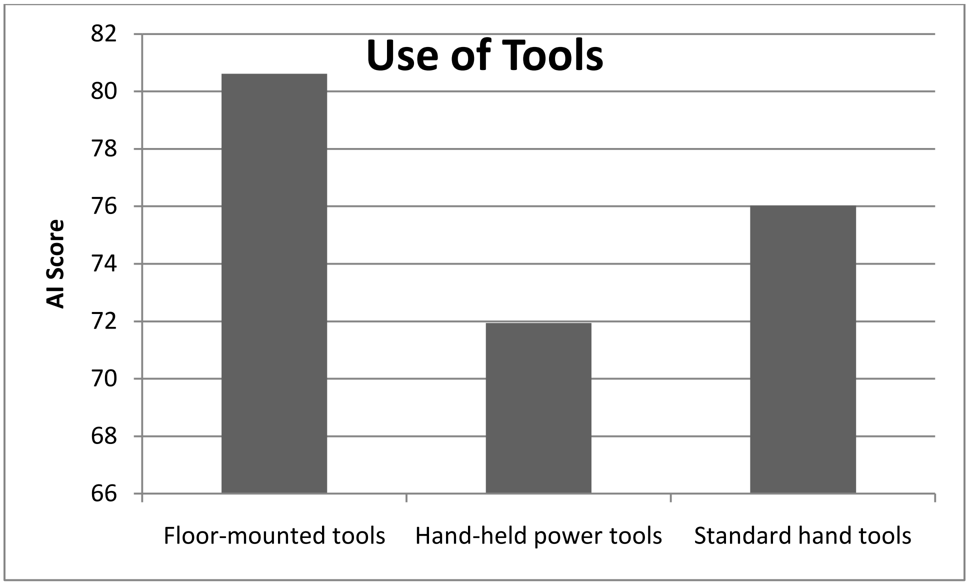
Figure 5.4 AST Curriculum Student AI Scores



5.2.4 Use of Tools in AST Activities

In the classes that I observed, tools are used very extensively in AST lab activities. This is a major distinguishing feature of the AST curriculum as opposed to ST. Students reported "often" to "always" when asked about their tool use when carrying out AST activities. The mean scores for Questions 12 to 14 are shown in Figure 5.5.

Figure 5.5 Use of Tools: Student AI Scores

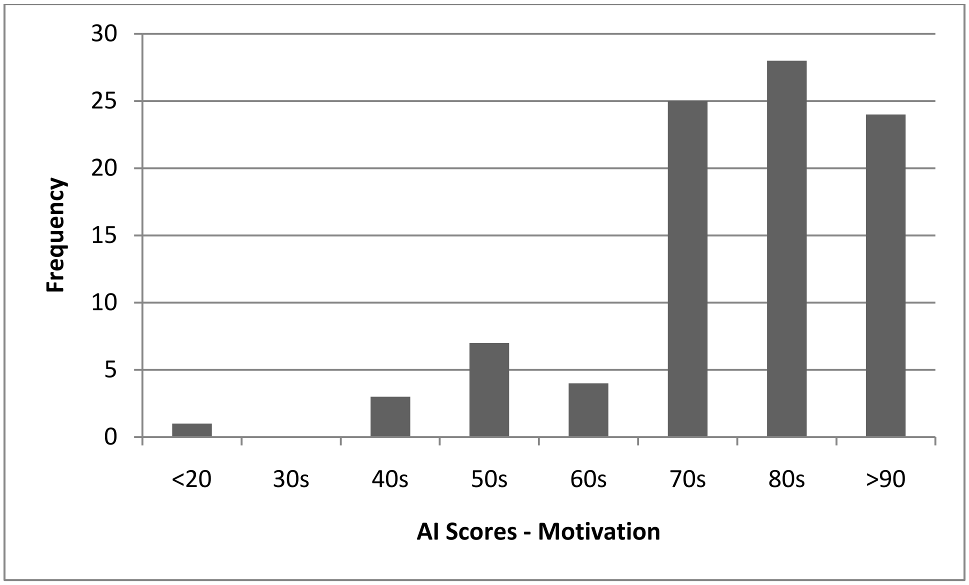


5.3 Category B – Students' Motivation and Confidence

5.3.1 Students' Motivation Level

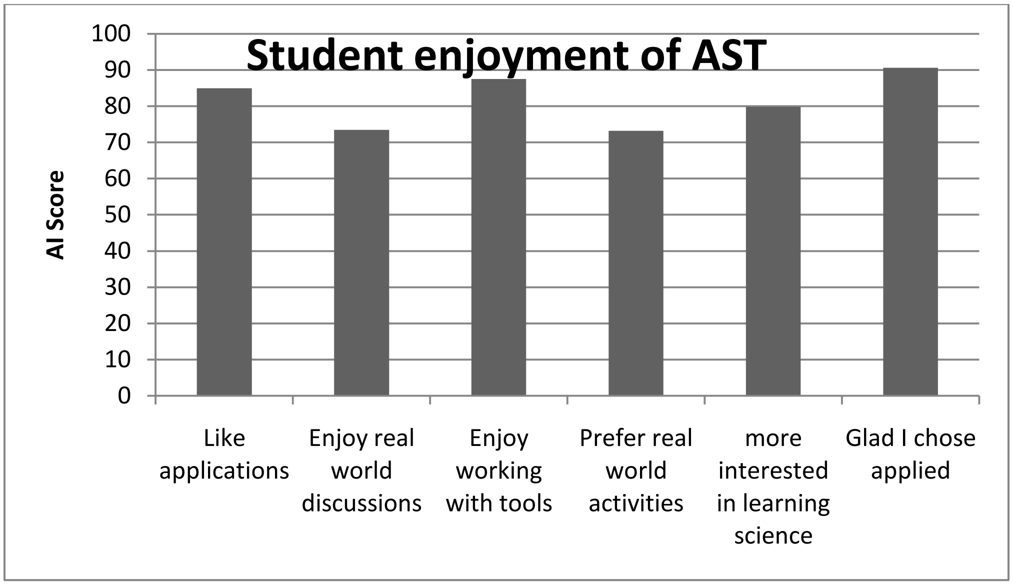
Each student was assigned an AI score corresponding to the mean of the responses for questions 18 to 24 and 26 – their description of their motivation to learn science and their feelings of their success in learning science. Figure 5.6 is a histogram of their responses (mean) $\mu = 79.2$ and (standard deviation) $\sigma = 14.3$. This mean corresponds to an average response of between "often" and "always".

Figure 5.6 Student Motivation to Learn AST



The motivation for learning AST is very high among these students. The mean AI score for motivation is 79.1 which indicates that most students responded “often” to “always” on questions regarding their motivation and confidence in AST. To better understand the aspects of student motivation I will break it into two sections: questions on what they like and enjoy about AST and questions about their feelings of success in the program. Figure 5.7 below shows that students report being “often” or “always” happy with their experience with AST. The vast majority of students (80.6%) say that they are “always” glad that they chose AST instead of ST. The very positive responses in the other questions show that they enjoy AST discussions; they like working with tools; they prefer AST activities to those involving scientific theory. They indicate that they now enjoy science more than they used to.

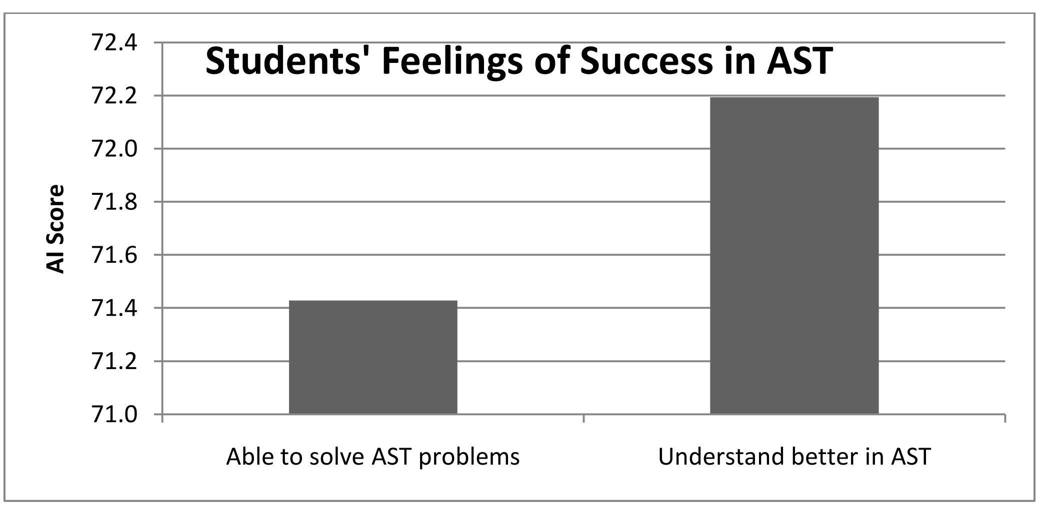
Figure 5.7 Student Enjoyment of AST



5.3.2 Students' Confidence Level

Questions 22 and 24 explore their feelings of success in AST. According to Figure 5.8, students express feelings of confidence in AST. They say that they are "often "able to solve problems in AST and that they "often" understand science more easily when learning it in AST.

Figure 5.8 AST Students' Feelings of Success



5.4 Gender Differences among Student Responses

Table 5.2 shows descriptive statistics of the scores for boys and girls.

Table 5.2 AST and Motivation AI Scores by Gender

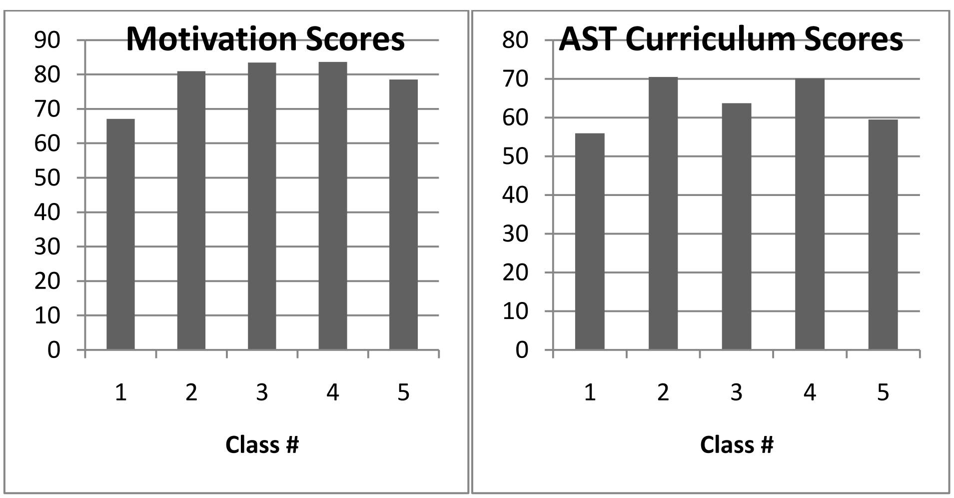
		Number	Mean score	Std. Deviation
AST score	Boys	55	61.6	13.2
	Girls	43	65.8	10.3
Motivation	Boys	55	77.5	15.3
	Girls	43	81.3	12.8

Overall, there was no significant difference between the AI scores of the boys and the girls on the overall AST and Motivation scores as determined by Independent sample t-tests and one-way ANOVA. There was similarly no significant difference between the responses of boys and girls when all questions in the Motivation category were examined. Four questions in the AST category showed girls responding significantly higher than boys. Two of these questions concerned students' perceptions of how frequently the real world was discussed in class. Another was about the frequency of doing evaluations on applications and the fourth concerned the frequency of doing activities in which students investigate how things work.

5.5 Class Differences among Student Responses

This section addresses the question of whether or not the class that the students are in makes a difference in how they respond to the questionnaire. One class had only one respondent, so it will not be considered in this section. Using a one-way ANOVA test I compared the means of both the Motivation and AST Curriculum scores among the 5 classes under consideration. Recall that the AST Curriculum score refers to the AI score for all questions on the student survey that had to do with the AST curriculum (activities, tool use, pedagogy, real world). This showed no significant differences in the means among the classes. Figure 5.9 shows the class-by-class scores for both categories of student questions. The motivation scores showed that most students were highly motivated by their AST classes. Most responses ranged from “often” to “always” on the motivation questions for the five classes surveyed. Similarly, as shown in Figure 5.9, the scores for the curriculum questions were not significantly different across the classes, although the responses were lower - in the “sometimes” to “often” range.

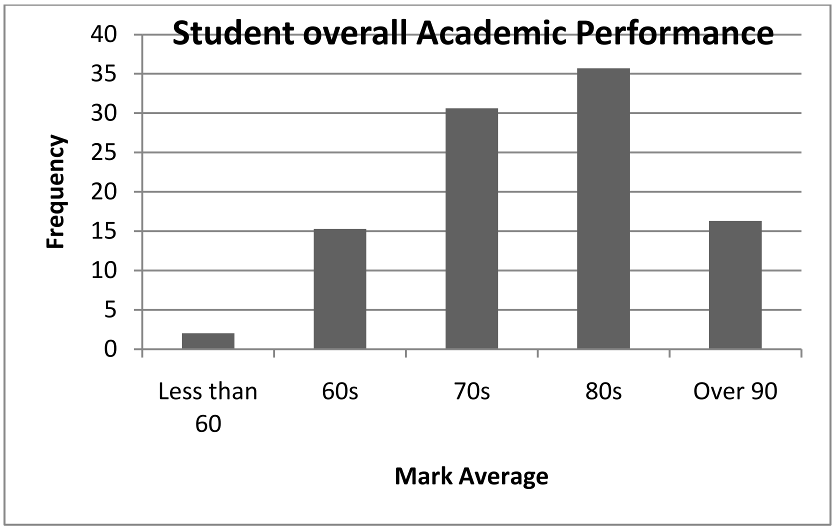
Figure 5.9 Student Motivation and AST Scores by Class



5.6 Student Responses by Overall Academic Level

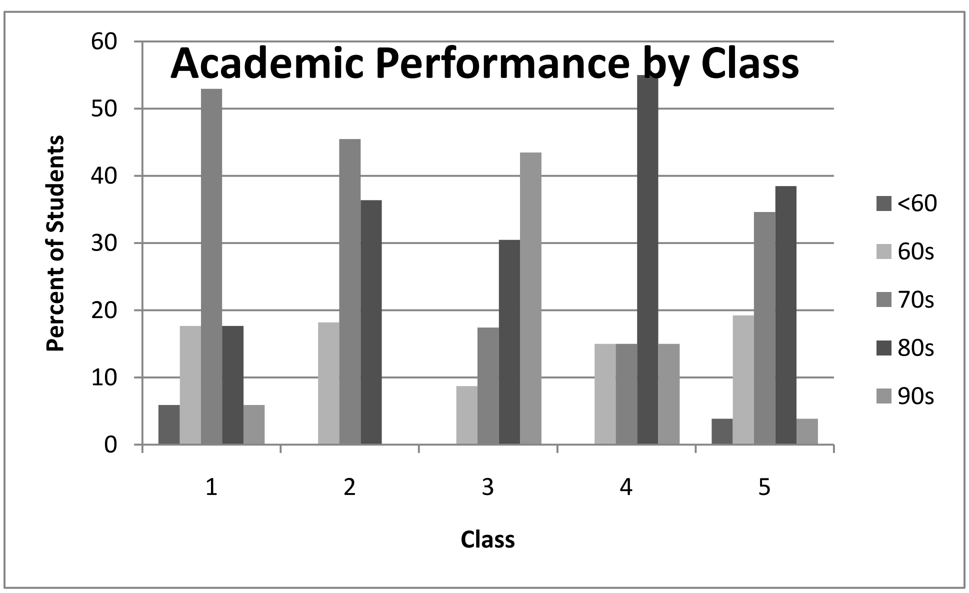
On the survey, students reported their overall academic average from their previous June final reports. They reported their overall report card average as being “less than 60”, “in the 60s”’ “in the 70s”, “in the 80s”, or “over 90”. Figure 5.10 shows the results they reported. For classes 1 and 2, the results are from June 2010. Classes 3, 4 and 5 are from June 2011.

Figure 5.10 Academic Performance – Students in all Five Classes



The profile of the overall academic background of the students by class is illustrated in Figure 5.11.

Figure 5.11 Academic Performance by Class Section



A one way ANOVA test comparing the means of student academic performance by class section showed significant differences between classes 1 and 3 ($p = .004$) and between classes 3 and 5 ($p = .010$) . This is illustrated in Figure 5.11 above. The graph of the results of class #3 shows a large number of students skewed in the over 90 category, whereas class #1 results are more normally distributed around a mean in the 70s. Classes #2 and #5 have most students concentrated in the 70s and 80s and class #4 in the 80s.

From Figure 5.11, it can be seen that the performance profile of Class #3 is higher than the others. This could be a reflection of the student selection for that class. In fact, many of the students in Class #3 are also taking Science of the Environment, the advanced course required to qualify students for Chemistry and Physics in Secondary 5. Therefore Class #3 tends to have students with higher overall academic averages than the other classes.

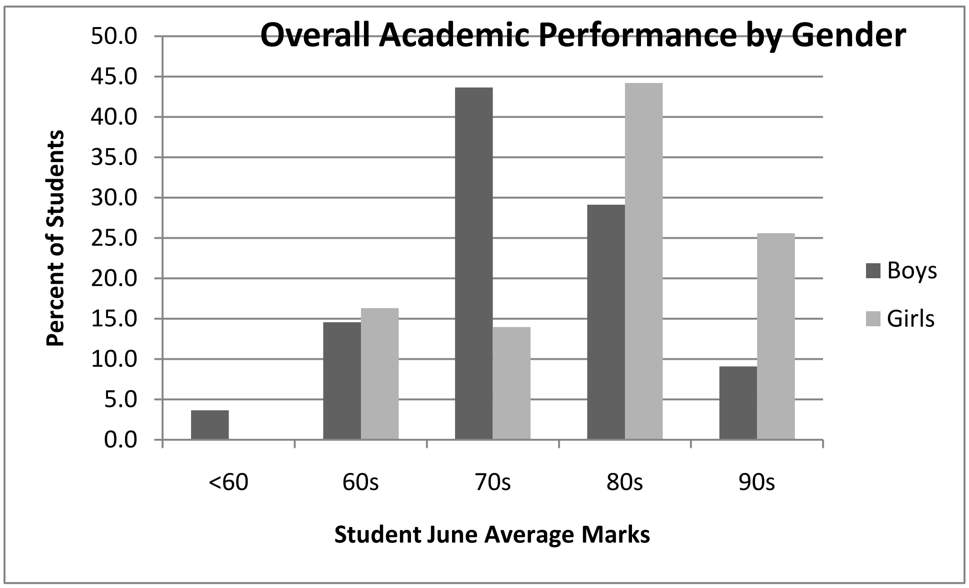
An analysis of Pearson r correlations showed that there is a small (**r** = .248; $p = .014$) but significant correlation between the overall academic performance identified by students from their previous year's overall final average and their AST score on the AST curriculum-related questions. Similarly, there is a small ($r = .204$; $p = .044$) but significant correlation between the overall academic performance and students' motivation and confidence levels in AST.

In other words, the better students perform academically in general, the more they tend to be motivated to learn AST and have confidence that they can succeed in it.

5.7 Gender and Overall Academic Performance

Figure 5.12 shows that, among the students who responded to the survey, female students report significantly higher overall academic performances than males.

Figure 5.12 General Academic Performance by Gender



Comparing the means using a t-test shows that the differences between boys' and girls' reported overall academic averages are significant, $t(96) = -2.697$, $p=.008$. In other words the girls in AST tend to have higher overall academic averages than the boys. This of course does not mean that the girls do better in these AST classes than the boys. It only means that the girls came into the Secondary 4 AST classes with higher overall academic averages from the previous year than the boys.

5.8 Summary of Findings – Student Survey

AST Curriculum: Students reported that in their classes there is a strong link established between their AST program and the real world that they are familiar with. This is consciously done by their teacher. In terms of a constructivist learning environment, students report that their teachers tend to access their prior knowledge about a given topic. They learn actively through a lot of hands-on activities as well. Teachers give them some independence as to the procedures to follow and the materials to use in their activities, but it's the teachers who almost always plan the activities. Interestingly it's the students' preference to have the plans laid out for them by their teacher.

Tools: According to the student survey responses, students use tools in their hands-on activities a lot. They use floor-mounted tools very regularly. This includes band saws, drill presses, mitre saws, and sanders. They use regular non-power tools such as hammers, hand saws, chisels and screw drivers frequently as well. They use electric hand tools (drill, glue gun, jig saw, etc.) as well but less frequently.

AST-specific activities: AST-specific activities seem to be well-embedded into the curriculum. Evaluating, repairing and finding out how technical objects work are reported as being done quite frequently. Taking the objects apart is less frequent, but still part of the process of working with technical objects.

Student Enthusiasm and Confidence: This is an area where students gave very positive responses. They say that they enjoy AST activities and prefer them to theoretical discussions. They enjoy working with tools and doing real world applications. Almost all students report that they are very happy that they chose AST rather than the general program.

Gender and class section differences: There was no significant difference between the responses of boys and girls in their motivation to learn AST or their feeling of success. Similarly the class section the students were in didn't make a significant difference in the overall AST scores or the motivation levels. However the girls in the classes surveyed reported significantly higher past overall academic performance than the boys.

Academic differences: Overall academic performance is positively correlated to motivation to learn AST as well as feelings of success in AST. Results indicate that the higher their past academic performance (as self-reported in the survey), the more motivated they are to learn AST and the more confident they are in their ability to succeed in AST.

Reliability of the Student survey questions: After the study was completed, I subjected the student surveys to a series of Alpha Cronbach tests and found a very high level of reliability. The Alpha Cronbach score for the 25 questions of the student survey was .81. If the question categories and student factors were included, the score rose to .83. Similarly for the student survey, the scores were .805 and .829 respectively. Both are considered to be high degrees of reliability.

The students from some of the classes I visited in this study told me clearly about what they do and how they feel about their AST experience. This student survey reveals a small but important part of the overall picture of the implementation of AST. It gave them a voice and they expressed themselves with clarity. In the next chapter I describe their classes in action. They showed me how they carry out AST activities, how they relate to each other and their teachers, and how they learn through the applications of science and technology.

Chapter 6: Applied Science and Technology in Action: The View from the Classroom

The following vignette describes an activity in Sally's Secondary 4 AST class at Howland HS. It is presented here to give the reader an introductory insight into the functioning of an AST learning activity- one which incorporates science and technology using a constructivist, inquiry-based pedagogy. It shows how she set the scene for her students and interacted with them as they worked their way through it.

Vignette #1 – The Constant Velocity Car

> "The company calls this a constant velocity vehicle", said Sally as she held up a small toy car for the class to see. "I want you to find out if this is honest advertising." After questioning their understand of speed of an object in motion and how to calculate it, Sally pointed to a table with meter sticks, stop watches, masking tape and toy cars. She challenged them to figure out a way of not only measuring the speed of the car, but also finding out of the speed is constant over a certain distance. Soon, in groups of two or three, they were in the school hallway measuring set distances for their cars to travel and marking different lengths with masking tape. In hushed tones they were discussing and arguing with each other, conscious of not disturbing the other classes. "How can we get it to go straight?" "Will the battery hold up?" "How far should the car go?" "How do we calculate the speed?" "How do we make sure it's constant?" were some of the questions overheard among the animated conversations going on.
>
> For the remainder of this 50-minute class and throughout the full period next day, students measured distances, timed their trials and calculated speeds. They ran back and forth from group to group comparing their methods with the others and asked Sally how to deal with obstacles as they arose. "That's cool how you're testing for speed using a 2-metre track. How are you going to record the time for the different distances?" she asked two girls. The mood of the groups varied from excitement to frustration to satisfaction and pride as they progressed through this activity. With Sally's guidance and a collective sharing of understanding among the students, they all came up with some form of conclusion about the honesty of the company's claim.

Photo: The Constant Velocity Car

As a two-day AST activity, Sally used it to reinforce and give personal meaning to the calculation of constant velocity. She gave them control over the procedure, all the while keeping a close on them to nudge them in the right direction when frustration set in or when she saw them going in an unproductive direction. All 21 students were thoroughly engrossed in it. It had just the right amount of challenge and hands-on action. In this chapter, I describe in detail many of the AST activities, like Sally's, that I observed in schools of Quebec.

What follows is an ethnographic report of field studies that I have conducted in two schools in Montreal, one suburban school on the South Shore outside Montreal, and one rural school north of Montreal. I followed the methodology advocated by Emerson et.al. (1995). Using the methodology I described in Chapter 3, I observed classes as they went about their regular activities. During the classes I talked to students, teachers and technicians, photographed their work and took copious notes about what I saw and heard. I describe and analyze the classroom activities in a total of nine classes of Secondary 3 and 4 Applied Science and Technology (AST) at the four high schools. I report on my observations under the following broad themes as they are linked to my research questions.

6.1 Research Questions:

1. What teaching practices, specific to AST, do teachers use in the classroom and lab? What activities do teachers use to differentiate between AST and ST? What tools, scientific equipment and consumable materials are being used specifically for AST?

Related themes:

- Use of constructivist teaching methodology (Bybee, 2002; Tobin, 1993; von Glasersfeld, et al., 2007; Yager, 1991)
- Use of AST-curriculum-specific activities and content (MEQ, 2007)
- Use of tools materials and equipment for AST activities

2. What are the outcomes of the AST program on student motivation to learn science? To what extent are students positively engaged in the learning of science in AST?

Related themes:

- Student engagement, motivation, behavior and interest
- Teacher's role in fostering student learning and motivation

I begin the chapter by describing the participants, their school settings and the activities I observed during the school visits. I present detailed descriptions of selected activities and relate them to a theme that I am focusing on at that time. The themes are

- The AST Curriculum
- Constructivism and Inquiry-Based Pedagogy
- Student Motivation and Engagement

Finally I summarize my findings under these themes.

6.2 Background to the Visits

On resuming my doctoral studies in winter 2010, I decided to study the implementation of AST in Quebec schools using a variety of analytical tools. As reported in Chapter 4, I first constructed an online survey of teacher practices in AST and invited all AST teachers in public English high schools in Quebec to participate. This survey gave me a picture of implementation of AST from the teachers' points of view. I also asked science consultants from three school boards to recommend teachers who might be willing to have me observe their AST classes during the 2010-11 and 11-12 school years. As a result I selected three teachers from Howland HS[3] and one teacher from Lake HS high schools for the first year. In 2011-12, two other teachers were selected – one from Maple HS south of Montreal and one from Trudeau HS north of Montreal. Students from the classes being observed were also invited to participate in an online student survey. The results of this survey, reported on in Chapter 5, helped me to enlarge my picture of the AST activities they did and their motivation to learn. An even

[3] The names of the high schools and all the teachers have been changed to protect their confidentiality.

more complete picture of the implementation of AST emerges from interviews I have conducted with the principals and teachers of the participating schools. I report on them in Chapter 7.

I conducted the classroom visits between December 1, 2010 and May 2011 in the two Montreal schools, Howland and Lake High Schools, and from October 2011 to December 2012 in Trudeau and Maple High Schools. In all I observed 44 classes for a total of 43.75 hours[4] (70 hours if time spent with the teachers and students before and after the classes is included). I also attended one school science fair and one field trip to a Quebec hydro dam and production facility. The fact that these various activities were done in nine different classes by six different teachers in four different schools allowed for comparisons of different approaches and different students. The complete list of the activities I observed can be found in Appendix H.

[4] Classes at Howland HS lasted 50 minutes while those at the other schools were 75 minutes long.

Table 6.1 and Table 6.2 summarize the teachers and students I visited.

Table 6.1 Number of Students

Teacher	No Students	Boys	Girls
Sally	25	19	6
Lianne	19	15	4
Trudy AST	18	13	5
Trudy EST	23	8	15
Celina Sec 4	35	19	16
Celina Sec 3	31	22	9
Madeline	25	16	9
Michael class #1	25	11	14
Michael class #2	25	9	16
Total Students	226	132	94
Total AST Students	203	124	79
Percent AST		61.1%	38.9%

Table 6.2 Teacher Participants

Name	Gender	School	Board Type	Years Teaching Science	Education
Sally	Female	Howland HS	Urban/Suburban Montreal Island	10 years	B.ed. – early childhood
Trudy	Female	Howland HS	Urban/Suburban Montreal Island	21 years – 13 in NB	B.Sc Biology and Chemistry and B.Ed
Lianne	Female	Howland HS	Urban/Suburban Montreal Island	8 years	BSc. Microbiology and B.Ed
Celina	Female	Lake HS	Urban/Suburban Montreal Island	7 years	B.Ed Sciences
Madeline	Female	Maple HS	Suburban Off-Island	6 years	B.Ed. English and Physical Geography
Michael	Male	Trudeau HS	Rural Off-Island	18 years	BSc and MSc Genetics, Environmental Biology

6.3 Theoretical Framework for the Classroom Observations

As described in Chapter 2, the study of the implementation of AST is based on three major conceptual themes: The AST curriculum, the pedagogy of constructivism/inquiry-based learning, and student motivation and engagement. I first explain what I mean by these three themes. Then I describe the visits to the AST classes in terms of these themes as they emerged during the observations. Each of the selected activities is revisited three times, once for each theme. In order to answer the research questions, I feel that it is important to focus on how each activity fits into the main themes of this study. I also illustrate my visits using vignettes of classroom activities with photographs of activities, and observations of behaviors and interactions.

6.4 Analytical Framework: The Three Conceptual Themes

1. The AST Curriculum: The aspects of AST which I have closely observed include the following. They are related to my research questions and related themes as described above.

- The AST content of the QEP – the 4 Worlds (Living, Material, Earth & Space, and Technological) –as they are related to the activity being observed.
- The Progression of Learning and the Compulsory Concepts for the first and second year of Cycle 2.(MELS, 2007, 2011b)
- The tools and materials being used for the activities.
- The use of the textbook and Teachers' guides as well as Learning and Evaluation Situations (LESs)[5] from other sources.

2. Constructivist / Inquiry-based Pedagogy: An ideal constructivist learning environment is characterized by the following learning situations. I have based my analysis of the constructivist nature of activities on my observations of these aspects as follows:

- Active learning: Students do activities in which they manipulate materials using tools and other equipment to solve a scientific or technological problem.

[5] An LES is a problem-solving situation in which students integrate different concepts and content knowledge in order to solve a real-world problem related to the curriculum topics being covered.

- Student control of their learning: When presented with a problem, students decide what procedures, materials and tools to use to solve it.
- Construction of their own understanding built on their prior knowledge: Building on what they already know students decide what they have learned from the results of an activity.

3. Student Motivation and Engagement:

- The state of “Flow” among students engaged in AST activities – to what extent students are intrinsically motivated to carry out AST activities.(Czikszentmihalyi & Nakamura, 2005; Pink, 2011) . See Chapter 2 for a discussion of constructivism and student motivation.
- How students interact with each other and their teacher.
- The level of student on-task vs disruptive behavior.
- Teacher motivational practices

6.5 Themes and Activities

In this section, the main body of this chapter, I trace these themes through selected activities, schools and teachers in four steps as follows:

- I give a brief description of seven selected activities I observed.
- I show how the teachers use the activities – projects, LESs and lessons to fulfill the requirements of the AST curriculum.
- I analyze the Constructivist / Inquiry-based nature of the pedagogy used by the AST teachers.

- I examine activities through the lens of student motivation and engagement.

6.5.1 The Activities

<u>Activity 1: The Toy Project</u>

School	Howland HS
Teachers	Sally, Trudy, Lianne
Number of Students	Classes of 25, 18, and 19 respectively
Duration of project	7 classes x 45 minutes each class

Students were given the following situation**: "**You have decided to make a toy for your nephew for Christmas. You want to create a pull toy that will have a light that blinks when he pulls the toy. You also want to have a driver whose head will bob up and down as the wheels turn." Over six days students designed the toy and built it in the tech lab in groups of two or three. On the last day they tested the toy as a presentation to the class. This project was done by the three different teachers at Howland HS with their respective Secondary 4 AST classes. See Vignette #2 for a full description.

<u>Activity 2 Force of Friction</u>

School	Howland HS
Teachers	Sally, Trudy, Lianne
The Classes	Secondary 4 classes of 25, 18, and 19 respectively
Duration of project	2 classes x 45 minutes each class

The same three teachers had their AST students study the factors which affect the force of friction. The lab involved pulling a wooden block along a surface and measuring the force required to move the block. The block was pulled along the surface by a string attached to a mass which was suspended down the side of the table using a pulley as shown in the photograph. They tested different surfaces and different weights. This was not an LES, but a traditional science exercise to familiarize the students with the phenomenon of frictional force.

Photo: Friction Lab

Activity 3 The Lung Capacity Machine

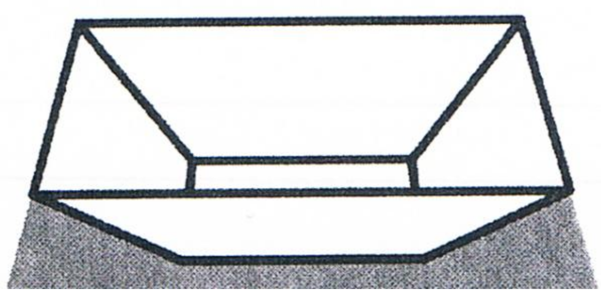
School	Lake HS
Teachers	Celina
The Class	35 students, Secondary 3
Duration of project	3 classes x 75 minutes each class

This was a three-day LES for Celina's Secondary 3 AST at Lake HS relating the Technological World to the topic of the human body. Students designed and constructed a device to measure lung capacity. They used it to measure their own capacity and compare it to the result they recorded using a commercial device.

Activity 4 The Solar Furnace

School	Lake HS
Teachers	Celina
The Class	31 students, Secondary 4
Duration of project	3 classes x 75 minutes each class

Celina's Secondary 4 AST students constructed a solar furnace and used it to heat water outdoors on a sunny day. Students spent two 75-minute periods designing and building it using the sketch shown here. They later tested it outdoors on a sunny day measuring the temperature increase over a 15-minute period and comparing this to a control sample not in the furnace.



Activity 5 The Anemometer

School	Lake HS
Teachers	Celina
The Class	35 students, Secondary 4
Duration of project	6 classes x 75 minutes each class

This was a six-day LES at Lake HS in which Secondary 4 students designed and constructed an anemometer – a device to measure wind speed. It called for the use of gears, pulleys, Popsicle-type sticks and home-made "wings" made from used plastic containers. Students created their own designs using the equipment provided. They tested its operation with a hair dryer – to simulate the wind. The diagram shows a student's anemometer under construction.

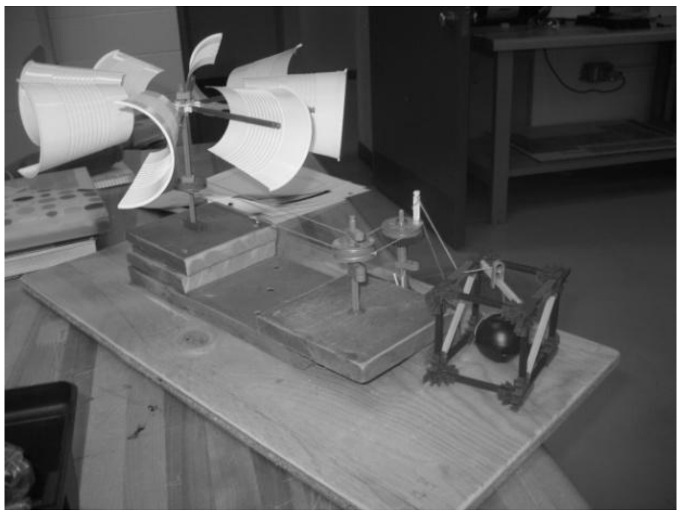


Photo: Anemometer under construction

Activity 6 The Bridge

School	Maple HS
Teachers	Madeline
The Class	25 students, Secondary 4
Duration of project	7 classes x 75 minutes each class

As part of their study of the Material World and The Technological World at Maple HS, Madeline's Secondary 4 students designed and built a concrete bridge which would have the ability to span a distance of 50 cm and be able to support as many bricks as possible without collapsing. See vignette #5 for a full description.

<u>Activity 7 The Hydraulic Arm</u>

School	Trudeau HS
Teachers	Michael
The Class	2 classes of 25 students, Secondary 4
Duration of project	5 classes x 75 minutes each class

Michael had his AST students do an LES in which they constructed a model of a hydraulic arm whose purpose was to scoop up a quantity of “kitty litter” and transfer it from one container to another – to simulate a steam shovel moving earth at a construction site. It was to be based on a design and physical model which he displayed in the front of the class. See Vignette #2 for a full description.

6.5.2 Theme: The AST Curriculum

In this section I begin by providing the reader with a brief review of the AST curriculum. I then describe in detail how the teachers followed the curriculum and used tools in the AST activities that I observed. As part of my study on the implementation of AST, I posed these curriculum-related research questions:

- How is AST being taught in Quebec schools?
- What teaching practices and activities, specific to AST, do teachers use in the classroom and lab?
- What tools and scientific equipment are being used for AST?

As I observed the classroom activities in action, I paid particular attention to how they were related to the AST curriculum as described in the Quebec Education Program and the Progression of Learning and supported by the textbook(Cyr, Forget, & Verreault, 2009; MELS, 2007, 2011b). I also observed how the students, guided by teachers and technicians, used tools and scientific equipment.

The Competencies: As described in Chapter 2, the AST program is competency-based. Students develop the same three competencies in all their Science and Technology courses throughout high school (MELS, 2007).

Competency 1: Seeks answers or solutions to scientific or technological problems.

Competency 2: Makes the most of his/her knowledge of science and technology.

Competency 3: Communicates in the languages used in science and technology.

The development of Competency 1 was the main purpose of all the AST activities I observed. In Competency 1 students solve problems involving scientific experiments, engineering design and repair of technical objects. However, while solving scientific and technological problems, students also develop Competencies 2 and 3. They construct their understanding of the related scientific phenomena and exchange information and communicate their scientific and technological findings.

AST Content: Chapter 2 explains the structure of the AST content. It is divided into Four Worlds: The Material World, The Living World, Earth and Space, and The Technological World. The Technological World receives a much greater emphasis in AST than in ST (MELS, 2007). In fact while working with the other three Worlds, teachers emphasize the technological applications of the topics being studied.

Tool Use: The introduction of the use of tools was a major change in the Science and Technology curricula of the QEP. In the past, tool use, especially floor mounted tools, had been the purview of Introduction to Technology (ITT), compulsory in Secondary 3, and Woodworking, an option for Secondary 4 and 5 students in some schools (MEQ, 1993). In anticipation of the implementation of the QEP, schools and boards had to either install new tools or update existing ones and make sure that they had the safety aspects of their labs in conformity with current regulations. As Director of Educational Services, I oversaw the preparation of science and technology labs in the schools of the school board. Teachers and technicians had to be trained in the use of the tools for use in the science programs as well. With its emphasis on hands-on activities and technology, the teaching of AST required an expertise and comfort with the use of tools.

6.5.2.1 AST Curriculum and Tool Use in the Observed Classroom Activities

In this section I briefly describe AST curriculum aspects on an activity-by-activity basis. I describe content emphasis of each projects and use of tools and other materials.

Activity 1 The Toy Project:

Teachers	Sally, Lianne and Trudy – Howland HS
AST Curriculum	Design and construction: Technological World: motion, energy transformation
Tool Use	Floor-mounted tools, hand-held tools

This project focused on the Technological World and, in particular, technical diagrams of the operation of the toy with the different types of motion (MELS, 2011b, p. 31) construction of motion transmission systems (MELS, 2011b, p. 34) and energy transformations (motion to light) (MELS, 2011b, p. 35)

Students were at ease with the use of all tools. The teachers and lab tech kept a close eye on the safe use of floor-mounted tools and occasionally guided students in their use. The drill press had the most use among the floor-mounted tools, followed by the belt sander and the band saw. Some used a hand held electric drill as well. Everyone used a glue gun, utility knife, scissors, screwdriver and pliers at some point. Tool use was a natural part of their activity.

Activity 2 Force of Friction

Teachers	Sally and Lianne – Howland HS
AST Curriculum	Science investigation: Material World: force of friction
Tool Use	Measuring instruments only

This project focused on force and motion in the Material World – in particular, the effects produced by a force and different types of force (MELS, 2011b, p. 15). In the Technological World the emphasis is on Mechanical Engineering – adhesion and friction (MELS, 2011b, p. 33). Tools, other than traditional measuring instruments, were not used in this activity.

Activity 3 The Lung Capacity Machine

Teacher	Celina – Lake HS
AST Curriculum	Design and construction: Secondary 3 Living World: Human body – respiratory system
Tool Use	Hand-held tools only

This was an example of a Secondary 3 application of science and technology under the theme of the Human Body. It was a technological application of the respiratory system in the Living World as well as Archimedes' Principle - measurement of volume (MELS, 2011b, pp. 6, 13, 20). The construction involved manipulation of materials, diagnosis and repair of technological objects. Students used hand-held tools for this project, namely utility knife, clamps, scissors and measuring tape.

Activity 4 The Solar Furnace

Teacher	Celina – Lake HS
AST Curriculum	Design and construction: The Technological World –energy, technological application
Tool Use	Hand-held only: glue gun, utility knife, paint brush, scissors measuring tape, ruler

This was an example of an application of science and technology under the theme of energy. It was presented in the Observatory Teachers' Guide A as an LES for Competency 1 – Seeks answers or solutions to scientific or technological problems (Cyr, et al., 2009; MELS, 2007). The construction involved design of the object, the manipulation of materials using light hand-held tools as well as adaptations of the object to carry out the task of heating water.

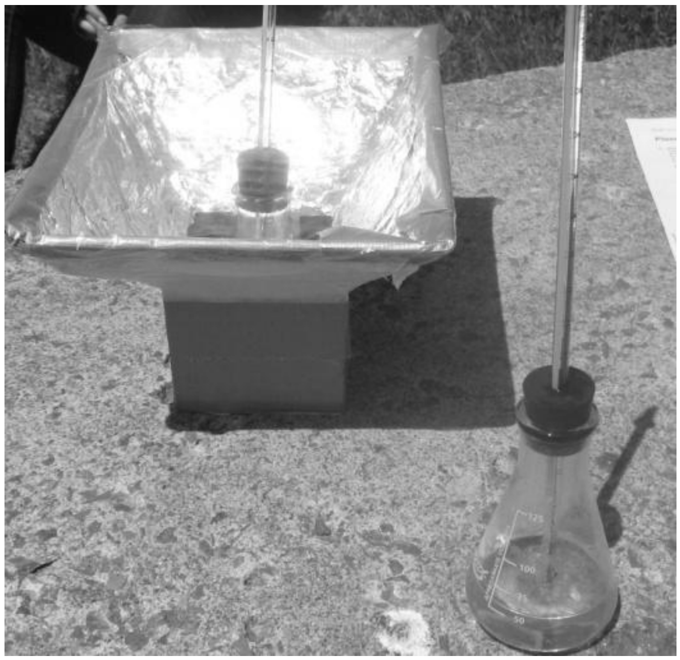


Photo: The Solar Furnace

<u>Activity 5 The Anemometer</u>

Teacher	Celina – Lake HS
AST Curriculum	Design and construction: The Technological World: technical diagrams, construction of technical objects, motion transformations
Tool Use	Floor-mounted and hand-held: Band saw, belt sander, drill press, glue gun, drill, utility knife, clamps, scissors, hammer, hand saw, mitre boxes, screw driver, measuring tape, ruler, hand sander

The Secondary 4 AST Progression of Learning in The Technological World (MELS, 2011b) states that “In Secondary IV, they continue constructing their scientific and technological knowledge and examine the influence of technology on the world around us” (p. 30). In particular, it specifies that a student “Chooses the appropriate type of diagram for a given representation” (p. 31) and undertakes the “Construction and characteristics of motion transformation systems.” (p. 34). In Cycle 1 students had learned about technological systems and energy transformation. In Secondary 3 and 4 they extend this to learning about linking different parts of a technical object and making motion transformation systems work.

Students used the full range of tools available in their “tech heavy” lab. They frequently went to the band saw, sander and drill press to build and modify their structures to support their anemometers. Students were very comfortable with the use of these tools and worked with them under the close supervision of either the lab technician or the teacher. As supervisors of the tool use they watched to make sure that the students wore their safety glasses, and operated the tools properly and safely. They regularly reminded the students of the safety rules.

Activity 6 The Bridge

Teacher	Madeline – Maple HS
AST Curriculum	Design and construction: Engineering project: Technological World and Material World
Tool Use	Floor-mounted and hand-held: Band saw, mitre saw, sander, glue gun, drill, utility knife, pliers, scissors, hammer, square, hand saw, mitre box

This activity was a Technological World Competency 1 problem where the student "Seeks answers or solutions to scientific or technological problems" (MELS, 2007, p. 13). It was an engineering project in which students had to take into account the properties and constraints of materials (MELS, 2011b, p. 35).

Tool use was an important part of the activity. Students needed the heavy tools for the construction of their concrete forms and many non-power tools for the continual manipulations involved in the construction.

Activity 7 The Hydraulic Arm

Teacher	Michael – Trudeau HS
AST Curriculum	The Technological World: Mechanical engineering, motion transformation systems, Pascal's Principle
Tool Use	Floor-mounted and hand-held: Band saw, mitre saw, sander, glue gun, drill press, router, drill, utility knife, pliers, clamps, scissors, hammer, square, hand saw, mitre box, measuring tape

This was an example of an application of science and technology under the theme of mechanical engineering. It involved "the construction and characteristics of motion transformation systems" and required students to choose links and create guiding controls as well as produce a construction diagram to represent the assembly - all compulsory aspects of the Sec 4 AST program (MELS, 2011b). Tools played a large part in the activity and all students treated them as a natural part of the process.

6.5.2.2 Analysis: AST Curriculum

The teachers I observed are very conscientious about following the AST curriculum. Students use the textbook as a guide and a reference book. The teachers use the LESs in the Teachers' Guide of the textbook, sometimes verbatim, for projects. They find the Progression of Learning document very useful to make sure that they are on track for covering the essential curriculum content of AST – especially because of the upcoming June MELS Uniform exam. June 2012 was the first time that this exam was designated as "Uniform", meaning that it must be written by all Secondary 4 AST students and the results subject to MELS' scrutiny.

Technological Design: Almost all of the AST activities described above involved the design and construction of technological objects. The teachers I observed spent time having their students produce plans involving freehand sketches and technical drawings. As described in the vignettes in this chapter, students are anxious to get into the hands-on work as quickly as possible. They tend to spend as little time as possible on the written technical drawings and do most of their planning on a trial and error basis as the project progresses. Though they realize that the design plan is an essential part of the activity and a requirement for the evaluation of their work, I observed that they mostly leave it to the end to produce the required drawings.

Tool Use: One major finding of my visits was that tool use is a natural, welcome aspect of AST. Students use all tools - floor-mounted, hand-held electric and manual – with ease and comfort. The oversight by technicians and teachers is rigorous with respect to safety, but the worry about their use that I expected to see was absent. In all classes I observed, students chose the appropriate tools and used them as needed as an ongoing natural process. Students told me that they were at ease with their use and felt that they constituted an essential part of their learning.

Vignette #2 – The Hydraulic Arm

In the following vignette, I describe an activity carried out at Trudeau HS, a rural high school north of Montreal. I chose this to showcase the curriculum aspect of my study not only because it illustrated many of the aspects of the Technological World, but also because of the intensive nature of the use of tools and other materials in the solution of a technological problem.

The Hydraulic Arm – Tech Heavy in Action

> On my first visit to Trudeau HS I didn't know what to expect. My experiences to date had been in urban and suburban high schools – not only during my recent research visits, but also for my whole career as an educator. The culture of the rural school was unfamiliar to me and Trudeau HS serves a mostly rural student population. What I found was a school where the applied approach to science learning was the preference of most students and AST was considered to be the "high level" program. For most boys and girls, using tools and doing hands-on projects were a natural part of their rural lifestyle and so the applied approach to science and technology fit naturally with their learning style.
>
> **Setting the Scene for the LES**: Michael introduced the hydraulic arm activity by discussing the heavy machinery that they all see regularly on their farms and on the roads and construction sites. He led them to a discussion on the need for these machines to have hydraulic arms to do much of the heavy lifting and moving. As a lead–in to the activity he and the class did a lab investigation of a syringe, focusing on Pascal's Principle, the basis for the theory and use of hydraulics. He then related the syringe and the pressure exerted by the liquid to hydraulic jacks that the students are all familiar with. As a class, they shared their experiences using jacks and Michael linked these with the scientific principles they were studying. Analyzing a technical object is an important part of the AST curriculum (MELS, 2007, p. 26) and the QEP specifies that, in Secondary 4, AST students must study the engineering aspects of motion transmission systems (MELS, 2011b, p. 33).

Ever the humourist, Michael quipped "It's jack week at Trudeau HS". He had the class do a 15-minute analysis of two types of car jacks to remind them of the important technical aspects of jacks – the links, degrees of freedom, forces, and controls involved. "Analysis of a machine is sure to be on the final exam." he reminded them.

Designing the Arm: Michael then introduced an LES whose aim was to construct a model of a hydraulic arm whose purpose was to scoop up a quantity of "kitty litter" and transfer it from one container to another. This was to simulate a steam shovel moving earth at a construction site. It was to be based on a design and physical model which he displayed in the front of the class He gave them a hand-out with instructions on how to design it. The class then went to work on their designs.

Photo: Michael's AST Classroom

The room was an amphitheatre-style class with four tiers of rows of long tables. It was decorated with students' science work displayed around the class and with many objects suspended from the ceiling – giving the room a festive atmosphere. Students worked mostly in groups of two with partners of their own choosing. Most pairings were either boys or girls, not mixed.

During the design period, Michael circulated continuously to respond to questions and help students with design ideas. I observed two different groups of students during this design phase. The first got to the task quickly and spent most of their time constructively, concentrating on their work. The second group, however, was much more boisterous. There were many minor disruptions but no hint of disrespect – just noisy and not always on task. When Michael was explaining instructions or concepts, however, they listened. He always showed them that he is on their side. He complimented them on their work but explained that it's the paperwork that counts in the final analysis so it has to be taken seriously. “I’m not worried about the time. I’m only worried that you get it right.” he told them.

After about 20 minutes, about half of the students were working. The others were chatting. It was a very social atmosphere and Michael didn’t comment on the behaviour. In general however, most students got the work done in an atmosphere of chatting and joking with frequent minor outbursts. Towards the end of the class almost no work was being done. It was the last period of the day and there was no hint of any discomfort on the Michael’s part. My impression was that the planning activity was far too long for this second group, but about right for the first class.

Building the Hydraulic Arm: The next 2 lessons I observed were in the technology lab. Here the atmosphere was all business. Students got to work and concentrated on the task at hand in their groups. There was almost no chatting or socializing about anything but the building project. Michael, as always, was relaxed and humorous helping students with questions and suggestions. Everyone was fully engaged.

Photo: Tech Heavy

The technology lab is often referred to as “Tech Heavy”. As such it is a large room equipped with floor-mounted tools, a heavy duty dust collection and ventilation system, large working tables and ample cupboard space for storage of projects. The photo above gives an idea of the use of the tools.

To construct their hydraulic arms students had a wide variety of tools available to them – band saw, drill press, sander, and mitre saw, among others. I had the opportunity to observe both of Michael’s AST classes in action. In both classes the students never needed to be told what to do. Though Michael circulated continuously from group to group offering suggestions and encouragement, the students work was self-directed. They knew what to do and what equipment to use. Their expertise with the tools was remarkable. The girls were as comfortable with the use of floor-mounted tools as the boys. One girl explained, “We’re all confident using these tools. We can do it, no problem!”

As I have observed in other schools, these students did not place a lot of importance on the designing process before they constructed their project. They are more comfortable working from a rough sketch and designing the details as they go. I observed one group closely to see how this process would work. They progressed effectively by discussing and planning in their heads with scant reference to their written sketch. For example, while putting together the arm, as one held two pieces of wood, they discussed where to drill a hole to join the parts. One of them went to drill the hole while the other sanded the base. Both returned, discussed the hole placement and returned together to the drill press to make an adjustment. This “hands-on planning” was typical of the designing process in Michael’s classes. It was also very common in the other classes I observed during my research in AST classes.

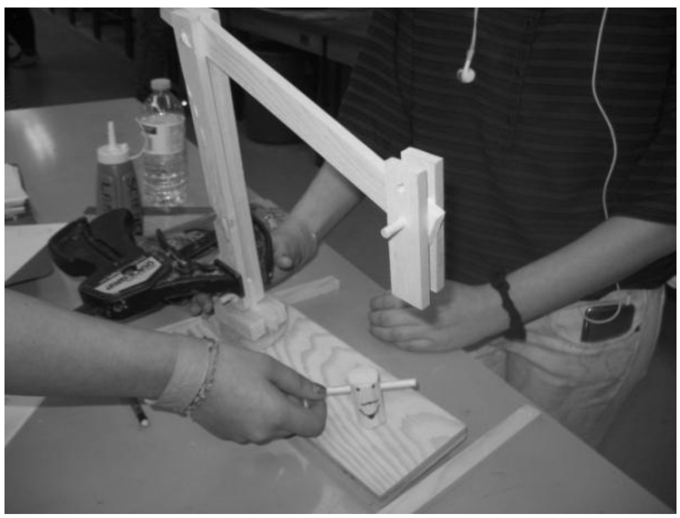


Photo: Hands-on Planning

Testing the Hydraulic Arm: On the day of testing, students retrieved their projects from the cupboards in the tech lab and brought them to the classroom described above. Michael set up a testing area on the demonstration bench at the front of the room. He placed a large tray of kitty litter and, group-by-group, students brought their projects forward to test how much litter they could scoop up and place in a second tray. Before the testing, Michael reminded them of the need to hand in a written design and report of their work. Realizing that they are less enthusiastic about written work than they are on the hands-on aspects of science, he told them, “Nothing counts if a written report isn’t handed in. Like it or not, that’s what you’re judged on!”

As each group underwent the test, groups of five to 10 other students stood around the area to watch with interest. As groups ran into

> problems, other students offered suggestions for improvements. There was no sign of frustration when things didn't work properly. They were in a mode of problem solving and eager to help each other. This was an impressive display of student engagement, motivation, cooperative relationships and learning of science applications.

6.5.3 Theme: Constructivism and Inquiry-Based Pedagogy

In this section I view the classroom activities through a pedagogical lens – looking for evidence of constructivism and inquiry-based methodology. This pedagogical viewpoint will help the reader better understand the link between the teaching practices and student learning – how the pedagogy of constructivism leads to student development of competencies and understanding of AST. What follows is a project-by-project analysis of the activities in terms of the constructivist nature of the pedagogy.

Activity 1 The Toy Project

This project involved a high degree of student control over the procedure. Students designed their toy on their own without any form of prescribed set of directions from the teacher. Most students showed real understanding even when things didn't work. Though they often had difficulty getting all things to work properly and together, they seemed to know why and could explain it. Sally used the projects to help explain concepts throughout the period. I also observed this project in Lianne's class. Both she and Sally used the same activity, but Sally tended to let her students be more in control of the procedures. Lianne gave her students more direction and left less to their discretion.

Activity 2 Friction Lab

This Friction activity had little of the constructivist nature recommended by the QEP and proponents of the Constructivist Learning Model (Driver R, 1994; MELS, 2007; Phillips, 2003; Yager, 1991). This was evidenced by the following aspects of the lessons:

- There was only a brief attempt to access students' prior knowledge.
- It was completely teacher-centered. The instructions were given by the teacher and the textbook. There was no opportunity for the students to try their own ideas and procedures.
- To a very limited extent, students did construct their own knowledge by coming up with their own conclusions about the factors which affect the force of friction, but there were accepted "right answers" that they were expected to find.
- Though it was an active, hands-on activity, it did not provide students the opportunity for innovation or deep thinking. They just followed the instructions.
- By their actions they demonstrated that they understood the basic concept of friction. They explained to the teacher and to me that the different surfaces affected the frictional force and they backed this up with the data they collected.

Activity 3 The Lung Capacity Machine

This was a highly constructivist activity. Celina gave the design control completely over to the students. They developed their own procedures based on their own understanding of the scientific principles. They constructed their own understanding of water displacement and its link to the volume of air. The activity was carried out in a real-life context, solving a problem which they recognized as meaningful to them.

They went from being somewhat bewildered to finding solutions. It took them some time and lots of discussions to realize that they had to construct a device which would measure the volume of water displaced by the air blown into the apparatus.

Activity 4 The Solar Furnace

Other than the fact that the students had a sketch of a cooker to follow, this was a highly constructivist activity. Celina gave the design control completely over to the students. She did not, however, make much effort to access their prior knowledge of the behavior of light – knowledge that could have helped them better understand how to angle the sides to best direct the solar energy onto the water to be heated. They were left on their own to construct their own understanding of heat reflection and absorption as well as heat transfer. The activity was based on a meaningful real-world context of energy use – especially in less advantaged world contexts. They displayed their understanding of the experimental process by setting up a control test along with their experimental test of the water heater.

Activity 5 The Anemometer

This was a highly constructivist activity. Students used their prior understanding of energy and motion to create their own design using a wide variety of materials supplied by the lab technician. The instructions from the teacher were minimal as she gave complete design control over to the students. As a result with a lot of trial and error, students constructed their own understanding of the transformation of wind energy to the motion of their wind measuring device in a meaningful real-world context.

Activity 6 The Bridge

This was another highly constructivist activity. Madeline drew on their knowledge of and their involvement with the Champlain Bridge and the problems it caused their families. She made it a very relevant project. Students created their own design for the bridge. A wide variety of designs resulted from the fact that she gave no models to work from. Student understanding was strong. This was a result of the need for the students to figure out for themselves the design the properties of the materials they worked with.

The lab technician did however undermine the students' construction of their own understanding by giving directives rather than helping them solve problems. He did not seem interested in the students' process of knowledge construction. His annoyance with Madeline showed that he had little regard for the pedagogy of constructivism that she was trying to follow.

<u>Activity 7 The Hydraulic Arm</u>

This was a partially constructivist activity. Michael presented a physical model to follow and gave out some instructions for its construction. Students however modified their own designs considerably – not in their initial design, but during the construction process as they realized that they needed to change aspects of the design because things didn't work properly. The placement of the hydraulic syringes was one such example. If they weren't places just right, the arm didn't function. They constructed their own understanding of water pressure and Pascal's principle by experimenting with the functioning of the syringes. They clearly understood that this was simulating a real-life situation, solving a problem which they recognized as meaningful to their community.

6.5.3.1 Analysis – Constructivist Pedagogy

Most of the LESs were constructivist in nature. They involved the students in active, hands-on learning. Most were contextual. They were related to the lives of the students and thus had real meaning for them. The teachers built on the students' prior knowledge and filled in knowledge gaps when necessary. What emerged as a key factor in the success of these projects was the amount of control the students had in deciding how to carry out the activity. It seemed that the more say they had in what methodology, materials and tools to use the greater was their learning and motivation.

There were a number of activities, however, which had little to do with students constructing their own knowledge and understanding. They were mostly traditional exercises similar to those from previous programs. Other than the Friction Lab, these have not been described in detail in this chapter but can be found listed in Appendix H. They were of short duration and students were provided with the materials and instructions by the teacher. They had little say in the procedures and followed the instructions they were given. I observed much lower motivation and enthusiasm levels during these activities. It appeared that students were motivated by marks rather than the nature of the activity. The teachers often used these exercises as a build-up to a more constructivist LES. It was seen as an expedient way to build the skills and knowledge. Using these activities for comparison purposes, it became clear to me that constructivist, challenging, hands-on projects are the key to student motivation - getting students interested and involved in science learning. In the next section I will pursue this in greater detail.

Vignette #3 - The Bridge

> The South Shore communities served by Maple HS are linked to Montreal Island by a series of bridges. At the time of this activity, one of the bridges was in the news as being unsafe and in need of replacement. This was a news story which captured the attention of the residents of these communities and the students of Maple HS.
>
> The class I visited was Madeline's Secondary 4 AST class made up of 16 boys and nine girls. It was an intellectually diverse group of students, about half of whom were interested in pursuing the sciences in Secondary 5. As part of their study of the Material World, Madeline, an experienced science teacher, asked her students to design and build a concrete bridge which would have the ability to span a distance of 50 cm and be able to support as many bricks as possible without collapsing. Using some guidance from Madeline, videos of concrete bridges from the Internet, and their personal knowledge of bridges, students came up with designs on their own for the construction. Alex, the lab technician made all materials available and supervised the tech lab so that the

students could go back and forth from class to lab as needed while doing the construction.

This activity was part of the AST technological design process which is described in the QEP as follows:

> This process is used when a need has been identified. The resulting study of the technological problem must take into account any conditions and constraints in the specifications. Then the real design process begins: finding solutions to operational and construction problems, defining shapes, determining the necessary materials, and designing the parts. (MELS, 2007, p. 26)

Madeline's Approach: Madeline approached the design aspect of her AST activities a little differently from most teachers. Though the program calls for a rigorous design phase before the students embark on the hands-on construction, Madeline kept this aspect to a minimum before the fact and left the detailed design until after the students had begun to manipulate their creation. Her approach was to have them get to work as quickly as possible. She had a brief full-class discussion with them about the problem at hand and had them begin work in their groups of two or three by drawing a rough sketch of what they intended to build. Her reasoning for this approach was two-fold:

- She knows that her students are motivated by hands-on action-oriented activities and quickly get bored with theoretical discussions and lengthy pre-activity designs. That's why they chose AST in the first place.
- She knows that their designs will likely change frequently as they encounter unforeseen obstacles during the building process. A detailed drawing after the construction will be a much more accurate reflection of the reality of their project and still give them the engineering design experience required by the program. (MELS, 2011b)

Over the next three periods the students worked on their bridge constructions. Madeline circulated continuously and had discussions with students about their designs and construction activities. She always questioned what they were doing and made them question their own thinking on how they were designing and building. As an observer I visited all groups of students and discussed with them their reasoning for their designs and the processes they were using. Students displayed a thorough understanding of their project. They articulated why they are designing it the way they were and some of the problems they were encountering along the way. They explained the need for reinforcing the concrete in the structures and the way they mixed the cement in order to get the consistency they needed. They could articulate their reasoning for the particular design they choose.

One subject that I broached in my travels around the class was their reasons for choosing AST instead of ST for Secondary 4. Many students told me that ST is too theoretical and that they quickly get bored with scientific theory and book-oriented activities. They love the hands-on learning through projects. “For me imagination and creativity are everything” said one girl. A boy and a girl in another group told me that they chose AST because they want to go into engineering or architecture. They see AST as harder as and more demanding intellectually than ST. Another group of three liked AST for the sharing of ideas and specializing in one activity at a time. They said that they always look forward to the class and the projects. “It’s challenging – definitely not boring!” said one boy. Another boy explained that, even though they often hit snags and sometimes have to rethink their designs, he’s sees this as a natural problem-solving process, not a source of frustration and discouragement.

Building the Bridge: The bridge building lasted three periods. The bridges were to be made out of concrete - like the Champlain Bridge. Students had to make forms to hold the concrete, mix the concrete using the appropriate materials and quantities, and fashion their materials into a functional bridge.

As soon as Madeline approved their design drafts, students began to build their bridges. They had two labs available to them. The “tech heavy” lab had the floor-mounted tools and students used it when they needed to prepare the materials for the molds. With their molds ready, they used the “tech lite” lab (lab with no floor-mounted tools) next door to create their concrete mixtures, test its consistency and pour the concrete into their molds.

Photo: Preparing Concrete in the Tech-lite Lab

Students worked in groups with the exception of one girl working alone. There were six pairs and four groups of three –

according to their choice. Five groups were boys only, three were girls only and two groups were mixed. For the most part, these were effective working arrangements. Madeline took a very laissez-faire attitude to their work. She made sure that they knew what the expectations were and let them work at their own pace. Other than one pair of boys, everyone was thoroughly engaged in their work. The task was sufficiently challenging and motivating that the students were on task during the full 75 minutes of every period. Some even came in early or stayed late. The discussions between students were often quite intense as they tried to solve the many problems that arose. Usually these discussions were about the design because they would not be working as originally expected. Students would take on different roles. Some emerged as the leaders, pushing their partners to agree with their vision and directing the construction work. Some passively accepted what the others suggested and did what they were told. One girl was the consensus-maker in her group of three. "So do we all agree on the change?" she said after a lengthy design discussion.

The off-task pair of boys spent their time in class discussing their social life and showing no interest in the bridge project. At the end of the second day of building, Madeline insisted that they attend to the job at hand. Their response was to create a very simple bridge just to meet the minimum requirements.

The Lab Technician Role: There were two lab technicians involved with the project. Alex was the concrete expert and helped the students mix and test the concrete in the "tech lite" lab. Geoffrey supervised the use of tools in the "tech heavy" lab. Alex seemed upset at the lack of rigor and discipline in the class. He told me that the students needed more direction as to how to do the cement correctly and how to build their bridges properly. In his interactions with students he was very directive – giving detailed instructions and not encouraging them to construct their own learning about the use of the materials. He told me that he was frustrated with the teacher! His opinion was that she should give a set of detailed instructions on every aspect of the project "in order to get it done properly".

Testing the Bridges: On the final day of the project, Madeline tested the strength of the students' bridges. They approached her with their finished products when they were ready. As each group underwent their strength test, others gathered around and watched with anticipation as the bridge was placed across a span of about 30 cm between two tables. Madeline slowly loaded it with bricks or hung weights from it to see how much it could support. Remarkably there were no failures. The bridges stood up to the additions of many more bricks than they had expected. There was a buzz of excitement as more and more weight was added. As this was proceeding, Madeline asked the students how they might improve their products and how they dealt with problems as they arose. In her conversations she was always probing for student understanding. “How did the amount of the ingredients in the concrete mixture affect the strength?” she asked often.

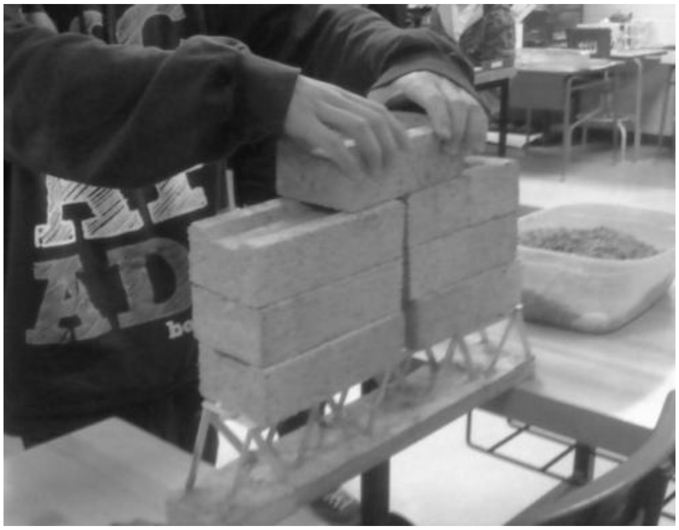


Photo: Testing the Bridge

6.5.3 Theme: Student Motivation and Engagement

In this section I view the classroom activities from the point of view of student motivation and engagement. As described in Chapter 2, I discuss the activities in terms of their ability to intrinsically motivate students to learn science and technology. I base my analysis on the behavior I observed and the continuous discussions I had with students and teachers throughout the lessons. What follows is a project-by-project analysis of the selected activities in terms of the student motivation and engagement.

Activity 1 The Toy Project

Students were fully engaged and on task. This class activity is an inspiring example of how AST activities can be so motivating. Though there were a few students in Sally’s class who took little interest in the project, this activity showed that students who are unmotivated by traditional teacher-directed activities can be enthusiastic and productive in constructivist activities which are meaningful to them. With the exception of one girl, the few girls in these classes were as engaged in the project and took as much initiative as the boys.

The AST students at Howland HS are considered weaker than the ST students because of the fact that Science of the Environment (SE), the advanced course for AST students required for Secondary 5 sciences is not offered. Therefore AST does not attract strong science-oriented students. As a result the AST student population tends to be less academically inclined and more difficult behaviorally than the ST classes. These students, however, show strong intrinsic motivation for hands-on constructivist activities that are relevant to them. For this reason, they reacted very positively to the toy project, produced strong results and displayed high motivation and engagement. Performing well in a difficult and complex task, they showed that this activity provided them with the learning conditions they needed. One boy in the class, for example, had an attention disorder and had an integration aide with him during science class to help him concentrate and to keep him focused on his studies. He worked steadily throughout the class periods while he was working in the lab. He exhibited little off-task behaviour and proudly produced a toy according to the specifications.

I observed three AST classes doing the toy project. In Lianne’s, Trudy’s and Sally’s classes the levels of motivation and engagement were similarly high while they were constructing their toys. All three teachers spent the final day having their students present their finished products to their class. While the presenters (usually groups of two or three) were very animated and enthusiastic, in one class the other students were not. This can be explained by the seating arrangement during the presentations. In Sally's class they were all seated in a large circle facing the presenters, giving them their full attention. In Trudy's class they were seated in their groups, making it easy for them to talk to each other. The result was that those who had not presented yet were anxious to discuss their own work, and those who had already presented became bored and chatted socially with their partners.

I had the opportunity to do a comparison of the motivation level an AST class with that of an EST class, the advanced Secondary 4 class of students planning to take further science courses in Secondary 5. Interestingly, though the EST students produced toy cars which were more aesthetically designed (more colorful, more creatively shaped), the quality of the mechanical aspects were similar and the level of motivation and engagement exhibited were very similar those of the AST students.

Activity 2 The Friction Lab

Comparing this lab to the very constructivist toy project provided me with a unique opportunity to observe the resulting differences in student motivation and behavior. Observing this activity in both Sally's and Trudy's classes allowed me to compare the levels of motivation in the two settings. Sally's class, mostly boys, has many students who tend to be boisterous and social when they are not fully engaged in hands-on work. During the friction activity Sally had to quiet them down on a number of occasions, especially when they had to analyze their data and draw conclusions. This contrasts with their behavior while constructing their toy, testing it and making adjustments for it to work properly. The toy activity was taken much more seriously than the friction lab and the students were much more focused and determined to make it work, resulting in very little disruptive behavior and far fewer social interactions. In fact the social interactions during the toy project were generally about ideas about the functioning of the toy. In Trudy's class the atmosphere was different. Most students were on task almost all of the time and they attended to the job at hand with no disruptive behaviour. What I noticed was a lack of enthusiasm. I overheard one girl saying to her partner, "Just tell me what to write down". Another boy, when I asked him how he rated this activity, said "in the middle".

This comparison of the toy and friction activities allowed me to better understand the effect of the nature of the hands-on activities on student enthusiasm for and motivation to learn science. The fact that an activity is hands-on and active is not enough to create motivation and enthusiasm. Meaningful personal involvement is what is required. A constructivist learning environment fulfills that need. However despite the non-constructivist nature of the friction lab, students still demonstrated understanding of the concept of friction.

Activity 3 The Lung Capacity Machine

There was very high engagement and motivation displayed by Celina's Secondary 3 students in this activity. There was some show of bewilderment at first due to confusion as to how to solve the problem. However students showed strong determination to come up with a workable solution as the class progressed. When things didn't go right or as the students expected, they redid them. Most were not satisfied with unsatisfactory results. They seemed to be able to self-evaluate as it was clear to them what constituted a good solution. There was little display of frustration or stress. There was a moderate level of noise throughout the activity - a result of positive, on-task discussions.

Activity 4 The Solar Furnace

The level of interest shown by Celina's Secondary 4 students was low at first as they tried to figure out the design they needed to solve the problem. Soon, however, as they realized what the project entailed and as they figured out how to design a workable model, their engagement and motivation increased dramatically. The more they came to understand the behavior of light rays the more enthusiastic they became in building their cooker. This project generated a great deal of satisfaction for them when they saw clearly that their solar furnace accomplished the task required – all as a result of their successful work. They could evaluate their own work as it was clear to them what the criteria for success were. They didn't need the teacher to tell them they had done well.

What struck me in this activity was the change in the level of enthusiasm as the activity progressed. At first there seemed to be little interest in the project. They seemed listless and had to be told to "get to work". They saw it as a boring process where they would simply follow the procedure given to them to get a predetermined result. They became engaged when they realized that it was a genuine problem with a real-world context that required considerable design input and skill on their part to get it to work properly. Their discussions went from off-task chatting to focused talk about how to solve the problem. Thus it went from being perceived as a boring exercise to a personally meaningful, challenging problem to solve.

Activity 5 The Anemometer

This activity was done in Celina's class only. The level of interest shown by the students was so high that they spent some of their own time at home beginning the design process. Even though (or perhaps because) the design was complicated and the instructions almost non-existent, motivation was very high throughout the six days. The satisfaction on successful completion of the anemometer was palpable. Students showed off their successes to their friends. They urged the teacher to see how well their product worked. The complexity of the task, rather than discouraging them, seemed to spur them on. As the period went on, the activity became more intense and the productivity increased.

Activity 6 The Bridge

All students (with the exception a pair of boys) were fully engaged from the beginning of each class. Living near the Champlain Bridge, they were strongly motivated to build a meaningful design. The atmosphere was noisy but not chaotic. Such was the level of trust between teacher and students that students moved freely between the classroom and labs as needed. Madeline's laissez-faire attitude seemed to be a positive factor in the student learning. She showed that she trusted them and they responded by acting responsibly. See Vignette # 3 for the details.

Activity 7 The Hydraulic Arm

This activity provided another clear example of how motivated AST students are by hands-on projects that they have control over and which have a meaning in their lives. In this activity, students exhibited what Pink (2011) describes as Type I behavior. By this he refers to intrinsic motivation characterized by autonomy (control over the project), mastery (the desire to continually improve it), and purpose (making something that has meaning to them).

The students made it clear that they love their teacher, Michael, and it was evident why that was so. During the whole time I observed his classes, he never raised his voice – whether to get their attention, reprimand them or stop them from behaving inappropriately. He didn't have to. He made it very clear to them what their responsibilities were and he made sure that the activities were motivating and important. He let them decide how to accomplish the tasks and supported them fully as they did them. If he felt that someone was wasting too much of the class socializing he would deal with it quietly and unobtrusively. For example, he went up to one girl who was chatting idly and simply asked "Need help?" This was enough for her to return to her task at hand.

The question often arises as to whether a good lesson is the result of a good teacher or a sound curriculum or a little of both. In this case the success of this inspiring project is a function of having the right teacher with the right personal and professional qualities delivering a curriculum which fits so well with the students learning styles. These are students who can be described as "bodily-kinesthetic" learners (Gardner & Hatch, 1989) and Michael understands how to deliver the curriculum so that they can learn.

6.5.3.1 Analysis of Student Motivation Theme

The vast majority of students I encountered love AST. During the course of my visits, I made sure to talk to all the students informally, individually or in small groups, about their reasons for choosing AST and their feelings toward the program. Most said that they chose AST because they like the hands-on, problem-solving, active nature of it. They liked to build things and figure out how things work. Many commented that taking notes from the board, reading the text and discussing the scientific theory bored them. This was their perception of the ST course – a perception they got from talking to ST students or from having taken ST in Secondary 3 themselves.

Student behavior was for me a telling indicator of their motivation and engagement. Sally's class provided me the clearest example of the behavior/motivation link. Her students would not concentrate on the activities when they were of the traditional classroom nature. They listened poorly to presentations on scientific theory and showed little interest when they had a hands-on activity that gave them explicit step-by-step instructions. Constructivist activities which had meaning to them, however, had their undivided attention. Suddenly their behavior became mature and productive.

Vignette #4: The Toy Project

The following vignette illustrated how Sally used a meaningful, constructivist activity to build student motivation and engagement. The activity was also done by the two other AST teachers, Lianne and Trudy and is a good illustration of how all three teachers collaborated on the planning of the project, but still carried it out according to how they see it best fitting into their curriculum in the best interests of their own students.

> The tech lab was an ideal setting for hands-on activities that required the use of heavy tools. It had been a workshop used for Woodworking and Introduction to Technology, 2 programs which were discontinued when the QEP was introduced in 2008 (Education, 1993). The school board had installed new floor-mounted tools (drill presses, belt sanders and band saws) and upgraded the work benches and storage spaces to conform to the needs of the new Science and Technology classes. Many schools have similar "tech heavy" Technology labs – i.e. labs equipped with floor-mounted tools and an expensive dust-collection system. Other schools, without the space available, have "tech lite" labs, without floor-mounted tools, where students do technology-related activities using hand-held tools. In this study, all schools are "tech heavy".
>
> **The Challenge:** Students were given the following situation**: "**You have decided to make a toy for your nephew for Christmas. You want to create a pull toy that will have a light that blinks when he pulls the toy. You also want to have a driver whose head will bob up and down as the wheels turn. You found some materials in your basement that could be of use."
>
> **Teacher Collaboration:** The three AST teachers had worked together to organize this activity and each had adapted it to her own needs. This was my first opportunity to see firsthand how the implementation of the QEP has prompted teachers to collaborate in the production of common activities. Using tools like the school board portal, they are able to produce and share their activities on portal "communities". Sharing a common science work room, they are in

regular daily contact with each other, sharing ideas, developing activities and discussing problems. Lianne’s class, for example, was the first to do the Toy Project. She decided to have her students create the cart and the driver only. She would leave the blinking light for a later date after they had studied electric circuits. Sally and Trudy, on the other hand, began the project in late February once they had done their study of electrical circuits. They wanted to do both the bobbing driver as well as the flashing light at the same time. They felt that the students needed to do a number of activities on electrical circuits before tackling the toy’s complex task.

Photo: Toy Project materials

The Activity: When I visited Lianne’s class, the students were into their second day of this activity. On the first day they had spent the period planning their toy – discussing and designing. As they entered the class the teacher and lab technician reminded them of their tasks and reiterated that they were to continue to work in pairs and devise this toy without any suggestions from them. They devised the procedures entirely on their own. They went right to work and continued through the entire 50 minutes. During the class, I interviewed all nine groups and found that they all had figured out a procedure to solve the problem. They all expressed confidence in their ability to produce the required toy. I noticed that they were not referring to their drawings, and, in fact, many did not have any drawings. When I asked individual groups about this, they answered that they worked best from hands-on trial and error. While the drawings helped in their initial thinking, they were not useful after that. One group told me that their plan “was in their head”. Their plans kept changing as they experimented with their toy and found what worked and what didn’t.

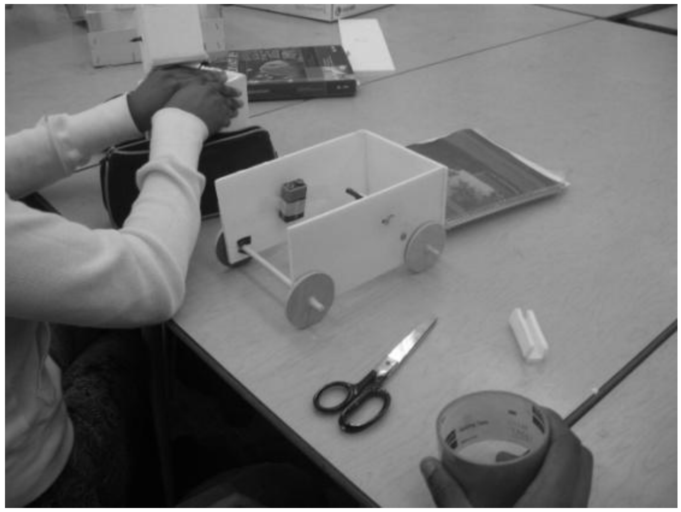


Photo: Building the toy

There was a visible level of enthusiasm in the class. The atmosphere was quiet and the students were on task all period. They were busy constructing the cart, fitting the wheels and axles, and devising a mechanism to attach the "driver" to a system to make it bob up and down. There was one special needs student with a teacher's aide. He was very actively involved and enthusiastic all period. He showed good humor and excitement with the activity. Students asked technical questions and some advice about the procedures but seemed happy to be figuring it out themselves. Many students used the floor-mounted and hand-held tools. They dutifully wore their protective eye wear and paid careful attention to the safety rules.

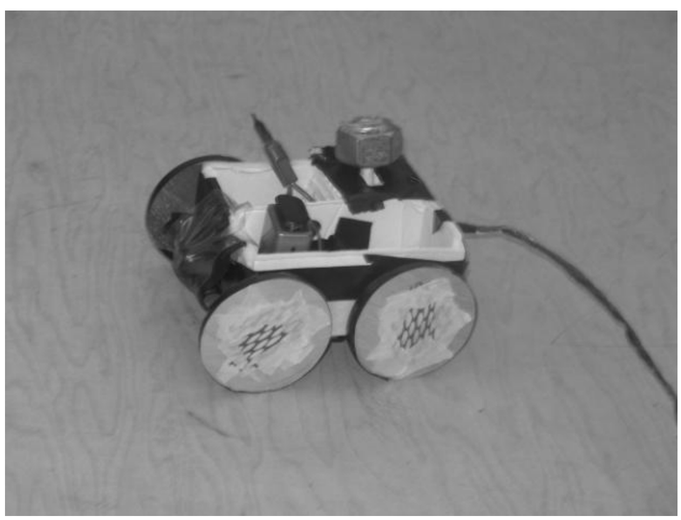


Photo: A Functioning Toy

The Presentations: When it came time for the presentations, Sally arranged the tables in her classroom so that all students were in a rectangle, facing the presenters. This encouraged discussions and ensured the attention of everyone. This is a boisterous class and Sally, a skilled teacher and motivator of teenagers, was always challenged to find ways to get and keep their attention. She called on Jesse and partner to start. She asked them to describe how the head bobs and the circuit for the flashing light. She asked them to complete the sentences "If you were to do it again…" and "I really needed…"

Stacy's group didn't get either aspect of the toy to work properly. Sally, not wanting to embarrass them said, "Tell us at least what you wanted to do." She praised their progress and probed what they could have done to make things work. Terry's group made the bobbing driver work, but not the light. Sally was quick to praise the effort, "This is a great idea. Cool how you had this motion turn into motion at 90°" But when Terry said "I'm sure with more time we would have made it work", Sally didn't accept this excuse and replied, "You had seven days in the workshop - enough!" The star of the show was Sun May. She is an exchange student from China. Even with her halting English, she managed to explain to the class her outstanding project. The mechanism and light worked perfectly and she received strong applause from the rest of the class. Interestingly, her "partner" was a partner in name only. Linda contributed nothing to the work and was content to observe, hoping to receive credit for the work Sun May did. In fact she spent most of her time chatting with boys in other groups.

Throughout the toy project, even with this boisterous class, the student behavior was no problem. There was rapt attention and respect for others' work. They all showed pride in their work, even when things didn't work perfectly. Sally constantly used the projects to help explain the scientific concepts throughout the presentations. Everyone had a product.

Vignette #5: The Lung Capacity Machine

A challenge for the Secondary 3 AST teachers is to find applications of science and technology that both fit with the theme of the human body and also motivate and engage the students with activities that are meaningful to them.

The Lung Capacity Machine: The second school I visited expanded my understanding of the potential of the applied approach to teaching and learning science and technology. Lake HS invited me to visit their AST teacher, Celina. Celina has been a science teacher for nine years and has truly embraced the applied philosophy. She has her students creating technological objects, working with tools and learning science through a strongly constructivist approach. Her students showed me that the applied approach can lead them to an understanding of and enthusiasm for science and technology. She teaches AST at both Secondary 3 and 4 levels. I had been curious to see whether or not the theme of the human body in Secondary 3 was conducive to the applied approach - whether there are applications of technology that the students can create assemble and maintain which are meaningful to students and which conform to the AST curriculum. This question was quickly answered when I observed an activity on measuring lung capacity.

Photo: Measuring Lung Capacity

"Does anyone in this class have asthma or know anyone who does?" asked Celina at the start of the class. A few answered that they had friends or siblings with the disease. This prompted a discussion, which many students contributed to, of some of the symptoms of the disease and factors which contribute to it. This led to the concept of lung capacity, the factors which may inhibit it (students said "smoking", "illness", "asthma" and "age") and how it can be measured. First Ellie, the lab technician, showed them how to use a commercial device to find their own lung capacity – the maximum volume of air that they could breathe in.

Celina then explained that they would have the challenge of designing and making a device to measure their own lung capacity. They would then use it to measure their own capacity and compare it to the result they will have recorded using the commercial device. "It's up to you to come up with your own design", she said. She told them not to expect a good design right away, but one which they could correct and redo by trial and error as the activity progresses.

The first half of the lesson was for collaborative designing in their groups of two or three. After that she told them to get materials and begin. As she circulated she told them, “Always try to improve on your ideas. Think how to measure volume.” The lab was equipped with plastic Ziploc® bags, rubber tubing, tape, some 4L plastic containers (used for water or antifreeze) and a few aquariums. Though there were no instructions given, students quickly figured out that they needed to blow air into the plastic bag using the rubber tubing and somehow displace water to find out the volume of air blown into the system. The most popular solution involved blowing into a submerged bag in an aquarium and measuring the change in water level as the bag filled with air. Other solutions involved displacing water in one full 4L container and catching and measuring the overflow (like Archimedes Principle) and other variations on water displacement. The students did this activity in two full 75-minute periods. By the middle of the 2^{nd} period, most had completed the construction. They used the remaining time to test their lung capacity, make any repairs and make a written report on their design, data and conclusions.

6.6 Conclusion – Summary of Key Findings for the Implementation of AST

I found the classroom visits to be a heartwarming experience. I didn’t expect it to be so positive. The teachers and students readily shared their experiences and feelings with me, showing a pride and confidence in their accomplishments that I did not expect. These teachers were very successful in motivating their students, in large part because of their respect for their students’ capabilities and their belief in the efficacy of the AST program.

Here is what I learned from my visits to the classroom about what can contribute to a successful implementation of AST. I will summarize the links I have found between AST curriculum, constructivist pedagogy, teacher collaboration, student engagement and student behavior.

The link between the AST curriculum and student motivation - Flow: The AST curriculum with its emphasis on the Technological World provides many opportunities for activities which motivate and engage students. The most successful activities seem to be those which follow the concept of “flow” - Autonomy, Mastery and Purpose, as described in Chapter 2 (Pink, 2011).

1. Autonomy: The students are given autonomy in the creation of their solution to technological problems. Students become intensely involved when they have to come up with the solution on their own. They may start the process with some sense of confusion, bewilderment and frustration. Soon, however, with cooperative group discussions and strategic interventions by the teacher, they find their way to creating their own solutions which they are very proud to “own”. It is a time-consuming process which usually takes a few more class periods than expected. While planning the toy project, for example, it took a lot of discussion - and trial and error- and a little bit of teacher intervention for them to figure out how to make the “driver” bob up and down as the car rolled forward. Once over that hurdle, however, their concentration and sense of ownership increased as they progressed.

2. Mastery: Students strive for mastery as they carry out the activities. Once they have decided on how to solve the technological problem, students become more and more determined to get it right and improve it whenever possible. For example, while mixing the concrete for the bridge project, students spent a lot of time testing different proportions of cement, water, sand and gravel to make sure they had the strongest concrete possible for their bridges. They were determined that their bridge withstand the greatest possible pressure.

3. Purpose: The activities give them a sense of purpose. Students become strongly involved with technological problem solving when they find the activity meaningful to them. It has a greater chance of success for them if they see it as an important problem to solve. Celina's students understand the importance of clean energy and energy scarcity in the developing world. Constructing and testing a solar furnace was a purposeful activity for them

Teacher collaboration: In three of the four schools I visited, there was only one AST teacher per level, so teacher teamwork and collaborative planning were not a factor. However at Howland HS, three teachers taught one AST class each. In my experience, teachers value their independence and like to do things their own way. In fact many have told me that this is one of the factors that strongly attracted them to teaching in the first place. The three Howland HS teachers planned the toy project together but each one carried it out according to their understanding of how their students learned best. Sally and Trudy had their students do both the construction of the toy and the addition of the electrical system of lights at the same time. Lianne, on the other hand, did the car construction first, earlier in the year, and added the lights two months later as part of their study of electrical circuits. It was a great benefit for them to have each others' help, to share their collective wisdom, and to divide up the preparation work load. It was also very important for each of them to have their own independence of action and respect each other for that. The three aspects of "flow" - autonomy, mastery and purpose - made for a very happy, productive atmosphere for these teachers.

The AST Curriculum: The teachers are able to cover the content of the Four Worlds required for the curriculum and the final MELS exams. They spend a lot of time helping students develop Competency 1 – solving scientific and technological problems - by focusing most of their active hands-on time on technological applications of science, as described in this chapter. Though technological design and construction are the main activities, most take a modified view of the design process. Recognizing that their AST students are highly motivated by the hands – on work time spent on paper and pencil designing is minimized to allow them to get to the action as quickly as possible. Students I observed showed themselves to be quite adept at planning "on the fly". The typical pattern was to produce a rough sketch of their creation, begin the construction, and modify it as they went along. The teachers, for the most part, recognized this learning style pattern and accepted it, all the while insisting on a final product which included a proper written design done according to their instructions.

Availability of labs and equipment and tools: As described in Chapter 2, one of the major changes in the teaching of science and technology with the introduction of the QEP has been the introduction of engineering design technology and the accompanying use of the technology labs and their tools and equipment. In AST this has been especially important. In the four schools I visited, all the AST teachers made frequent and full use of the wide variety of both heavy floor-mounted tools, hand-held electrical tools and regular hand tools – depending on the nature of the activity. Lab technicians played a vital role in maintaining a safe environment and training both the teachers and students in their use.

In general the students were motivated by the use of these tools and equipment. Some told me that they appreciated the confidence that their teachers put in them by giving them full access to tools and equipment, thus allowing them to carry out their activities in the best possible conditions. There was no observable gender difference in the use of tools. Boys and girls seemed to be comfortable using them as necessary. Tool use was a natural part of classroom activities.

The Constructivist Learning Environment: There was a strong positive link between constructivist learning and student motivation, enthusiasm for learning and engagement. The more that a project was built on students' prior knowledge, gave them control of the activity, had them work collaboratively and had personal meaning for them, the more they were motivated to construct their own understanding and knowledge. Student behavior in such a constructivist environment was positive and on-task. On the other hand, in classes with potentially disruptive students, behavior was at its worst during traditional, teacher-directed, theory-related activities.

The classroom visits thus gave me insights into how AST classes work under the guidance of experienced and skilled science and technology teachers and with the tools and equipment recommended by the QEP. In the next chapter I will report on interviews I had with these teachers as well as with their administrators and the science consultants who worked with them to implement AST.

Chapter 7: Interviews

What do Teachers, Consultants and Principals Say about AST?

After observing the AST classes in action at the four schools in the study, I conducted a series of interviews. First I talked to the teachers to get their perspectives on the classes I had observed. Next I met with their principals of the schools I visited. I also interviewed three of the science consultants in Quebec, two of whom served three of the four schools in the study.

Each of these three groups of interviewees gave me a different perspective of AST and its implementation- perspectives which allowed me to build a more complete picture of what goes on in the AST classroom.

- The teachers have the most central role to play. They see things from a front-line perspective. They interact with the program and the students on a personal and immediate level. Their comments are personal, direct, emotional and first-hand.
- The principals have a broader perspective. Some of them have a good idea of what goes on in the AST classroom, but their knowledge is, for the most part, second hand. They help create a bigger picture of AST implementation by adding an administrative perspective. In particular they can explain
  - programming issues
  - school board requirements
  - parental concerns

- The consultants gave me a picture of the implementation of AST from the point of view of teacher supporter and program expert. They inform this study of the broad curriculum issues of program implementation:
    - professional development needs
    - material requirements, both textual and physical
    - the nature of the ongoing support for teachers and schools –essential for the success for the implementation

These findings and insights from these interviews are triangulated with those from the classroom visits to help build understandings for the main research questions for this study:

1. What teaching practices, specific to AST, do teachers use in the classroom and lab?

2. What is the relationship between the teachers' epistemology and practice especially as evidenced by their approach to the AST curriculum?

3. What tools, scientific equipment and consumable materials are being used specifically for AST?

4. To what extent are students positively engaged in the teaching and learning of science in AST?

Though the interview questions for these three groups covered similar topics, each group also had questions which were specific to the role they play in the system. Appendix J shows the themes and sub-themes that emerged from the interviews.

As described above each of the three groups of interviewees had a different set of perspectives on the same issue – the implementation of AST. From the interviews certain themes emerged. Some of the themes were common to all three groups. T he AST curriculum and approach was strongest among the teachers and consultants and less so for the principals. T he theme of pedagogy was important for teachers and consultants, but not principals. Teachers and principals were concerned with student motivation and behaviour, but not the consultants. Administrative concerns regarding enrolment and programming touched all three groups, especially the principals. Consultants were strongly concerned with support for teachers, but the principals and teachers talked less about this. Teachers discussed the issue of labs, technicians and tool use at length.

In this chapter, I report on the interviews that I conducted as described above. I present the interviews in each category separately for teachers, principals and consultants. The reports are theme-based. Each theme is examined according to all participants in each category. Once all the themes have been explored for each group, I analyze them for commonalities, differences and implications for science teaching and learning in Quebec.

7.1 Interviews with Teachers

I conducted interviews with the six teachers whose classes I observed - from the four schools I visited. All six teachers had been recommended to me for their superior teaching skills by the science consultants of their respective boards and their recommendations had been heartily endorsed by their principals.

Table 7.1 Teachers

Name	Gender	School	Board	Age range	Years teaching science
Sally	Female	Howland HS	LBPSB	40s	10-15
Lianne	Female	Howland HS	LBPSB	30s	5-10
Trudy	Female	Howland HS	LBPSB	40s	15-20
Celina	Female	Lake HS	LBPSB	30s	10 - 15
Michael	Male	Maple HS	SWLSB	50s	20-25
Madeline	Female	Trudeau HS	RSB	30s	5-10

Appendix J shows a sample of an interview table generated from one teacher interview. It shows the themes, sub-themes and coding. Appendix K shows a sample of two of the themes that emerged from the teacher interviews and the corresponding coding for each teacher.

The formal interviews lasted from 25 to 75 minutes. The teachers responded to the following questions:

1. How long have you been teaching? Here?
2. What is your background in mathematics/science? Highest level of courses? Degree(s)? Experience?
3. Were students selected for AST? If so, how?
4. How does your lesson preparation differ from the preparation involved with programs in the past?
5. Do teachers at your school collaborate in their preparation and teaching? If so, how?
6. What activities and content are different? From the past? Between AST and ST (if applicable)?
7. Is the motivation to learn different between ST and AST students? Is it different from their motivation to learn in pre-reform courses? If so please elaborate.

8. How do you assess the students' learning? LES? Rubrics?

The following themes emerged from the interviews:

1. Teacher background – Their education and teaching experience
2. AST curriculum and approach – How they teach and evaluate AST
3. Pedagogy - constructivism/Inquiry – To what extent they use constructivist/inquiry-based pedagogy
4. Student engagement – To what extent their students are motivated to learn AST
5. Use of tools, labs and technicians – Their relationship with lab technicians and lab work.
6. Administrative/ Student selection – Administrative issues regarding who takes AST

These themes are strongly reflected in the observations made during the classroom visits. They are also enhanced by the many informal conversations I had with the teachers during the classroom visits. I discussed many aspects of their teaching and their students with them both during the classes and before or after as the opportunities arose. I would ask about their thinking behind their teaching practices, their relations with their students and the successes and difficulties they had with the implementation of AST. My recollections of these informal conversations are included in the findings from the visits and interviews and, as such, form an important part of this ethnographic study. As described in Chapter 6, I observed the AST activities in four different schools through the same thematic lenses. In the final chapter of this dissertation I will triangulate these findings by linking the teacher interview data with the classroom observation findings.

7.1.1 Teachers' Theme 1: Teacher background

The educational background of the six teachers is very varied. Trudy, Celina, Lianne and Michael had science university preparation – all of them in a biology-related field. Two studied biology and chemistry, a third, microbiology and the fourth, genetics and environmental biology. All six are veteran teachers, with between 6 and 23 years teaching experience. All have taught sciences for most of their careers. Only Madeline has taught the sciences of the QEP exclusively. The other four have experience teaching both pre-QEP and QEP sciences at different levels. They are thus able to compare AST and its curriculum and approach to the previous Quebec science outlined earlier in Chapter 2.

7.1.2 Teachers' Theme 2: AST Curriculum and Approach: Personal Approach

The questions I posed to the teachers allowed them to describe their personal feelings for and approach to AST. The AST curriculum asks teachers to center their teaching of scientific and technological problems around practical, real-world applications of science and technology. It recommends a constructivist/inquiry-based approach and requires teachers to integrate engineering technology into their teaching. The teachers described how they approach AST and in some cases the adjustments they are making or plan to make to conform to the curriculum approach.

All six teachers discussed their personal attitude and approach to teaching and how it fits in with their work in the AST program. All of them emphasized their comfort with the program and what they have had to adapt in their practice. Sally, who had no science educational background, likes learning with the students. "I'm a co-learner," she says. "I learn a lot from them. I learn from their questions." She likes the fact that AST pushes the students to solve problems and learn science from having done activities first. She enjoys solving problems with her students. Conversely, Trudy, a trained biology teacher, described herself as a traditional science teacher – teaching the science concepts first and then backing them up with hands-on lab activities. She talked about how she has started the process of changing to the AST approach of presenting activities and problems first. She has begun to use the AST activities in technology to direct the learning before beginning the scientific concepts. Like Trudy, Lianne is also moving toward the AST approach. She says "Sometimes labs need to generate content and other times we need to consolidate the scientific method in the traditional way (teaching concepts first)."

Michael, on the other hand, has been a self-described constructivist throughout his teaching career: "This new approach wasn't much of a paradigm change for me. The actual planning of lessons hasn't changed for me." He likes giving the control of the projects to his students. "When they get the challenge I try not to help them," he says, and adds, "but I'm a sucker and help them if they really need it!" Madeline, too, agrees with the primacy of the hands-on activity as the start of the learning of concepts. Her approach is to begin with a small activity and build on that rather than "go after the big picture right away." "I'm a hands-on type of person," she says.

From their answers to these questions I detected an emerging comfort level and enthusiasm for the direction that AST has taken science teaching. While I would describe four as constructivist teachers, two, Trudy and Lianne, are moving in that direction - towards a learner-centered/ student control approach. All six are science teachers who embrace a hands-on approach and the approach that AST requires seems to fit in with their teaching methodology, albeit with the many adjustments due to the addition of engineering technology and the applied approach.

7.1.3 Teachers' Theme 3: Pedagogy - Constructivism/Inquiry

Having recognized that all six teachers have adapted their practices to fit the AST approach, the next theme which emerged from the discussions was the extent to which their teaching practices are constructivist and inquiry-based. As previously discussed in Chapter 2, a constructivist/inquiry based classroom is student-centered. It is one, based on the Constructivist Learning Model (Yager, 1991), in which the students construct their own knowledge and understanding in an active learning environment. Students do real scientific inquiry on topics that relate to them in the real world. The discussion I had with the teachers gave me insight into the extent to which they follow a constructivist/inquiry-based pedagogy.

All of the teachers strongly espouse an active learning environment. Sally was very clear: "I find they learn more if I have them do an experiment." Sally described an activity which demonstrated her practice of having the students develop their own procedures and approaches to solving a scientific problem. Referring to the constant velocity car activity, described in Chapter 6, she said "They had to figure out the procedure and figure out error possibilities. This was the best lab because I gave them nothing. They figured it out completely on their own – materials, methods. There was always some complication. I want to do all my labs like that next year." For Michael, not only does the learning have to be active, but the students need to move frequently. "I have to get them up and moving for maybe only 5 min. … I have to think of something to get them out of their chairs," he says.

Giving the students control over their learning is an aspect of constructivist teaching methodology which they all discussed. Celina believes that the students should come up with their own designs whenever possible and use a trial-and-error process when things don't go right at first. She feels that the planning and design phase of a project is key to having them construct their understanding. As noted earlier, Trudy believes in or uses a more structured approach, which is why she finds it difficult to relinquish control. Trudy_was critical of her own reticence to give up this control. She felt that she gave her students too much direction this year– the procedures to follow and the data tables to complete. Her intention was to change this: "Next year we'll have them talk about it and develop their own procedure and data tables." She plans to give her students more responsibility and work with the other teachers to train their students for this, not only in AST, but also in the Science and Technology classes in Secondary 1 and 2. Like Trudy, Lianne agreed that her teaching was in the process of taking a more inquiry-based direction with more emphasis on student discovery.

Madeline agrees that the learning has to mean something to her students personally. "If you start with something very large they want to see how it's related to them. It can be a daunting task. They can relate more to it…" She strongly endorses the aspect of inquiry in her teaching. "If it's something that happens in the news. The oil - spill everyone had heard about. We did an experiment where we simulated an oil spill in a tub of water in the back and had to try to figure a way to contain the spill and clean it up."

7.1.4 Teachers' Theme 4: Student Engagement – Motivation and Behaviour

Motivation: Within their pedagogy of constructivism in an inquiry-based classroom, the teachers described their students' motivation to learn science and their behavior as learners. Among four out of the five teachers, a common theme in motivating students to learn science was the need for students to find personal meaning in what they are learning. According to Sally, "You have to think of things more broadly or the students don't see the value in it. Students need to see the value in what you are teaching." Lianne explained that "If you connect them to their real lives they understand it better and they become more interested. They can relate to it." Michael linked his students' high motivation to their natural, perhaps rurally-inspired, liking for building things. Madeline pointed out that because of the personal meaning that her students get from their AST activities, “their motivation is more intrinsic.”

None of the teachers brought up (due to personal modesty, I assume) the fact that their personal teaching skills, including their understanding of student drive, are a major factor in their success in motivating their students. During my classroom observations I was struck by their strong teaching skills – their understanding of how students learn, their close personal relations with their students, and their ability to get the best from them. When I mentioned to Michael that it was obvious to me that his students really liked him and his class, he admitted that it was true. He stated that students in general “are all about the teacher and how they feel about the subject – not the curriculum topics.”

Two teachers did however link the nature of the science curriculum directly to their students’ motivation. Both Michael and Lianne teach other Secondary 4 sciences and point out that their AST students are much more motivated than the ST or EST (advanced Secondary 4 program) students. Michael indicated that this is a persistent problem: “The most unmotivated kids are in the ST. In the ST section it’s always a fight to get in work from them. It’s been the same over the last 3 years.”

Behaviour: In my years as a career educator, the issue of student behaviour has always been a concern for teachers. Classroom management concerns have always centered on the problem of motivating students so that they will be engaged with their learning. If they are not, disruptive behaviour is often the result. My observations during my classroom visits indicated to me that AST engages students. Teachers connect this with personal meaning and active learning.

Three teachers made links between motivation to learn science and student behavior. Sally said that her AST class was a good illustration of that link. She said that many of her AST students create many discipline problems in the school – but not in AST. She points out that she has to make sure to keep her students active. “If they aren’t doing something they get out of control. They need to be handling or manipulating or taking things apart. Every time they get out of hand I have to find something for them to do.” Michael said that he makes no referrals to the office for his AST students for disciplinary purposes. “Kids in general like the program”, he said and then he added with a little smile, “They will often come here to chat and try to get out of other classes to be in science.” Celina agreed that with an engaging activity students want to stay and see it through. In fact she said that they sometimes want to begin their planning before the first class so that they can get a head start on the project. I asked Madeline how she dealt with a pair of students who were not doing any work in class on their bridge project. She told me that her solution was to isolate them from the students they had been socializing with by having them work on their bridge in another room by themselves.

7.1.5 Teachers' Theme 5: Tools, labs and technicians

The implementation of AST required teachers to develop their pedagogy in conformity with the program and prepare their curriculum to include technology and science applications. In most cases, to do this required the updating of their labs to make them into technology labs by installing or refurbishing floor-mounted tools and the required infrastructure for operating them. Teachers, students and technicians had to be trained in the use of the tech labs. Activities had to be prepared to deliver the technology aspects of AST. In describing their implementation of AST three teachers brought up their use of the tech labs, five discussed their relationships with the lab technicians.

Tech Labs and Tools: Sally and Michael talked about their frequency of use of the tech labs. For Sally's class, a total of about one and one-half months was what they needed to do three major activities. The rest of the time they used their well-equipped classroom for their activities. She explained that they only need to go to the tech lab when the activity requires the big tools. It is a space very conducive to scientific inquiry: "Students know that they have to do work there when they go there." For Michael the tech lab has not changed the way he teaches. His class is very familiar with the room and they are in and out of it on a very regular basis.

The use of tools was not an issue among the three teachers who discussed them. The students seem to like using them and are not intimidated by them. Michael explained, "I wasn't worried about tool use. For me I didn't even blink with this new requirement." Only three (Sally, Michael, and Madeline) talked about tool use in the interviews, while Trudy, Celina and Lianne did not. In my classroom visits, however, I observed all of them using tools with considerable comfort and skill.

Lab Technicians: Lab technicians maintain the science and technology laboratories in all schools. They manage the purchase and maintenance of equipment, tools and consumable materials. The help supervise students during activities and work in close collaboration with the teachers. The four who brought up the lab technicians' role were adamant that without them they could not do the activities that they do. As Sally says, "Lab techs? I could never do without them!" All four of the teachers rely on them to assemble and prepare the necessary materials. Two teachers also have the technicians help them plan activities and rely on them for certain aspects of the planning: "Leslie knows how much wood we need and all other materials. She suggests different materials to make things work better. She is essential." In Michael's school they have a lab tech and a wood room tech. "The science tech will help look for ideas. The woodshop fellow maintains the tools but doesn't help in the planning" he explained.

7.1.6 Teachers' Theme 6: Administrative Issues and Student Selection

Teachers are generally not directly involved with the curriculum choices that students make or the programming issues that surround these choices. It became clear from these interviews that student choice is the driving force in the enrolment of students in AST. In response to the question "Who takes AST?" they all had some comments to make about these issues. They all began by stating that it's up to the students to choose whether to take ST or AST for Secondary 3 and 4. From their comments, however, it became clear that different schools have different policies which affect who actually enroll in AST. Sally explained that while, at her school, students are free to choose AST or ST, only the ST students are offered the advanced EST program and that "Only advanced kids can get into physics or chemistry." Thus students interested in pursuing the sciences in subsequent grades are likely not to choose AST. In Michael's and Madeline's schools on the other hand, the advanced courses are offered to both AST and ST students, so eligibility to take Secondary 5 sciences is not limited. As Madeline explained, "It's purely up to the students. It also depends on which options are open to them and whether or not they can fit it in. They are allowed to choose the (advanced) option if they wish."

There are other factors affecting the students' choice of program. Sally, Lianne and Michael talked about how the students meet with their teachers and guidance counselors to discuss what program would be most appropriate for them. While parents simply want what is best for their children, it is unclear to them what "best" means. And for students, Sally says, "It depends on what they want to do, but they don't know what they want." Michael points out that at his school, "there is a big difference between those who take AST in 9 (Secondary 3) and those who don't. Stronger kids tend to take AST. I don't know why. In this school the impression is that if you're smart, take AST. It's been this way for three years." Celina also pointed out that her Secondary 3 AST class was made up of strong students, but that they would all be steered onto ST for Secondary 4.

Where the school is located may also have an effect on the students' choice. Michael makes a link between the rural nature of the area served by his school and the choice of program. "This is a very rural area," he explained. "Many live on farms or on hobby farms, so a lot of kids have grown up in a tech hands-on environment. They like the AST."

7.2 Interviews with Principals

While teachers provide an insight into the nature of the AST program and students from their perspective, their principals presented me with a background for the administrative and organizational aspects of the implementation of AST in their schools. They also provided me with an understanding of the community's reaction to the implementation of AST.

Table 7.2 Principals

Name	Gender	School	Board	Age range	Years as administrator
Mark	Male	Howland HS	Montreal B	60s	20-25
Judy	Female	Lake HS	Montreal B	40s	10-15
Jessica	Female	Maple HS	Rural	50s	5-10
Nelly	Female	Trudeau HS	South Shore	40s	5-10

The principals responded to the following questions:

1. Please describe any differences you have heard of or observed yourself between the AST and ST classes in your school.

2. What feedback have you received from parents, teachers and students regarding the AST course?
3. Do you find or hear of increased or decreased motivation for learning science among students in AST?
4. Do you receive requests from parents and students regarding either choosing or avoiding the AST program?
5. Are ST and AST offered to all students regardless of ability?
6. Do you program AST in such a way as to be able to offer AST students the SE program and thus be eligible for Chemistry and Physics in Grade 11?

The following themes emerged from the interviews:

1. AST program and AST/ST Differences
2. Feedback from parents, teachers, students and community
3. Student engagement
4. Programming and selection of students
5. Staffing: Teachers and technicians

7.2.1 Principals' Theme 1: The AST program and AST/ST Differences

Nelly from Trudeau HS was the only principal to discuss the AST program at length and with considerable curriculum knowledge. She had been a science teacher for many years at the same school where she is now the principal. The other three were aware of the administrative issues, but not the curriculum ones. Judy and Mark knew that AST was being taught competently but could not comment on the course content or the methodology. They were not aware of any parental or teacher concerns about the program. Jessica and her vice principal Nadia, while not commenting on the program itself, did discuss the problem of the changing evaluation and reporting system. They were concerned that the element of teacher judgment has been removed from the creation of student marks. They worry that this might affect the success rate of their students.

Nelly also expressed concern about the exams. “There is now confusion about the exams as they’re going back to 50-50 and content-based with multiple choice questions,” she said. She worried that the teachers are now confused as to what should be emphasized to prepare the students for this type of exam: “The teachers will have to roll the dice to figure out what to emphasize. It will be a couple of years before they understand the tendencies.” For the students the changing exam format was also a big concern. She pointed out that “some students have never seen a multiple choice question (having come up through the Reform). Kids had no clue that the correct answer was one of the choices given!”

Nelly talked about the community reaction to AST, “The buzz is that the general (ST) is like the old way it was and the applied (AST) is a bit new and scary.” She said that they had an initial impression that AST would be easier because it is more hands-on than AST. “It is not an easier course,” she pointed out. Though there may be a little less content to cover, AST is just as challenging as the ST program especially with its greater emphasis on technology than ST.

7.2.2 Principals’ Theme 2: Feedback from parents, teachers, students and community

Three of the four principals had received no substantial feedback about the AST program from parents or students. Jessica and Judy find that the parents can be confused about whether their children should choose ST or AST as they prepare to enter Secondary 3. All four principals say that the students seem happy with the choice they make and few want to switch at the end of Secondary 3.

Unlike the other three, Nelly has received a lot of feedback from parents about the AST program. “We have incredible positive feedback from parents.” She said. “Now they are amazed at what their kids are doing. ‘My kid never used to like science.’ they say. They are now saying that their kid loves science and that’s partly the course and partly the teacher.”

7.2.3 Principals’ Theme 3: Student motivation

Motivating students in AST does not seem to be a problem according to all four principals interviewed. Discipline problems are absent from these classes. “They tend to like their science” says Jessica, “compared to CST math where there are sometimes problems.” Both Nelly and Judy say that the technology component is what motivates them. This was not a topic about which they had much to say.

7.2.4 Principals’ Theme 4: Programming and selection of students

This theme touches on school organization, an area where the principals show considerable interest and expertise. School requirements for science programs vary significantly. Mark and Judy pointed out that in their schools they only offer the advanced Secondary 4 science programs to students in ST, not AST. This means that AST students will not be eligible for Chemistry and Physics in Secondary 5. However Judy reported that a door is still open for AST students:

“The school board offers a summer bridge course for those who can handle it.” Those that pass are welcomed into the Secondary 5 sciences.

In Nelly’s school, students are offered the advanced programs in Secondary 4 in both ST and AST. She points to the difficulty of offering all the courses to all the students. “We have to live in the reality of the programming,” she says. “I have to balance the science and the math groups. Decisions have to be made to balance groups. Sadly some don’t get their first choice.”

In terms of equipping the student with the information they need to choose between ST and AST, all principals reported that they engage in a number of initiatives. Science teachers in Secondary 2 inform their students about the choices for the following year. Guidance counselors organize information sessions for parents and students. According to Nelly it has taken three years to learn how to prepare the students for the choices they have to make. “We now have a better handle on the programs when we describe them to the students. We are placing kids more effectively.”

7.2.5 Principals’ Theme 5: Teachers and technicians

Judy and Nelly were the only two to bring up teacher quality as a factor in the success of AST at their schools. According to Judy, “The teachers are great and that’s part of the reason there are no problems.” Nelly talked about how the choice to become an AST is not always easy for a teacher. Many don’t feel well enough trained to handle the technology in AST and others are uncomfortable with using tools in the tech labs. Those that do choose to teach AST however are strongly motivated and do great work with the students. In reference to the current Secondary 4 AST teacher (Madeline), Nelly said, “She’s doing a great job. The kids are very comfortable. She is teaching applied properly and well. They’re accomplishing things they never knew they could.” She also pointed out that the teachers and technicians make a great team. “The technicians are super. They just run with things - their expertise and comfort level and their ability to work with the teachers to develop ideas cooperatively and collaboratively. ”

7.3 Interviews with Consultants

Each of the English school boards in Quebec has consultant responsible for overseeing the teaching of high school Science and Technology in the schools. While in the smaller boards, one consultant may have a number of different portfolios, in the larger boards, one consultant has science as his or her only portfolio.

> Consultants are usually hired from the teaching ranks and tend to be known as strong, innovative teachers among their colleagues and school administrators. They are often selected not only for their skills and dedication as a teacher, but also for their demonstrated, or perceived, leadership skills. Generally they are respected by their colleagues and have a positive influence on them. Science consultants lead curriculum change and pedagogical innovation in the schools. They also lead change by many behind-the-scenes organizational activities: meeting with their counterparts in other boards, conferring with the ministry representative, participating in the preparation of evaluation instruments, advising the school lab technicians, organizing professional development opportunities for teachers, and participating in personal self-improvement opportunities. (K. Elliott & Asghar, Forthcoming)

In this section I will describe the interviews I have had with three science consultants from three of the largest English school boards in Quebec regarding the implementation of AST in their schools. Two of the three consultants I interviewed were from the school boards where I made classroom observations. I felt that it was important to get their perspective from a board-level point of view. They understand the curriculum requirements from a pedagogical perspective as well as the broad organizational issues that the board deals with – what courses to offer, how to prepare teachers for them and how to support the schools.

Table 7.3 The Science Consultants

Name	Gender	Board	Age range	Years consulting science
Joanne	Female	Montreal A	40s	5-10
Cindy	Female	Montreal B	30s	5-10
Marilyn	Female	South Shore	40s	5-10

The interviews were based on the following questions:

1. Who takes AST in your school board?
2. How are you supporting AST teachers?
3. What are teachers saying about AST?
4. What, if any, are the differences in teaching approach between ST and AST?
5. What are this issues involved in student choice?
6. To what extent are AST students in secondary 4 continuing to Chemistry and Physics in secondary 5?

The following themes emerged from the interviews:

1. AST enrolment – the extent to which students choose AST rather than ST

2. AST Curriculum and Pedagogy – the nature of the teaching methodology used by AST teachers and the extent to which the AST curriculum is followed
3. Support for teachers – how consultants help AST teachers with professional development and AST activities

7.3.1 Consultants' Theme 1: AST enrolment – Who Takes AST?

School boards vary greatly in their procedures for enrolling students in AST, according to the consultants I interviewed. All 3 Consultants cite difficulties of programming the many Secondary Science and Technology courses as well as parental perceptions of the academic level of the AST course. They explained the three different administrative approaches to AST enrolment.

1. Montreal Board A: AST is offered in Secondary 3 only – with the exception of one small school where it is offered in Secondary 4. The result is that in 5 high schools AST is offered in Secondary 3 but almost all students take ST in Secondary 4.

2. Montreal Board B: Students have the choice of AST or ST in both Secondary 3 and 4, but AST enrolment is limited in Secondary 4 by the fact the advanced SE is not offered to AST students, thus making them ineligible for Chemistry and Physics in Secondary 5. Exceptionally, one out of the 11 high schools does offer SE to AST students. Thus for 10 of the 11 high schools Secondary 4 is the last time most AST students will take science courses.

3. South Shore board: All schools offer both AST and ST in both Secondary 3 and 4. Each school decides if and how to offer the SE advanced course in Secondary 4 on a year-to-year basis.

Joanne described the programming situation at Montreal Board A as follows: “In many schools there is just one core class of AST, while in other schools AST is offered as a free choice. There is often a parental perception that the applied class is for weaker students.” All of the consultants point to the problem of the complexity of programming both AST and ST along with the advanced programs which accompany them. Some schools find it very difficult to schedule all of these courses. The compromise many make is to offer only the EST advanced program to the ST program and leave aside the SE advanced program for the AST students.

At a suburban South Shore board, AST is offered to all students. This is also done in combination with SE, the advanced program, for those students who want to continue with science in Secondary 5. The consultant admits that this causes programming difficulties with some schools and that there is no guarantee from one year to the next that it will always work. One school requires conditions for enrolment in the AST/SE combination. These include a recommendation from guidance counselors and teachers as well as simultaneous enrolment in higher level math courses.

7.3.2 Consultants' Theme 2: AST Curriculum and Pedagogy

The three consultants described the approaches that their teachers take to the teaching of AST. A common theme was the difficulty of integrating technological applications into the course content. Since the Technological World receives more attention in AST than ST (MELS, 2011b), they feel it is important to support teachers in developing technological applications in content areas throughout the 4 Worlds. This problem is particular acute in the Secondary 3 AST program with its theme of the human body. "Teachers at the Grade 9 (Secondary 3) level struggle with finding enough technological applications having to do with the human body. It's harder to find technology to integrate the applied approach", said Joanne.

Marilyn linked the constructivist approach to learning with the AST program. She said that, though it not written explicitly in the QEP, the understanding is that it is intended that teachers begin a new topic with an application rather than the scientific theory. In fact she points out that the early training sessions from the MELS emphasized the importance of beginning with the application of a scientific concept first. This places a concept in a context that students are familiar with thus allowing them to better access their prior knowledge of and interest in the subject at hand. She also pointed out, in agreement with the Constructivist Learning Model (Yager, 1991), that "Minimal instructions should be in all science courses. They design their own experiments. That's the way to develop the competency."

Cindy illustrated the pedagogy of AST with an example of the approach to teaching pressure in gases. “In AST the focus is the technology and the science that is applied to it. For example, in studying the science of air pressure ST begins with the theoretical study of pressure and gases. AST, on the other hand, begins with the tire and how it inflates. In both cases they learn the science of the gas laws.”

AST, with its emphasis on the applications of science and technology, calls for the extensive use of laboratory facilities to help students develop their understanding not only of the scientific theory but especially the technological aspects of the curriculum. All consultants agreed that the lab technicians are vital contributors to the maintenance of the labs, the development of lab activities, and the encouragement of students to succeed in AST.

Marilyn pointed out that the lab technicians train the teachers in the safe use of the tools which are now an important aspect of the technology labs. With technicians’ help and supervision in the labs, the students are now at ease using the tools and equipment. She also suggested that they also help create and develop excellent AST activities in collaboration with the teachers.

7.3.3 Consultants’ Theme 3: Support for teachers

The consultants described their support for teachers as being a variety of isolated activities they participated in with their teachers. They talk about how the AST teachers struggle with their understanding of the “applied” nature of AST. They also referred to the training sessions given to their teachers by the MELSsponsored STIC team. While at one board the teachers, in general, did not find the STIC workshops useful, the teachers from two others found them very helpful, especially in the area of engineering design and the technology aspects of the AST content. Much of the support they give to the teachers is on an ongoing needs basis and involves informal meetings and communications by email and through portal communities.

Joanne described a number of different initiatives she was taking with her AST teachers. She works with one group on a monthly basis, for example, during which time they do curriculum mapping to plan activities. This helped with the planning early in the implementation process. She has a provincially-sponsored project with another group of teachers where they are developing a handbook for AST teachers – mostly around the theme of technology – with curriculum maps and resources.

All three consultants point to the ongoing networking initiatives they work with. They support their teachers by using their school board portals and websites to distribute teaching ideas, evaluation instruments, activity descriptions, and other suggestions as they arise. They encourage and occasionally facilitate teachers in the schools in collaborating together on their planning and carrying out of learning activities (LESs).

7.4 Analysis/Synthesis – The Interviews

Here I am going to synthesize the main factors that are critical to the implementation process and seemed to be important to all three groups. The AST teachers, the school principals and the school board science consultants view AST from different perspectives. What follows is a synthesis of what they all said in terms of the similarities in their points of view and the differences they expressed. I also will analyze the implications of the discussions on the implementation of AST.

AST curriculum and approach: AST is very different from the Secondary 4 programs of the past. Basing the learning of science on the applications of science is an approach that is new to the schools and has required major changes in teaching methodology, laboratories and equipment. Teachers have had to integrate technology into the curriculum in all sciences, but especially AST where The Technological World receives more emphasis in the classroom and on exams. This has required a great deal of professional development coordinated by the school board science consultants and MELS as well as collaborative efforts by teachers to develop learning activities.

Pedagogy - constructivism/Inquiry: An active learning environment is characteristic of AST classrooms. Increasingly students are given control over their learning. They are involved in the planning of activities and taking responsibility for the learning that they get from them. Many of the activities are based on the realities and interests of the students – bringing the real world into the classroom.

Concern is growing about the evaluation of students in Secondary 4 MELS compulsory exams. The fact that the exams have many multiple choice questions and require a lot of recall of scientific facts is causing teachers to spend less time on constructivist/inquiry-based pedagogy and more on traditional teacher-centered transmission of “the facts”.

Student motivation and behavior: Students like AST. They like the active, hands-on nature of so many of the activities. They find that they can relate personally to the topics and this contributes to their high motivation. There seems to be a strong link between positive student behavior and motivation to learn in AST. Student misbehavior is almost non-existent. Another factor in the high student engagement with AST is the high quality of the teaching. Teachers teach AST by choice. Its pedagogy fits in well with their belief system.

Use of tools, labs and technicians: The tech lab is an important learning area in AST. AST classes regularly work in these labs depending on the nature of the work at hand. They are equipped with both floor-mounted and hand held tools. Students are at ease with these tools and use them effectively for AST activities. Teachers received extensive training in tool use and are beginning to become comfortable with them. Lab technicians are essential to the success of AST lab work. The make sure that all the required equipment is on hand and often help plan the activities. They also oversee the safe operation of the tools and other equipment.

Administrative/ Student selection: School boards and schools vary greatly in how students choose or are chosen for AST. Enrolment is limited in some schools by the fact that the advanced courses are offered to ST students only. It is complicated to schedule all of the advanced Secondary 4 science programs and many schools cannot fit them all into the timetable. However some schools manage to offer the full set of courses and students are free to choose for themselves.

Teachers, guidance counselors and principals prepare the students carefully so that they can make an informed choice between ST and AST. Information sessions are held for students and their parents. In some, mostly urban, schools AST is seen as the program best for weaker students. In other rural and suburban schools, on the other hand, AST attracts the top students.

Interviews with teachers, principals and consultants have added another set of qualitative data to this study of the implementation of AST. In the final chapter, I will synthesize the data from all the sources, both qualitative and quantitative, to come up with a set of conclusions about the implementation, recommendations for improvement and suggestions for further research.

Chapter 8: Synthesis

What has been learned from this Study?

Since 2010 I have been studying the implementation of Applied Science and Technology (AST) in English High Schools in Quebec. Beginning in the 2008-09 school year, as part of the Quebec Education Program (QEP), AST has been implemented across the province in Secondary 3 and 4. Students have the choice of Science and Technology (ST) or AST at these two levels.

I have pursued three main aspects of AST throughout this study. First I investigated what was behind AST in terms of learning theory and pedagogy and how AST was different from traditional science programs. Next I wanted to find out how AST is being taught, both across the province and in selected classes in the Montreal area. This involved finding out who takes AST, who teaches it, what teaching practices are followed, and what tools and equipment are used. Finally I wanted to put my pro-AST values to the test and see whether or not participating in AST classes engages students and motivates them to want to learn science.

What follows is a synthesis of the findings of this study. In each of the preceding chapters I recounted in detail the methodology, data analysis and the findings of each research instrument separately – teacher and student surveys, interviews of teachers, principals and science consultants, and classroom visits. In this final chapter I bring it all together and analyze the findings in terms of the research questions.

First I review the theory and vision of AST – how it fits in with the QEP and where it stands with respect to constructivism and inquiry-based pedagogy in science. Next I bring together my research findings regarding the implementation of AST in Quebec schools in terms of the curriculum under the heading Description. Then I present the findings on the Outcomes - the effects of AST on student engagement and motivation to learn science. Finally I present policy recommendations which arise from my findings.

As described in Chapter 3, as Director of Educational Services for a large school board in Quebec, I had a very close involvement with the implementation of AST as part of my responsibility for the oversight of the QEP. This included responsibility for professional development of teachers, provision of teaching materials and the furnishing of the tools and equipment required for AST (and all other Science and technology programs). My involvement with this study, immediately before and after my retirement from work, made me both a researcher and a source of research information with an approach highly valuing AST and its pedagogy. As described in Chapter 3, Methodology, I assumed a reflexive role in this research. In this dissertation I refer frequently to my previous personal involvement in the implementation of the QEP as well as my own personal comments during the qualitative research activities (Flick, 2011; Lincoln & Guba, 1985; Miles & Huberman, 1994).

This was a mixed-methods study which combined both quantitative and qualitative research methodology (Bryman, 2007; Creswell & Plano Clark, 2007). Extensive quantitative data was gathered from the teacher survey, the student survey and enrolment data (Gordon & McNew, 2008; Ritter & Sue, 2007; Topp & Pawloski, 2002). Qualitative data came from the AST classroom visits in schools and interviews with teachers, principals and science consultants (Emerson, 1995; Kirk, 1986; Maxwell, 2005; Miles & Huberman, 1994). Each of these sets of data has been extensively described in the preceding chapters of this study. I triangulate the findings of each part of this study to arrive at a comprehensive set of conclusions regarding the implementation of AST in our schools.

8.1 Theory: Applied Science and Technology – What's behind it?

AST is one of the programs in Mathematics, Science and Technology - one of the six Subject Domains in the QEP. In AST students develop three competencies – solving science and technology problems, making the most of science and technology knowledge and communicating in the language of Science and Technology. Students must choose AST or ST for their science and technology option in Secondary 3 and 4 and write a compulsory MELS exam at the end of Secondary 4.

Three aspects of AST differentiate it from the programs in the past:

- The integration of engineering technology with the science content
- The pedagogy of constructivism and inquiry-based learning
- The use of real-world applications of science as tools for students to learn scientific concepts.

Technology: The decision to introduce engineering technology into the Science and Technology programs is based on extensive worldwide research linking the use and understanding of technology to improved learning in science (Bybee & Fuchs, 2006; Charland, 2009; Loiselle, 2009; UNESCO, 1983). Implementing technology education has required AST teachers to alter their science teaching practices to include engineering design and related laboratory activities in their curriculum. Professional development offered by school board consultants and MELS has been extensive. As a result, teachers now include engineering design in many of their activities, not only in AST, but also in all levels of Science and Technology. Some of these activities were described in Chapter 6.

Constructivism/Inquiry-based Pedagogy: As described in Chapter 2, in the past 60 years of science teaching in Quebec the science methodology has moved from behaviorist to constructivist/inquiry-based pedagogy. The programs of the 1950s and 60s were teacher-centered with some hands-on “cookbook-style” labs. Through the 70s and 80s science programs became more activity-oriented. In the 90s, with the introduction of Physical Sciences in Secondary 4, constructivist methodology became explicitly prescribed. Now, AST and all the Science and Technology programs of the QEP are constructivist/inquiry-based. In a constructivist and inquiry-based learning environment the students construct their knowledge in an environment of active learning, built on their own prior knowledge with learning activities which are meaningful to them and in which they have control over the process of the activities (Driver R, 1994; Louise Lafortune & Deaudelin, 2001; Tobin, 1993; Windschitl, 1999; Yager, 1991). They work in an atmosphere which mimics the real world of science (NRC, 2000).

As described in Chapter 6, students are actively constructing their own knowledge and understandings doing activities in which they are increasingly in control of the decisions as to the nature, procedures and materials.

Applications of Science: AST places its learning emphasis on the applications of science and technology in the real world (MELS, 2007). The Technological World occupies a much larger place in AST than in ST. In all the content areas of AST the emphasis is more on the technological applications than in ST (MELS, 2011b). Students are focusing attention on real-life applications in many of their learning activities. Often teachers lead up to a scientific concept with an activity or a description of an application which is meaningful to the students personally.

8.2 Description: Curriculum, Pedagogy, Enrolment and Support

In this section I bring together the findings from the teacher and student surveys, the classroom visits and the interviews. I review these findings on a theme-by-theme basis, triangulating the findings into broad conclusions. Many common themes emerged from the surveys, interviews and classroom observations. They are triangulated into a multi-perspective analysis of the implementation of AST. Four main themes emerged from this study regarding the description of how AST is being taught as elaborated in Table 8.1 below.

- AST Curriculum: What’s in AST – content and activities
- Pedagogy: How it’s being taught
- Enrolment: Who takes it – programming and gender

- Support for Teachers: Professional development and ongoing help

Table 8.1 Themes and Sub-themes

Theme	Sub-Theme	What this Means
AST Curriculum	AST Content and Evaluation	The extent to which teachers follow the content of AST as described in the QEP and how they evaluate students
	AST – ST contrast	Differences in approach and content
	Labs – Tools, Equipment, Technicians	How teachers conduct lab activities and their use of tools and equipment The services provided by lab technicians.
Pedagogy	Real World	The extent to which the "real world" is part of the activities in the AST classroom
	Constructivism and Inquiry	The extent to which teaching methodology follows the Constructivist Learning Model and Inquiry-based pedagogy The contrast between teachers' epistemology and their practice
Enrolment	Programming	How school programming affects who takes AST
	Gender	Whether or not there are gender differences in AST enrolment
Support for Teachers	Professional Development	How teachers are trained to teach AST
	Ongoing Support	Support available to teachers to help them on an ongoing basis.

8.2.1 Theme: The AST Curriculum

Curriculum Content and Evaluation: Since teachers from across the province responded in large numbers to the teacher survey, the findings can be used to make general statements about teachers' response to AST. In the student survey, students from selected classes responded. Both the teacher and student survey agreed that teachers are thorough in their coverage of the Four Worlds in the AST curriculum. The Science and Technology curricula from Secondary 1 through 4 all base the content on the Four Worlds: Living World, Material World, Technological World and Earth and Space. Interviews with teachers and findings from classroom observations show that AST teachers tend to place more efforts on the Technological World and less on Earth and Space. This emphasis is reinforced by the fact that 40% of the Secondary 4 AST exam is on the Technological World (MELS, 2011a). Surveys showed a strong emphasis on the content of the Material World and the Living World – the latter especially in Secondary 3. Teachers' told me that their unfamiliarity with Earth and Space could account for its lesser emphasis. The Progression of Learning also indicates that Earth and Space topics need only be covered in Secondary 4 (MELS, 2011b).

Technology in AST: From the interviews and classroom observations it is clear that there is a much greater emphasis on the Technological World in AST than in other programs. Students and teachers reported in their surveys that they frequently work with technological objects. Tool use in the tech labs is reported by teachers and observed by this researcher to be much more frequent in AST as well. Probably the biggest difference, however, is the AST emphasis on the study of applications of science and technology.

Evaluation/Assessment of AST: From the teacher interviews and classroom observations, it became clear that teachers assess their students using a variety of evaluation instruments. They use Learning and Evaluation Situations

(LESs) to assess how their students perform on complex problem–solving tasks. As described in Chapter 2, an LES presents the students with a real-life problem which requires them to use their acquired content knowledge in a variety of areas and show the development of one or more competencies of AST. Depending on the teacher, students do one or two LESs per term. They use more traditional tests and quizzes on an ongoing basis to keep track of how well their students are acquiring the content knowledge, and therefore how successful they are in their teaching practices. They use mid-year and June final exams to evaluate their students' attainment of competencies. A ministry-mandated formula is used to arrive at a final mark for their students, combining the three term marks in a 20:20:60 ratio. As of June 2012, Secondary 4 students must write and pass a compulsory MELS exam which counts for 50% of the final mark (MELS, 2011).

Two major changes in evaluation philosophy are responsible for a major shift in evaluation of students under the QEP. One is the shift from the evaluation of knowledge to the evaluation of competencies. According to MELS, "A competency is the capacity to carry out activities or tasks by drawing on a variety of resources, including knowledge, skills, strategies, techniques, attitudes and perceptions." (MEQ, 2003, p. 2). The other, following from moving from a pedagogy of behaviorism to one of constructivism is "the shift from a paradigm of teaching to one of learning" (MEQ, 2003, p. 2). As a result, with the implementation of AST, teachers moved to the use of LESs to help evaluate the attainment of competencies.

Evaluation issues did not arise during the surveys and the first year of visits and interviews as teachers had not yet experienced Secondary 4 compulsory AST exams. During the second year of interviews and the last year of classroom observations, however, the compulsory MELS exams became an issue. During the interviews, in response to the question of how they evaluate their students, teachers and principals reported that they were concerned that the newly-announced emphasis on multiple choice questions was making teachers worried that the exams were going to emphasize content knowledge at the expense of problem solving ability. Teachers said that this would certainly affect how they taught the course – more content and fewer constructivist (LES) activities. Teachers, consultants and one principal emphasized how seriously this has begun to affect the pedagogy of AST.

The compromises that teachers have to make in their methodology in order to comply with the content driven nature of the assessment systems and its implications for hands-on and problem-based approach are widely reported on in the wider educational community in science and other subject areas as well.

AST – ST Differences: AST is seen as more hands-on than ST according to the descriptions of principals and teachers. According to some teachers, AST is seen as the more difficult of the two but with somewhat fewer scientific concepts to learn. From the interviews and classroom observations it is clear that there is a much greater emphasis on the Technological World in AST. Students and teachers reported in their surveys that they frequently work with technological objects. Tool use in the tech labs is reported in the teacher surveys to be much more frequent in AST as well. Probably the biggest difference, however, is the AST emphasis on the study of applications of science and technology. Students are expected to build, repair and maintain technological objects (MELS, 2007). This aspect of AST was the main focus of most of the activities I observed during the classroom visits.

Laboratory Use: Technicians, Tools and Activities: An important change that the AST curriculum brought to the study of Science and Technology was the change in the vocation of the science lab. With the introduction of the Technological World, schools were required to provide laboratories that could accommodate inquiry-based activities with a technological emphasis. Large floor-mounted tools had to be installed or refurbished. Space had to be adequate for complex activities. The labs had to be maintained and supplied for the activities. The interviews, surveys and visits together showed the complex nature of the task of using the labs to implement AST. The teacher and student surveys showed that while schools were in general well-equipped with appropriate labs, teachers were at different stages of the use of these labs. Many teachers were familiar and happy to use the tools, especially those who I interviewed and whose classes I visited. Other teachers expressed serious concern, using the comment section in the survey, about both the appropriateness of including the technology aspect into the program and their lack of training in the use of tools. Students I observed and talked to were fully comfortable with tool use. Many were surprised that there could be an issue with them. Data from the teacher survey, however, showed that tool use and the full use of the technology lab was not strong for many teachers across the province.

During the classroom visits I observed the work that the lab technicians did. In discussions I had with them, the teachers and their principals, it became clear what an essential part of the science and technology teaching enterprise they are. They prepare the materials for the activities, maintain the tools and equipment, help supervise the students, and, in most cases, participate in the planning of activities. There is unanimous popularity for them and the role they play. Most agree that AST could not be taught adequately without them.

8.2.2 Theme: Pedagogy

Real World: The AST program makes it clear that AST is to be taught in the context of the world that students live in. It describes science and technology as being "characterized by its attempt to develop simple, intelligible models to explain our complex world" (MELS, 2007, p. 1 Chap. 6). Teaching science in a real-world context is an integral part of a constructivist, inquiry-based pedagogy. It is seen as key to sustaining interest and engagement among students (Dewey, 1916; Fensham, 2009; Tobin, 1993; Yager, 1991). Through all the data collection phases of this study, it was clear that teachers and students take the inclusion of familiar real world activities and information as an important aspect of the pedagogy of AST. In the teacher survey, AST teachers across the province reported that they make a concerted effort to contextualize their presentation of

AST topics in the world that their students are familiar with. They often refer to familiar applications of science when they begin new AST subjects.

During the classroom visits and in the subsequent interviews with teachers, I found that the AST activities that the teachers chose to use were always grounded in subjects which their students understood as important and interesting to them. Madeline's bridge project, for example, was based on her community's concern for their bridge's safety. Celina's solar cooker activity developed from her students' concern for clean energy. Michael's hydraulic arm construction project came from his rural community's interest in heavy machinery.

Constructivism and Inquiry: During this study I tried to assess to what extent the teachers have created a pedagogical environment using a constructivist, inquiry-based methodology. As described throughout this dissertation, this includes an active learning environment where students construct their own knowledge and understanding in an environment modeled on real scientific inquiry (Barrow, 2006; Cobern, 1995; Driver R, 1994; Roth, 1993; Stohr-Hunt, 1996; Windschitl, 1999). In their surveys, teachers indicated that they have created active learning environments for the most part. They are less inclined however to have their students construct their own knowledge. The teacher survey results presented in Chapter 4 showed that teachers across the province seldom have students help them plan what they will learn and often give their students detailed instructions for their learning activities. They only sometimes let students develop their own procedures and decide on what materials to use. Having students develop their own procedures and decide on the materials necessary are key elements in student control and these practices were less present according to the surveys. This indicates that they are tentative about giving their students control of the activities.

During the classroom visits, however, I observed that most of the newly-developed AST projects were more constructivist and inquiry-based in nature than the teacher surveys would indicate. Though there were some guidelines given by the teachers I visited, for the most part the students developed their own procedures and decided on their material and equipment needs within their student groups. The surveys of the students in these classes (see Chapter 5) for the most part support these assertions. One exception however, according to the student surveys, is that they seldom help the teachers plan the overall learning.

The teacher interviews gave interesting insights into how they view their own pedagogy of AST. This shed light on the relationship between their epistemology – their beliefs about what knowledge is and how it is constructed - and practice. Sometimes they were in agreement and other times, in conflict. Michael, Madeline and Sally expressed comfort in the constructivist environment and professed to use it in most activities. They make sure that their students do most of the planning and allow them to carry out the activities on their own. They took care, however, to guide their students when they were floundering. Lianne and Trudy struggled with implementing it fully. Both are thoughtful and effective teachers. They expressed that they appreciate the importance of giving students control over their learning, but had not yet fully embraced it in their classroom practices. Both said that they were in the process of moving toward more student control and would implement it more fully the following year. This reluctance to fully embrace constructivist pedagogy is an example of the "constructivist dilemma" discussed in Chapter 2. Teachers are pressured to cover a great deal of content in a time frame which they feel does not allow for the "luxury" of constructivist/inquiry-based practices. This can certainly explain the reluctance of many teachers, like Lianne and Trudy, across the province to fully incorporate constructivist practices.

8.2.3 Theme: Enrolment

Programming: As the QEP Science and Technology programs were being implemented in Cycle 2 high school, school boards and schools had to decide how to program the complex set of secondary 4 courses. As described in Chapter 2, students had the choice of ST or AST as a compulsory base course as well as optional advanced courses to choose if they wanted to pursue Physics and/or Chemistry in Secondary 5. To complicate matters, each of AST and ST had a different option attached to it with different numbers of hours and units. ST had a 4-unit option called EST and AST had a 2-unit option, SE (MELS, 2007). This made programming very difficult in an already tight schedule in Secondary 4.

On top of this organizational problem was an added problem – perception of the comparative value of ST and AST. When AST was first introduced to the school community, teachers and parents understood that AST was designed for students who wanted a more hands-on, engaging learning environment. This was the intention of the MELS when they produced the QEP Science and Technology programs. What they did not anticipate was that many members of the community would interpret this as giving a lower status to AST with respect to ST. Many parents, and some teachers and principals, thought that AST, being more "hands-on" and more "applied", was for those with lower academic aspirations. Interviews with teachers, principals and consultants confirmed that, among the two largest boards, one offers almost no AST while the other programs it in such a ways as to allow very few Secondary 4 AST students to pursue further studies in science in Secondary 5 by not offering the advanced SE to AST students (except in one school). In other off-island boards the situation was quite different. While some schools offer only limited AST, others have large AST enrolment and in fact accord AST the higher status by enrolling the stronger students in it. The only generalization that can be made about provincial enrolment is that is very varied.

Enrolment Data: I include enrolment data here to give a province-wide picture of who takes AST. I requested enrolment data from all Quebec English school boards and received complete data from 4 out of 9, information from a fifth board that they offer no AST and from a sixth board that they offer AST in Secondary 4 at only one small school. This represents about 80% of the total enrolment in Secondary 4 Science and Technology across the province. The AST enrolment varies considerably from board to board and even from school to school in many boards. This does allow for certain conclusions to be made concerning enrolment of AST vs that of ST. In general many more students take ST than AST. As an illustration, Table 8.2 summarizes six boards' enrolments.

Table 8.2 AST Enrolment Secondary 4 - 2011-12 School Year

School Board	Number ST	Number AST	%AST students
Board 1 (rural)	391	56	13%
Board 2 (Urban) (2010-11)	1325	757	36%
Board 3 (rural)	179	169	49%
Board 4 (rural/urban)	1170	233	17%
Overall – 4 boards	3065	1216	28%
Board 5 (rural)	All students	0	0%
Board 6 (urban)	All students except 1 class in 1 school	1 class	<2%

As Table 8.2 shows, the percentage of students taking AST in Secondary 4 varies considerably. Within these boards the school statistics vary considerably as well. Many of the larger schools have only 1 class of AST and most students enrolled in ST. Some smaller schools offer only ST or AST. A few large schools offer only ST and I have found one large school which has most students in AST. Interviews with principals, teachers and consultants shed light on the reasons for the differences:

- According to two principals and two consultants, it is difficult to program all the science and technology courses in the tight Secondary 4 schedule.
- Schools favored the ST over AST when they felt that a choice needed to be made since ST seemed to be closest to what they had offered in the past and most familiar to parents and teachers.

Gender: Data from the same three boards shows that the percentage of boys enrolled in AST varies from school to school and board to board. Table 8.3 shows these board by board enrolments by gender.

Table 8.3 Overall Enrolment by Gender in Sec 4 AST-2011-12 School Year

School Board	Number of girls	Number of boys	% Boys
Board 1	33	44	62%
Board 2 (2010-11)	332	425	56%
Board 3	77	92	54%
Board 4	110	82	43%

From Table 8.3 it can be seen that, for the most part, boys are enrolled in AST in greater numbers than girls. This varies widely from school to school however. The classes I visited, for example, varied widely in enrolment by gender as shown below. Table 8.4 summarizes the Secondary 4 AST enrolments by gender in the classes in the study.

Table 8.4 Enrollment by Gender – Secondary Classrooms Visited

Teacher	Number of Students	Percent Boys
Sally	**25**	**76%**
Lianne	**19**	**79%**
Trudy	**18**	**72%**
Celina	**35**	**54%**
Madeline	**25**	**64%**
Michael Class #1	**25**	**44%**
Michael Class #2	**25**	**36%**
Total Students	172	59%

Gender differences vary widely from class to class. The three highest percentages for boys were in the classes where students are not eligible for Secondary 5 sciences. In the two classes with the lowest percentages of boys, students are eligible for Secondary 5 sciences. Boys seem to predominate in classes where science is not part of their future academic plans. They will not be pursuing science in Secondary 5 because of the programming of the school; they don’t have an extra optional SE course to get into Physics and Chemistry. This is an area that would require a more in-depth study in order to draw firmer conclusions about boys and girls in AST.

Enrolments (ST vs AST; girls vs boys) vary considerably from board to board and even from school to school across Quebec. Overall one can conclude that

- There are far more students in ST than AST across the province but the proportions vary widely from school to school and board to board.

- More boys than girls take AST in Secondary 4.

8.2.4 Theme: Support for Teachers

Supporting teachers to enable them to implement the AST curriculum was an issue discussed in Chapter 4 – Teacher Surveys and Chapter 7 – Interviews (with consultants). AST has required teachers to make considerable changes in what they teach and how they teach it – to reconcile their epistemology with their classroom practices. The curriculum has changed markedly with the addition of engineering technology. Teachers are required to use technology labs with a new set of tools and other equipment. They are increasingly required make their activities constructivist and inquiry-based. An important aspect of the implementation of AST has been the supporting of teachers to enable them to adapt to these new requirements. Much has been written about the need for and the nature of the support teachers need in order to change their teaching methodology and course content to meet the requirements of a reformed curriculum (Fullan, 1993; Louise Lafortune & Deaudelin, 2001; Pelletier, 2005). Referring specifically to the implementation of the QEP, Lafortune (2009) advocates for strong “accompaniment” of teachers – closely guiding and supporting teachers in their new situations. Researchers call for greater collegiality (Khourey-Bowers, et al., 2005), greater time spent on professional development (Shymansky, et al., 2004), and deeper understanding of science concepts (Jeanpierre, et al., 2005).

The teacher survey revealed that professional development is an important element in teachers' ability to teach AST effectively. The survey found that those who expressed the most satisfaction with their support also had the highest AI Index scores – thus correlating their AST teaching effectiveness with the professional development support they received. Consultants gave a comprehensive picture of the nature of the support that teachers receive in Chapter 7. Interviews with consultants shed some light on the efforts that have taken place to get AST up and running as well as the ongoing initiatives to help teachers continue to make progress. They described the workshops to introduce the program, the training sessions from the MELS STIC[6] team, their ongoing contact with the teachers on an individual basis, their involvement with teaching resources (textbooks, guides, LESs from LEARN, online portals, etc.) and their promotion and facilitation of collaboration with other teachers.

In my role as leader in the Educational Services Department in one large school board, I oversaw the work of the science consultants and participated in these support efforts. One area in which consultants gave strong support was the production of assessment and evaluation instruments. Looking at old exams enables teachers to understand where they need to place the emphasis in their teaching. Science consultants from all boards still collaborate in an annual process of preparation of year-end exams for different levels of Science and Technology under the auspices of MaST. As the years pass, the bank of these exams increases in size with the addition of the latest exam questions. Consultants

[6] The Science and Technology Implementation Committee (STIC). They deliver teacher PD mostly on technology aspects of the programs.

also coordinate the collection of Learning and Evaluation Situations (LESs) prepared by teachers and groups of teachers working together under individual school and board initiatives as well as part of ministry-funded professional development projects. Consultants take the lead in the production and distribution of teaching materials and meet with teachers to help with and promote AST activities (Elliott and Asghar, forthcoming).

An interesting angle on teacher support was given by one principal. She pointed out that the AST teachers may need less support than other ST teachers because they tend to be strong supporters of AST and quite anxious to teach it, and therefore more likely to be comfortable with its content and pedagogy. Among the teachers I visited and interviewed, external support was not considered to be a big need. Their confidence level in their own program and abilities made them feel that external support was not necessary. In fact consultants often met with two of them to get ideas from them on how to help other teachers.

Finally the discussion of teacher support would not be complete without mentioning the support given by the lab technicians. As described earlier, they are unanimously described by the teachers as being an essential element in the successful implementation of AST in their schools.

8.3 Outcomes – Are students motivated to learn AST?

In this section I will describe the study's findings regarding aspects related to student motivation. I will triangulate the findings from both the student and teacher surveys with my observations of AST classes and what the teachers and principals had to say during the interviews. The evidence paints a very positive picture of student motivation in AST. Put simply, students like being in their AST class and are strongly engaged with the AST activities. Table 8.5 summarizes the theme.

Table 8.5 Student Motivation

Theme	Sub-theme	Comments
Student Motivation	Motivation to learn AST	Evidence of motivation during AST activities
	Student behavior	Student behavior during AST activities
	Gender differences	Comparison of boys and girls engagement with science activities.

Motivation to Learn AST: As described in Chapter 2, Pink (2011) describes what drives students to want to learn – autonomy, mastery and purpose. If students have control over their learning, can strive to improve, and see what they are learning as significant to them, then they are more likely to be motivated to learn. Flow Theory, described in Chapter 2 proposes that students are intrinsically motivated to learn when they pursue activities for their own sake, not for reward or to avoid punishment (Czikszentmihalyi & Nakamura, 2005; Kohn, 1999).

In this study, evidence of student motivation came from a number of sources – the teacher surveys, the student surveys and the classroom visits. The teacher surveys reported on the teachers' perception of student motivation in AST across the province. The student surveys and classroom visits involved seven

Secondary 4 AST classes with a total of 172 students. A powerful piece of evidence for how motivated students are to learn science in AST is the student survey. In other words, to find out how they feel, ask them! Of the 172 students I visited 99 responded to the student survey. The vast majority of these AST students made it clear that they like AST, they are more interested in learning science than before and they like the discussions and activities. They also reported feeling confident in their abilities to solve problems and understand the concepts. They are happy with their decision to choose AST. Students from all of the classes surveyed had similar positive feelings.

The teachers concur with these findings. They reported in the teacher survey that they find the students overwhelmingly positive about doing the AST activities, and this was an observation from teachers across Quebec. They find students to be positive about discussing and doing real life applications of science and technology.

In my classroom visits I watched carefully for evidence of student motivation and enthusiasm for AST activities. Observing the students and teachers in action allowed me to analyze different aspects of student motivation – the links of motivation with pedagogy, student-teacher relations, nature of the activities, successful results. As the visits progressed, certain aspects of the activities seemed to link to higher motivation:

- Personal meaning: If the students could relate personally to the activity they showed more enthusiasm, wanted to succeed and spent most of their time on task.

- Student control: When students had a real say in how the activity should be carried out and what materials to use, they showed determination to succeed and spent time in concentrated efforts to solve the problems.
- Challenge: Students reacted positively to challenge. They displayed enthusiasm when they had to solve a difficult problem. If the task was too easy, or results predetermined, they displayed boredom – often evidenced by off-task social behaviour.
- Active hands-on learning: These AST students liked "doing" science. They liked using tools and other equipment as part of the problem solving. They appreciated the confidence their teachers showed in their ability to handle tools safely and responsibly and decide for themselves what they needed to do to achieve success in the activities. One negative aspect of this was that it was difficult for the teachers to get their students to take the time to write their detailed plans before beginning the hands-on work. I noticed during my visits that they allowed their students to get to the project as soon as possible and recognized that their planning would happen during the project often on a trial-and-error basis. The detailed plan was required only after the fact as part of the written report.

Discussions with students as they were working on their projects were an important part of the evidence for student motivation. They made it clear that they were happy with their choice of AST because it gave them access to active hands-on problems to solve and minimized theoretical discussions and text book-oriented experiments and content.

Interviews with teachers and principals confirmed my impressions from the surveys and classroom visits regarding student motivation. They agreed that students like being in AST. They acknowledged that students appreciate getting personal meaning from AST. Principals added that the high quality of the teaching is another positive factor in student motivation. Students like being in AST, but so do the teachers! Though it might be initially hard to recruit AST teachers, the ones that do volunteer do a great job delivering the program to stimulate the AST students.

Student Behaviour: Studies have showed that when students are engaged in their learning, they tend to be more engaged in their work and exhibit less off-task and disruptive behavior (Kohn, 1999; Pugh, et al., 2010; Vedder-Weiss & Fortus, 2011).

Observing AST classes in action provided the most compelling evidence for the relationship between the nature of AST activities and student behaviour. It was clear how seriously students took their work. When comparing a constructivist AST activity (eg. The Toy Project) to a traditional teacher-directed lab (eg. The Friction Lab) with the same class and teacher, the difference in student behaviour was remarkable. While meaningful personal involvement was high in the former activity, the Friction Lab had little of that. Students reacted by frequent off-task behaviour – social interactions, disruptions and unproductive chaos. During activities which were constructivist in nature, the teachers seldom had to reprimand students or remind them to get to work. Students used their time in class productively, attending to the task at hand. Discussions I overheard among students were almost always about the work they were doing. When the activities were more teacher-centered (i.e. when students had little say in the procedure and what they were doing was more theoretical and less meaningful to them) behaviour became more of a problem. Teachers frequently had to call on students to quiet down, stop socializing and attend to their work.

The teacher interviews confirmed that student behaviour in AST was not a big issue. They linked the intrinsic motivation engendered by the AST curriculum as a factor in reducing the need for them to impose disciplinary measures on their students. In fact those that teach both AST and ST said that in many cases it is the ST students who are less motivated and therefore tend to need more disciplinary interventions. The principals concurred with this assessment – that discipline problems are largely absent from AST classes.

Gender: According to the student survey, boys and girls seem to be equally motivated to learn AST and both experience similar positive feelings of success in their AST activities.

While observing the AST classes, I paid attention to any differences between the level of involvement of boys and girls to see if there were any gender differences. I took note of the gender mix of the working groups and the interactions of the boys and girls. No real differences were evident. The student groupings were very varied. In general working groups consisted of two or three students, sometimes single-sex and sometimes mixed. In the mixed groups leadership roles were assumed by both sexes depending on the group. I did not notice any difference in enthusiasm, on-task behaviour or work ethic. There were no observable gender-related patterns.

8.4 Discussion and Implications of this Study

The purpose of this study was threefold: to find out the extent to which the theory and philosophy of the Applied Science and Technology curriculum is incorporated in the teaching of AST in English Schools in Quebec, to find to what extent the pedagogy of constructivism is embedded in the classroom, and to gauge the level of motivation and engagement of students in the learning of AST. In this penultimate section I will discuss what this study tells us about some important issues concerning the implementation of this curriculum from teachers' perspectives.

<u>Constructivism</u>:

- How constructivist is the pedagogical approach used by the teachers?
- What are some of the impediments to using a constructivist pedagogy?

<u>AST Curriculum:</u>

- Do the classroom practices reflect the MELS AST curriculum?
- What are some of the impediments to following the curriculum?
- What is the influence of professional development on the teachers' abilities to deliver the curriculum?

<u>Student Motivation to Learn Science and Technology</u>:

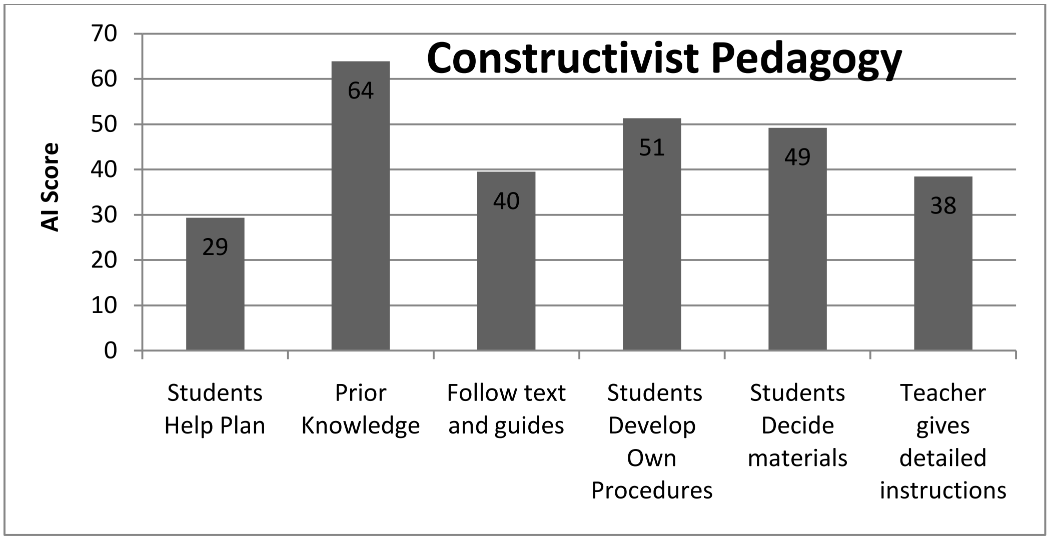
- What factors influence the positive attitudes of students toward the learning of AST?

8.4.1 AI Score

As described in Chapter 3, I developed the Applied Index Score (AI) as a tool to quantify and analyze a teacher's self-reported effectiveness as an AST teacher in terms of their delivering the curriculum, use of constructivist pedagogy and motivating their students. It enabled me not only to look at teachers' effectiveness overall and by category, but also to analyze the trends of AST teaching across the province. I was able to analyze the different categories of questions and relationships among questions by establishing correlations among them and calculating significant differences.

8.4.3 Constructivism

Constructivism as a philosophy of learning is the main theoretical construct of this study. The classroom practices of AST teachers were constantly viewed with respect to the degree to which they adhere to constructivist teaching philosophy (Bybee, 2002, Dewey, 1916, Driver, 1994, Tobin, 1993, von Glasersfeld, 1996, Windschitl, 2006). One of the main findings is that the teachers' use of constructivist pedagogy is very varied. The diagram below (from Chapter 4) shows that the questions making up this category have AI scores which are very varied. This is one illustration of the difference in teachers' epistemology - their belief about what knowledge is and how it is constructed - and the pedagogy recommended by the AST program.



This indicates that teachers from across the province embrace certain aspects of constructivism but have reservations about others. The most consistency in favour of constructivism is in the area of accessing prior knowledge, one of its cornerstones. On the other hand, teachers are quite consistent in their reluctance to let students help them plan their learning activities. In both of these areas, the findings agree across all data collecting instruments, both qualitative and quantitative. What the teacher province-wide survey and the survey of students in the classroom visits did show, however, was that teachers are much more positively disposed to having their students develop their own procedures and decide what materials to use while doing activities. In other words, once the teachers have decided what the learning activities will be, they give some of the control over the implementation of those activities over to the students – a partial constructivist approach. Both teachers and students seem happy with that arrangement.

This finding fits in well with Yager's (1991) Constructivist-Behaviorist continuum in which teaching practices in the science classroom can vary on the scale according to the needs of the teacher and the teaching situation (See Chapter 2, p. 26 for the full table). This study has shown that different teachers can situate themselves at different places on the continuum depending on the aspect of pedagogy in question. The data from surveys and visits show that certain issues tend to be more on the constructivist side of the continuum such as:

- "Issue seen as relevant"
- "Students take actions"

Some are more on the Behaviorist/Objectivist side such as:

- "Identifies the issue / topic"
- "Students practice self-evaluation"

Still others tend to be somewhere in the middle such as:

- "Identifies written and human resources"
- "Plans investigations and activities"

In agreement with Bybee (2002), Dewey (1916), Driver (1994), Potvin & Dionne, 2007, Tobin (1993), von Glasersfeld (1996), and Windschitl (2006), the teachers in the classrooms observed resist the temptation to "pour in" the facts but rather put their students into situations so that they can construct their own understandings of scientific phenomena – but always under the watchful eye of the teacher to make sure that students don't get too far off track. Social constructivists like Driver (1994) and Palinscar (1998) advocate for the deliberate exchange of ideas among students - the co-construction of knowledge. In all of the activities I observed, students worked in groups of two or three in an atmosphere of purposeful and active sharing of ideas. In fact the student survey showed that students strongly prefer working with partners.

Impediments to Constructivism: Constructivist activities take time. All of the activities I observed took from to two to seven class periods to complete. Teachers told me repeatedly that students need time to think through their plans to solve these complex problems. They readily admitted that it would be much faster (and some would say, more efficient) if they gave their students full instructions and asked them to simply follow them step-by-step.

A second impediment is the final exam. While some research shows the benefit of standardized exams for qualifying for higher education and employment (Bishop, 1997), others advocate for alternative evaluation systems for assessing deep understanding in line with reformed curricula (McDowell, 1995, Sadler & Zeidler, 2009). Though the evaluation of the final exam was not part of this study, teachers, consultants and principals, especially in the year leading up to the first compulsory provincial final exam, frequently told me that they had to give up some of the time-consuming constructivist activities so that they could concentrate on the content they felt would be part of the exam. They felt strongly that the exam would not reflect the constructivist nature of AST and therefore it was in the best interests of their students to abandon some of the constructivist pedagogy in favour of drilling content knowledge. This was another challenge to their epistemology – forcing an unwelcome change of their teaching methodology. A thorough study of the final AST exam would show whether or not the teachers' fears were well founded.

A third impediment to constructivism is philosophical – the teachers' epistemological views on the efficacy of constructivist pedagogy. There is abundant literature by cognitive psychologists which opposes constructivist pedagogy (Kirschner, Sweller, & Clark, 2006; Mayer, 2004). Some teachers in the teacher survey expressed agreement with this opposition. Two of the teachers selected for classroom observations also discussed their initial reservations with the pedagogy but, with experience teaching it, decided to adapt their methodology to a more constructivist approach.   Some teachers, as expressed in the survey comments and in private conversations with me over the years, remain to be convinced of the learning potential of constructivism. They are constantly weighing in their minds how to get their students to learn better. In my experience most teachers come to the conclusion that there is not one way to teach. They know from experience that they must match their methodologies to the learning situations at hand. For example they may need to give a presentation on a particular concept in front of the whole class to prepare them for an activity they are planning or to prepare them for a content –specific test or exam. They often have to vary their approach according to individual needs of some students. For example while some students are fully able to proceed with a constructivist activity on their own, others need a more directed approach to help them make progress in the same activity. Part of the art and skill of teaching is to know when to use what approach.

8.4.2 AST Curriculum

One of the aims of this study was to find out the extent to which teachers follow the MELS AST curriculum. While, according to the teacher survey, teachers seem to cover the more traditional content areas quite thoroughly, they are less inclined to deal with operations with technical objects and tool use – the new aspects of AST which make it so different from the previous science curricula. The Technological World and its associated study of technical objects and use of tools are not necessarily in their comfort zone. Recall that the teacher survey respondents were teachers from across the province and not specially selected for their participation in the survey.

Tools and Technology: The six teachers I visited in their classrooms, however, were selected for their adherence to the program, their enthusiasm for AST as well as for their science teaching skills and experience. They did not exhibit the same weaknesses with regard to the operations with technical objects and tool use. They and their students were much more at ease with tool use as they reported in surveys, interviews and conversations and as observed during the classroom visits. This contrast between the classes I observed and the province-wide survey shows that there is a gap between the general province-wide reality and the potential. In fact, if the individual teacher survey results are examined, it can be seen that there is a wide spectrum of progress from little technology and tool use to the frequent use shown by the six teachers. A repeat of the teacher survey in a year or two would likely produce higher AI scores for the tool use and

AST curriculum categories as teachers become more comfortable with these aspects of the curriculum.

Applications: The study of the applications of science is the basis for learning scientific theory in AST (MELS, 2007, p22). While the study found that AST teachers do focus on applications, it was not clear to what extent teachers begin a scientific or technological topic by first introducing a scientific application of it. While teachers reported in the survey that they sometimes do, students in the selected classes said that they often do. The MELS AST curriculum document does not clearly state whether or not applications should come before theory, but many teachers and consultants interpreted the program to state that applications should come first. This needs to be clarified to teachers. This question could be the subject of further research.

Teacher Support - Professional Development: The need for and nature of the professional development (PD) required to implement inquiry-based science curriculum is widely researched (Jeanpierre, Oberhauser, & Freeman, 2005; Khourey-Bowers, Dinko, & Hart, 2005; Shymansky, Yore, & Anderson, 2004). Most of the AST teachers surveyed reported that they had attended school board- and/or MELS-organized STIC workshops in preparation to implement AST. These workshops, attended by teachers with their colleagues, typically involved both overviews of the AST curriculum and its content as well as practices and activities directly applicable to the classroom. There was a significant correlation between the AI score and their participation in school board STIC workshops ($r=.332$; $p=.01$, $n=63$). This is particularly true for their ability to use tools (r=.349; p=.01, n=63) and their delivery of the AST curriculum (r=.318; p=.01, n=63). In other words, these formal workshops seemed to make a difference in their ability to teach AST especially in the areas of technology where they are less familiar. Interestingly, teachers often complain that their attendance at large centralized PD workshops is a waste of their valuable time – that they could spend their time more productively preparing their courses on their own or with their immediate colleagues. This study questions that assumption and shows that there may be value especially when new programs require that they work out of their comfort zone.

PD is particularly effective if it focuses on specific teaching practices and has the participation of teachers from the same school or subject (Desimone, Porter, Garet, Yoon, & Birman, 2002). From the interviews with teachers, principals and consultants it was clear that a multi-pronged approach is favoured. There is a pattern of large board-wide and STIC workshops to introduce the program at the beginning of the implementation, followed by ongoing consultant meetings with smaller groups of teachers to answer the particular needs of individual teachers and schools. The issue of the effectiveness of teacher professional development is discussed on an ongoing, regular basis among science consultants in Quebec (Elliott & Asghar, forthcoming).

8.4.4 Student Motivation and Engagement

A third aim of this study was to find out to what extent students are motivated to learn science and technology with constructivist pedagogy and the AST curriculum. One remarkable and unexpected finding was the consistently high level of student motivation to learn AST and their rapt engagement with the learning activities. They like it. Research shows consistently that students are motivated to learn science when they find personal meaning in what they are learning (Bergin, 1999; Fensham, 2009; Gallagher & Tobin, 1987; Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2010). Intrinsic - as opposed to extrinsic - motivation is another factor in high student motivation (Deci, Koestner, & Ryan, 1999; Kohn, 1999). This study showed that when students did activities that they considered relevant to them personally, the level of engagement was high evidenced by a very high degree of on-task behavior, determination to complete the activities successfully, and overtly espressed pleasure in the process. Under these circumstances students also expressed that they liked the work because it interested them and not for the marks or threats of negative consequences.

Comments from the student survey, for example, are almost totally positive. 38 students responded in the optional comment section at the end of the survey. Only four were somewhat negative. Thirty four were very positive. Most were simple expressions of youthful exuberance like: “Science is the besttttttt!!!!!!!!”, “It's Absolutely Amazing”, “much better than general science”, and “This is awesome!” Others were more thoughtful, for example, “Applied science is a class best for those who enjoy doing hands-on projects and enjoy learning by example rather than theory.” All aspects of this study, the surveys, visits and interviews, produced data which concur with this positive finding regarding student motivation. AST seems to be a positive experience for students.

The way AST activities are carried out in the classes I observed are consistent with Flow Theory and Drive (Czikszentmihalyi & Nakamura, 2005; Pink, 2011). Students have a substantial degree of autonomy in designing procedures and selecting materials. They are motivated by the activity to strive for mastery - achieving to the best of their ability. They see real relevance or purpose in what they are trying to accomplish. As reported in Chapter 6, the stark difference in observed student engagement between the constructivist Toy Project and the behaviorist study of heat capacity is evidence for the differences in motivation for the two types of activity. Recall that the classes observed in this study were regular classes (as opposed to enriched groupings of students) which were taught by highly recommended teachers. A closer look at the motivational aspects of AST among teachers across the province would be of interest to the furthering of understanding of student engagement in science.

8.4.5 Gender Differences in Student Motivation

This study (see Chapter 5 for the student survey and Chapter 6 for the classroom observations) showed no significant gender difference between the attitudes to learning science among the AST students. These findings do not agree with current findings in the literature which report that there have been consistent gender differences in the interest show toward the learning of science for decades (Catsambis, 1995; Jones, Howe, & Rua, 2000; Osborne, Simon, & Collins, 2003; Weinburgh, 1995). Weinburgh (1995) explained, “Over the last 21 years, boys have consistently shown a more positive attitude toward science than girls. This has not appeared to change over time." (p. 396).

Student attitude towards learning science is a complex issue which involves among others, academic performance, self confidence, interest in science-related activities, career interests, curriculum content, and teacher skill (Osborne, Simon, & Collins, 2003). Further research into AST student attitudes would certainly be necessary to understand the results of this study.

8.4.6 Strengths and Limitations of the Study

In this section I will describe some of the strengths and limitations of the study of the implementation of AST. Among the strengths are the

- comprehensiveness of the mixed-methods methodology
- high degree of Alpha Cronbach reliability scores

The limitations discussed here are

- the selection of classes to visit
- the lack of measures of student learning in AST

The study's main strength comes from the mixed-methods nature of the description of the teaching practices, pedagogy and student motivation. All aspects were described and analyzed from multiple points of view, both quantitatively and qualitatively. While each method gave an incomplete picture, the combination together presented the full story. The province-wide story that the teacher survey told was completed and enriched by the classroom observations of selected classes and the interviews with teachers, consultants and principals. Students told their side of the story in the student surveys and elaborated on this in the informal discussions with me during the many visits to their classes. While the teacher survey gave me a picture of the average situation across the province, the visits and interviews showed me what the potential of AST was –with highly recommended teachers in ideal learning environments with regular (not enriched) classes.

Reliability among the questions of both the teacher and student surveys was another strength of this study. Anderson (1990) describes reliability as "the extent to which subsequent administrations (of the test or survey) would give similar results" (p. 12). After the study was completed, I subjected both the teacher and student surveys to a series of Alpha Cronbach tests and found a very high level of reliability.

Some of the study's strengths however also were some of its limitations. By visiting the classes of highly recommended teachers only, I did not get a picture of the classroom atmosphere of the average AST class. I did not witness the difficulties experienced by struggling teachers, or those without the tools and equipment of the ideal set-up.

I restricted the study to AST classes and teachers only. This prevented me from fully understanding the AST vs ST differences and the advantages and drawbacks of the ST program and pedagogy. Restricting the student survey to those on the selected classes only deprived me of data from AST students in less ideal situations. Their points of view would have been very informative and given me a more complete picture of AST from a student's point of view.

This study did not tackle the very important question of the effect of AST on student learning of science and technology. This was beyond the scope of the research questions. Further investigation of students' performance on ministry exams and other evaluation situations would have given a greater understanding of AST's value to how students learn science and technology.

8.5 Recommendations from this Study

Studying the implementation of AST first hand has given me an opportunity to reflect on the nature of science pedagogy. Throughout my career, I have always been puzzled as to how a subject as intrinsically interesting (to me) as science could turn off so many students by the time they reach the end of their secondary studies. As a science teacher, science consultant, school administrator and curriculum director, I never stopped wondering how science should best be taught so as to both create a scientifically literate society and instill a love of learning about the natural world that surrounds us.

I have now studied the implementation of AST from many different points of view. As I explained in Chapter 3, I was personally involved with the initial phases of its installation. I personally supervised the curriculum planning, the school facility upgrades, the teacher professional development and the preparation of teaching resources. This study has extended my understanding by allowing me to watch classes in action, talk to teachers, principals and consultants, survey teachers across the province and survey and talk to AST students.

What follows is a set of recommendations to the science education community including teachers, school administrators, science consultants and government and school board policy makers regarding the future of Applied Science and Technology.

AST Curriculum and Pedagogy: AST is a radically different program from the high school science courses of the past. The inclusion of technology, the pedagogy of constructivism and the emphasis on applications of science make it unique.

Recommendations: Technology

- Ensure that schools are equipped with the tools, materials and technical support to carry out the activities in the Technological World.
- Evaluate the need for special training for teachers in the use of the tech labs. Some need it; some don't.

Recommendation: Constructivism/Inquiry-based Pedagogy:

- Make the pedagogy of constructivism explicit. Ensure that teachers understand the basic elements and include them in a certain number of learning activities.

Recommendation: Applications of Science

- Ensure that many of the learning situations in AST are applications-based – that teachers begin with the application and then expand the resultant understandings to the learning of the relevant scientific theory.

Recommendation: Personal meaning

- Make sure that there is always a meaningful link to the students' real lives when devising an AST learning situation.

Recommendation: Student control

- Let the students many opportunities to make their own decisions as to how to solve a problem or proceed with an activity. Let them decide on the procedures and what materials to use. Be judicious in when to intervene and when to give directions.

  Recommendation: Challenge

- Make the activities real problems. Do not provide a detailed list of instructions. Require the students to use their own reasoning ability to come up with a working hypothesis for the project.

  Recommendation: Active hands-on learning

- Keep the students moving, thinking and manipulating. Have them research, talk and hypothesize. Have them use tools and equipment regularly and safely.

Support for Teachers: Teaching AST has required that science teachers make substantial changes in the science content they teach and the way they teach it.

Recommendation: Provide AST teachers with ongoing support in the following areas:

- curriculum content changes, especially the Technological World
- the methodology of using applications of science as the basis to teach the scientific theory
- using a pedagogy of constructivism and inquiry-based learning. Include support on how to build in student control over their projects.

Programming and Enrolment: It is difficult for many schools to offer the full range of science and technology courses to Secondary 4 students. As a result there are many differences between schools and between school boards as to how they program AST and the number of students who enroll in it.

Recommendations:

- Emphasize that AST and ST are equivalent programs for students of all abilities and that both can lead to successful participation in Secondary 5 sciences and, subsequently, CEGEP science programs.
- Ensure that AST students have access to the optional advanced Secondary 4 science and technology programs to make them eligible for Secondary 5 sciences.

Evaluation of AST students – Exams: With the inclusion of multiple-choice content-oriented questions in the compulsory final AST exam in Secondary 4, teachers report that they must now adjust their AST approach to include more traditional content, leaving less time to pursue the required constructivist/inquiry-based pedagogy.

Recommendation:

- Those in charge of creating the MELS final AST exam ensure that the evaluation of students be done in such a way as to respect the pedagogy outlined in the QEP. An evaluation needs to be done comparing the nature of the exams with the AST program. Precise recommendations need to be made as to how to bring the two into agreement.

8.6 Future Directions

This is probably the first study to be done of the implementation of AST. As in so many early investigations, there are many questions which arise during the course of the study which need to be studied further. As I devised the various qualitative and quantitative instruments and then analyzed the findings many new questions arose – questions that could not be answered by this study, but which I think merit further study. Here are some of them.

1. Student performance results: How do AST students do in Secondary 4 MELS compulsory exams? How do AST students' results compare with those of ST students? In this study I had originally intended to tackle these questions but I realized that this would have been premature since the first compulsory MELS exams were just written in June 2012. Drawing conclusions from these results would not have been valid.

2. Gender: Does the AST approach appeal to boys more than girls and do boys do better in AST than ST? This would help science educators better understand how boys learn science in this era of concern over the academic achievement of boys and their high dropout rate in Quebec.

3. Efficacy of constructivism and inquiry-based learning in science education: Using AST classes as a research theatre, it would be instructive to experiment with different approaches to inquiry-based constructivist activities to refine our understanding of which approaches work best.

4. Programming and perception: Since some schools program AST and its Secondary 4 SE option into the students' schedules and others don't, it would be

important to find out what factors and conditions lend themselves to enabling all students to have access to AST and SE in order to open up advanced science learning in Secondary 5 and CEGEP for more students.

8.7 Final Statement

Applied Science and Technology is an innovative new program which is inspiring students to learn science and technology with enthusiasm, knowledge and skill. It is being taught successfully in many classes across the province and many inspirational AST teachers are leading the way to showing that science can be learned in new and meaningful ways. It has been a privilege to be associated so closely with its implementation and to observe and talk to so many dedicated science educators.

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APPENDICES

APPENDIX A: Quebec Education Program - Broad Areas of Learning and Cross Curricular Competencies

Broad Areas of Learning

- Heath and Well-Being
  - To ensure that students develop a sense of responsibility for adopting good habits with respect to health, safety and sexuality
- Career Planning and Entrepreneurship
  - To enable students to make and carry out plans designed to develop their potential and help them integrate into adult society
- Environmental Awareness and Consumer Rights and Responsibilities
  - To encourage students to develop an active relationship with the environment while maintaining a critical attitude toward consumption and the exploitation of the environment
- Media Literacy
  - To enable students to exercise critical, ethical and aesthetic judgment with respect to the media and produce media documents that respect individual and collective rights
- Citizenship and Community Life
  - To enable students to take part in the democratic life of the class or the school and develop an attitude of openness to the world and respect for diversity

- **Cross Curricular Competencies**
  - Uses Information
  - Solves Problems
  - Exercises Critical Judgment
  - Uses Creativity
  - Adopts Effective Work Methods
  - Uses Information and Communication Technologies
  - Achieves his/her Potential
  - Cooperates with Others
  - Communicates Appropriately

APPENDIX B: Invitation to AST teachers to participate in the AST Survey

Dear (School Board) Science Teacher;

I am a doctoral student in science education at McGill University. I have been a science educator and administrator for most of my career in education – teacher, consultant, school and board administrator (ESD at LBPSB). My interest is in science teaching methodology and I have always been curious as to how students learn science best. In particular, I am interested in the implementation of Applied Science and Technology (AST) in the English schools of Quebec. I am curious whether AST is making any difference in how students learn science and technology.

As part of Phase 1 of my research, I would like to find out from you how you teach AST (and ST, for that matter if you teach both) since you face the daily reality of the demands of your students and the requirements of the new curriculum.

This will involve your completing a 29 - item online questionnaire for each of AST and ST – depending on what you teach. It should take you 15 to 20 minutes to complete. Though I will ask you to identify yourself, your school and the science you teach (AST and/or ST), this information will be kept confidential and there will be no way in my report to identify either you or your school. Participation is voluntary on your part and you may withdraw at any point. I will email you again in May 2011 to ask you to do this survey a second time after you have completed the activities for 2010-11.

This research is only for the purposes of my doctoral work. It has been approved by the Lester B Pearson School Board and the McGill Ethics Review Board. Once my data has been collected and analyzed, I will share my overall findings with all participants.

Thank you in advance for your cooperation in this project. Don't hesitate to contact me by return email if you have any concerns about this survey. I would love to hear from you.

Click on this link to begin the survey http://bit.ly/astsurvey

Thank you in advance for your support in this project.
Ken Elliott,
PhD Student, McGill University (and)
Retired Director of Educational Services, LBPSB

APPENDIX C: Consent Letter: Teachers

Date

To: Teacher name

Re: The Implementation of Applied Science and Technology in Cycle 2 Year 2 in English Schools of Quebec

Dear xxx,

I am a doctoral student in science education at McGill University. I have been a science educator for most of my career in education – teacher, consultant and administrator. My interest is in science teaching methodology and I have always been curious as to how students learn science best. In particular, I am interested in the implementation of Applied Science and Technology (AST) in the English high schools of Quebec. I am curious whether AST is making any difference in how students learn science and technology.

As part of my research, I would like to find out from you how you conduct some of the activities in your AST class and how your students react to these activities. I would like to observe a few of your AST classes, interact with your students and interview you about your experiences with teaching AST. I would also like to find out from your students how they participate and learn in the AST class. This will involve their completing a 25 - item online survey – a student version of the one that teachers across the province will be completing.

All nominative information about your students will be kept confidential and there will be no way in my report to identify the student, you or the school. I will share my findings publicly on completion of this study. I would ask for your support in encouraging your students to participate in this voluntary survey. It should take 15 – 20 minutes of their time. Please note that participation in this project is voluntary and you and your students may withdraw from participating at any time.

I hereby consent to participate in the research project "The Implementation of Applied Science and Technology in Cycle 2 Year 2 in English Schools of Quebec". I understand that this consent can be withdrawn at any time and that participation is voluntary.

Signature of teacher: ____________________________

Thank you in advance for your support in this project.

Ken Elliott,

PhD Student, McGill University (and)

Retired Director of Educational Services, LBPSB

APPENDIX D: AST Teacher Survey

Welcome to this survey. Please fill in your background information and answer the 29 questions. Most questions refer to the activities you do with your students in your class and laboratories. All information that can identify you or your school will remain strictly confidential. Please select answers to the first 25 questions based on the frequency of occurrence as follows: 1. Never or almost never 2. Seldom 3. Sometimes 4. Often 5. Almost always Note: AST refers to Applied Science and Technology; ST refers to Science and Technology.

*response required

What is your family name? (First survey only)

What is your first name? (First survey only)

For how many years have you been teaching science? *

School Name School Board * Choose

Courses * Please check all Science and Technology courses that you teach this year.

Lab equipment * Please check the equipment that you have available for use in your AST or ST program

- Floor-mounted tools eg. drill press, band saw, sander, etc
- Hand-held electric tools eg. drill, jig saw, circular saw, etc
- Hand-held non-power tools eg. hammer, saw, sander, chisel, cutter, etc
- Equipment used in previous programs eg. Physical science 416/436, Physics 534, Chemistry 534, etc

Which course? * Choose the course for which you will answer this survey now

Question 1* I include applications of science and technology in the real world as part of classroom activities.

Question 2* When beginning a new topic I introduce the topic by discussing a real life application before discussing the scientific theory.

Question 3* In my class students learn how science relates to their lives inside and outside of school.

Question 4* Students help me plan what they are going to learn.

Question 5* I include applications of science and technology in the assessment of students

Question 6* In my class new learning relates to experiences or questions about the world inside and outside of school.

Question 7* I include diagnosis of the operation of technological objects in the activities in my class.

Question 8* I include repair of technological objects in the activities in my class.

Question 9* I include activities in which students take apart and/or (re)assemble technological objects in my class.

Question 10* I find out what students already know about a topic before an activity or discussion of a new topic begins.

Question 11* Students do activities regarding the applications of science and technology when studying the MATERIAL WORLD.

Question 12* Students do activities regarding the applications of science and technology when studying EARTH AND SPACE

Question 13* Students do activities regarding the applications of science and technology when studying the LIVING WORLD

Question 14* Students do activities regarding the applications of science and technology when studying the TECHNOLOGICAL WORLD

Question 15 * I closely follow the teacher's guide and textbook to direct classroom activities and lab exercises.

Question 16* Students develop their own procedures to solve science and technology problems in the laboratory.

Question 17* Students use FLOOR-MOUNTED POWER TOOLS (drill press, mitre saw, table saw, belt sander, etc) when carrying out activities.

Question 18* Students use HAND-HELD POWER TOOLS (drill, circular saw, hand-held sander, etc) when carrying out activities.

Question 19* Students use HAND TOOLS (hammer, saw, sander, chisel, cutter, etc) when carrying out activities.

Question 20* Students decide what materials to use when solving a science and technology problem in the laboratory.

Question 21* Students do activities in the lab at least once a week.

Question 22* Students react positively when hands-on activities on applications of science and technology are proposed.

Question 23* Students participate enthusiastically in discussions of applications of science and technology

Question 24* Students seem to prefer activities involving applications of science and technology to those involving scientific theory.

Question 25* I give students detailed, step-by-step instructions for laboratory activities

Question 26 * What training did you participate in to prepare you to teach AST (and/or ST)? Choose all the answers that apply to you.

- Professional day workshop(s) given by the school board.
- Workshop(s) given by the MELS - eg the STIC workshops
- Sharing session(s) organized by the school board.
- Visit(s) by the school board consultant
- School-level workshop(s)
- External conference(s)
- Other

Question 27 * In your lesson preparation, what sources of support do you use? Choose all answers that apply to you.

- The Quebec Education Program
- The textbook and/or Teacher's Guide from the publisher
- Materials and suggestions from the school board consultant
- Resources from LEARN
- Resources from MELS
- Resources from the school board Portal community
- Collaboration with teacher colleagues
- Other online resources
- Other

Question 28 * The support I get from the those sources listed in Question 27 is sufficient for me to conduct AST/ST activities to my satisfaction

Question 29 Do you have any further comments about the implementation of AST in your classroom?

APPENDIX E: Student/Parent Consent Letter

Date

Re: The Implementation of Applied Science and Technology in Cycle 2 Year 2 in English Schools of Quebec

Dear (school) Student;

I am a PhD student in science education at McGill University. I have been a science educator for most of my career in education – teacher, consultant and administrator. My interest is in how science is taught and I have always been curious as to how students learn science best. In particular, I am interested in the implementation of Applied Science and Technology (AST) in the English high schools of Quebec. I am curious whether AST is making any difference in how students learn science and technology.

As part of Phase One of my research, I would like to find out from you how you participate and learn in your AST class. This will involve your completing a 25 - item online questionnaire about your experience in AST. I will be observing some classes of AST and may ask you a few questions about your experiences with the activities in the class and laboratory.

All information will be kept confidential and there will be no way in my report to identify you, your teacher or your school. I will share my overall findings publicly on completion of this study. The survey should take 15 – 20 minutes of your time. Please note that participation in this project is voluntary and you may withdraw from participating at any time.

If you agree to participate, please sign this consent form in the space provided:

I hereby agree to participate in the research project "The Implementation of Applied Science and Technology in Cycle 2 Year 2 in English Schools of Quebec". I understand that this consent can be withdrawn at any time and that my participation is voluntary.

Name of Student: __________________Signature: ____________________

Parents:

I hereby give consent for my son/daughter _________________ to participate in the research project.

Name of parent or guardian: _______________Signature: _______________

Thank you in advance for your support in this project.

Ken Elliott,

PhD Student, McGill University (and)

Retired Director of Educational Services, Lester B Pearson School Board

APPENDIX F: AST Student Survey

Welcome to this student survey. It will ask you about your experiences in your Applied Science and Technology (AST)class. Please fill in your background information and answer the questions. Most questions refer to the activities you do in your class and laboratories. All information that can identify you, your teacher or your school will remain strictly confidential. Please select answers to the 25 questions based on the frequency of occurrence as follows: 1. Never or almost never 2. Seldom 3. Sometimes 4. Often 5. Almost always Note: AST refers to Applied Science and Technology; ST refers to Science and Technology.

*required response

What school do you attend? *****

Gender*

Please select answers to the following questions based on how often the following occur in your AST course.

The answers are as follows:
1. Almost never (or never)
2. Seldom
3. Sometimes
4. Often
5. Almost always

Notes to students:
The term "applications of science" means the uses of scientific knowledge. "Technological objects" are the things you may study, take apart, build, or analyze in the class or lab.

Question 1 ***** I learn about applications of science and technology in the real world as part of classroom activities.

Question 2 ***** When a new topic is being introduced, we discuss real life application before discussing the scientific theory.

Question 3 ***** We learn how science relates to our lives inside and outside of school.

Question 4 ***** We help the teacher plan what we are going to learn.

Question 5 ***** Applications of science and technology are part of the evaluations we do in class.

Question 6 ***** New learning relates to experiences or questions about the world inside and outside of school.

Question 7 * In class we do activities in which we investigate how things work.

Question 8 * In class we do activities in which we take apart, study, and/or (re)assemble technological objects.

Question 9 * In class we do activities in which we repair technical objects.

Question 10 * Before we begin a new topic in class, we discuss what we already know about it.

Question 11 * As students we develop our own procedures to solve science and technology problems.

Question 12 * In the lab we use floor-mounted power tools (drill press, mitre saw, table saw, belt sander, etc) when carrying out activities.

Question 13 * In the lab we use hand-held power tools (drill, circular saw, hand-held sander, etc) when carrying out activities.

Question 14 * In the lab we use hand tools (hammer, saw, sander, chisel, cutter, etc) when carrying out activities.

Question 15 * As students we decide what materials to use when trying to solve a science and technology problem.

Question 16 * I would rather the teacher give me a complete set of instructions than figure out some procedures myself or with my fellow students

Question 17 * We do activities in the tech lab at least once a week.

Question 18 * I like it when hands-on activities on applications of science and technology are proposed.

Question 19 * I enjoy classroom discussions of real world applications of science and technology

Question 20 * I enjoy working with tools while doing activities

Question 21 * I prefer activities involving real world applications of science and technology to those involving scientific theory.

Question 22 * I feel I am able to solve problems presented in AST.

Question 23 * I find myself more interested in learning science than I was in earlier grades.

Question 24 * I find that I understand science more easily when learning about practical applications of science and technology.

Question 25 * When doing an AST activity in the lab or classroom, I prefer to work with a partner rather than by myself.

Question 26 * I am glad I chose Applied Science and Technology instead of Science and Technology.

Question 27 * How good is the textbook in helping you understand the work in AST?

Question 28 * What science courses do you hope to take in the future? (Check all that apply to you.)

Question 29 * What was your approximate overall average mark on your report card at the end of June 2010?

Comments: Do you have any further comments about the Applied Science and Technology course?

APPENDIX G: Field Studies: Observation Checklist

Description of activity

- Nature of the activity. Date, Time, Competency(ices), Aim, Process
- AST-specific content and process
- Connection of application to scientific theory
- Teacher's role
    - Direct instruction vs student initiated
    - Evidence of building on prior knowledge
    - Evidence of student construction of knowledge/understanding
    - Nature of student-student and student-teacher interactions
- Nature of assessment of students' work
- Description of materials used: tools, consumables, science equipment

Outcomes

- Evidence of student engagement: students' questions, enthusiasm, concentration
- Evidence of student understanding
- Gender: Evidence of difference or similarity in how girls and boys are treated, how they act, initiatives they take

APPENDIX H: Summary of Classroom Visits

School	Activity	Teacher (s)	Visits	Classes per project	Science Concepts	Tool Use?	Constructivist level	Motivation level
How land HS	Egg Break	Sally	1	1	Force transfer	hand	moderate	Moderate
	Toy Project	Lianne, Sally, Trudy	8	7 :50 min	Motion Engineering Design	Lite Heavy	High	High
	Friction Factors	Sally Lianne Trudy	4	2:50 min	Force of friction	none	low	Low

	Constant velocity toy car	Sally	2	2:50 min	Speed	hand	moderate	Moderate
	Thermal energy	Sally Lianne	2	1:50 min	Factors affecting th energy	none	low	Low-moderate
	Field Trip	Sally	1	1 day	Electricity generation	n/a	n/a	Moderate
	Electricity demo	Sally	1	15 min	Conductance	none	not	Very Low
	Circuits	Sally Lianne Trudy	3	1:50 min	Series and parallel circuits	none	not	Low
	Repair of circuits - ES	Sally	1	1:50 min	Series and parallel circuits	none	moderate	High
	Lab exam	Lianne	1	2:50 min	Circuits	None	not	High
Lake HS	Owl Pellets	Celina	2	2:5 min	ecology	hand	not	High
	Lung Capacity	Celina	2	3:75 min	Respiratory system	hand	Very high	high
	Solar Furnace	Celina	2	3:75 min	Energy transfer	Light and heavy	moderate	Very high
	Anemometer	Celina	2	3:75 min	Engineering design Force transfer	Light and heavy	high	Very high
	Lab Exam Preparation	Celina	1	1:75 min	Circuits	none	not	High
	Tool construction	Celina	1	4:75 min	Motion and energy Engineering Design	Light and Heavy	high	Intense
	Lab Exam	Celina	1	1:75 min	Conductance	n/a	not	High
Map le HS	Bridge Construction	Madelin e	4	7:75 min	Engineering Design Materials	Light and Heavy	Very High	High
Trud eau HS	Hydraulic Arm	Michael	4 Class A	5:75 Min	Engineering Design Forces and Energy	Light and Heavy	Very High	Intense

	Hydraulic Arm	Michael	2 Class B	5:75 Min	Engineering Design Forces and Energy	Light and Heavy	Very High	Intense

APPENDIX I: Interview Themes

Teachers		Principals		Consultants	
Theme	Sub-theme	Theme	Sub-theme	Theme	Sub-theme
Teacher background	Education	AST curriculum and approach	AST vs ST	AST curriculum and approach	AST vs ST
	Teaching Experience		AST Program		Tools
AST curriculum and approach	Personal approach		Assessment and Evaluation		Curriculum Issues
	AST vs ST	Staffing	Teachers		Advanced vs regular AST
	AST Approach		Technicians	Pedagogy - Constructivism/ Inquiry	Constructivism
	Teacher Collaboration	Feedback from community	Parents		Inquiry based
	Assessment and Evaluation		Students		AST approach
Pedagogy - Constructivism/ Inquiry	Active learning	Student engagement	Motivation	Administrative	Enrolment
	Student Control		Behavior		Student selection
Student engagement	Motivation	Administrative	School policy		School organization
	Behavior		Student choice	Support for teachers	Consultant support
Tools, labs and technicians	Labs		Programming		Support materials
	Tools and Equipment				STIC
	Technicians				Textbooks
Administrative Student selection	School policy				Teacher collaboration
	Selection problems				
	Programming				
	Choice reasoning				

APPENDIX J: Interview Tables Teachers

This is a sample of a part of an interview table for one teacher. It is coded by theme and sub-theme.

Sally

Theme	Sub-theme	Coding: Quotes
Teacher background	**Education**	I did my bachelor's degree in early childhood studies – in elementary education. I studied no science in university or cegep. I have to learn science myself. I had to take math in university but I didn't have to take any science. I did HS chemistry but not physics.
	Teaching Experience	I've been teaching 6 years here as well as 5 years at another board – in an alternative school at the NFSB. I taught Gr 10 everything including Gr 10 physical science
AST curriculum and approach	**Personal approach**	I was only a couple of pages ahead of the kids. I like it that way –keeps me on my toes - learning with the kids
		I really enjoy learning something new and helping them learn it. I'm a co-learner. I learn a lot from them. I learn from their questions
		Students seem to know so much. They Google things. They ask me to Google things.
		What I struggle the most with is Physics. I really enjoy doing it with the ASTs. I learn from Irwin (physics teacher).
		It's my first year doing AST. Physical Science was more theory based.
		Next year I will do a final project – a design to solve a problem. At the end they will be able to do so much more. They will do a science fair project to solve a problem as part of the curriculum next year. I will get them more things to do next year. Build a bank of technical objects to analyze and take apart.
	AST vs ST	They need to learn the same topics but AST students deconstruct materials first. Manufacture how would this work?
		ST teach properties and about the materials first. . How would this work first.

		AST approach a topic from technical aspect first. You get them to figure it out first. Maybe you need to heat it to mold it …Their questions direct the knowledge
		ST talks about the theory first
		AST are more into building projects than the ST.
		There is a lot more content material to cover in ST.
		ST topics not in AST: periodic table, atoms, molecules for example. ST has more chemistry in sec 4. ST has more on biomes for example. AST should have learned it in Gr 9. Only oxidation and combustion are in AST
	AST Approach	I have to do an activity. I find they learn more if I have them do an experiment. They make the connections afterwards.
		They learn more if I have them do an activity first and they ask questions based on what they have done. I don't know if that's how the course is written. I learn from doing the activity first
	Teacher Collaboration	We collaborated a lot. Where are you going next? Where are you going? For example, I shared an activity where I presented objects to show force and energy. They asked, how did you start the activity? For forces I had them look at a number of objects: radio, windup flashlight, spring, stapler with spring. I asked what the different types of energy were. Where does the energy come from?
		We would say, I know Nat's strength is chemistry. I would ask her Chemistry-related questions.
		We had to work together to figure things out. The three of us often did same thing but three different ways. We would make a rough plan of where we wanted to go
		Anything we did went up on the portal. We had ad hoc meetings whenever we felt we could talk things out. We would chat and talk it out on a regular basis (usually in our common science staff working area.).
		We did the same projects at different times. I was the guinea pig and did things first. The others take what I do and make it better. Talking it out is how we all learn.
		We had no time off together and we did not use common times for getting our student groups together.
	Assessment and Evaluation	I assess them on their level of understanding concepts. Eg. Give me an example of a link. Are they using proper terms? Do they get it?

		I give them a reflective piece after doing a project.
		We have tests for comp 2. I would give them a test to describe. A standard test for comp 2. Now there are going to be multiple choice questions. We have to fill the gaps with paper tests and lab reports
		I introduce rubrics all the time I use comp scales 1 to 5. But now they are making comp scales compulsory. I now use a 10 point scale to make it easier to understand.
		I have to put in % for GPI. GPI doesn't do the translating. I don't put in 5s and 3s. Tests just have a mark.
		I always give a variety of short/long answers looking for key words to show understanding.
		For me I want to evaluate where they are now.
		I eyeball their marks to see where they are. I take into consideration the level of difficulty. I make my decision on the evidence I collect.
		Next year it's 20-20-60. Final term is the longest and has the most weight. So it's fairer.
		Lab exam counts 20% of comp 1. 20% of 40%. Next year there is no comp 3. It's all either theory 60% or practical 40%.
Pedagogy - constructivism/ Inquiry	**Active learning**	I find they learn more if I have them do an experiment.
	Student Control	Do all the cars go at the same speed? They had to figure out the procedure and figure out error possibilities. This was the best lab because I gave them nothing. They figured it out completely on their own – materials, methods. There was always some complication. I want to do all my labs like that next year

APPENDIX K: Interview Themes – Teachers

This is a sample of combined coding from two themes from the teacher interviews: Personal Approach and Pedagogy - constructivism/Inquiry

Personal approach

Sally

I was only a couple of pages ahead of the kids. I like it that way –keeps me on my toes - learning with the kids

I really enjoy learning something new and helping them learn it. I'm a co-learner. I learn a lot from them. I learn from their questions

Students seem to know so much. They Google things. They ask me to Google things.

What I struggle the most with is Physics. I really enjoy doing it with the ASTs. I learn from Irwin (physics teacher).

Next year I will do a final project – a design to solve a problem. At the end they will be able to do so much more. They will do a science fair project to solve a problem as part of the curriculum next year. I will get them more things to do next year. Build a bank of technical objects to analyze and take apart

I have to do an activity. I find they learn more if I have them do an experiment. They make the connections afterwards

They learn more if I have them do an activity first and they ask questions based on what they have done. I don't know if that's how the course is written. I learn from doing the activity first

Trudy

More of hands-on approach. How things work. I'm more pen and paper math etc. I changed toward this as the year went on.

Lianne

Sometimes labs need to generate content and other times we need to consolidate the scientific method

Difficult to find projects to give them a task they can do.

Michael

This new approach wasn't much of a paradigm change for me. The actual planning of lessons hasn't changed for me.

I may do a month of more traditional and then a projects.

When they get the challenge I try not to help them. But I'm a sucker and help them if they really need it.

Madeline

Sometimes I start with a small activity and then build on it. Rather than go after the big picture. Sometimes easier to build up

I used the same hands on approach when I taught ST. I'm a hands on type of person

Pedagogy - constructivism/Inquiry

Sally

Active learning: I find they learn more if I have them do an experiment.

Student Control: Do all the cars go at the same speed? They had to figure out the procedure and figure out error possibilities. This was the best lab because I gave them nothing. They figured it out completely on their own – materials, methods. There was always some complication. I want to do all my labs like that next year

Trudy

Active learning

Student Control: We give too much – data table, instructions. Next we'll have them talk about it and develop their own procedure and data tables

Would give students more responsibility. Gradually train them. Gr 7 and 8. I think we're very structures and controlling. Would do more inquiry based.

Lianne

Active learning:

Student Control: From doing the AST lab exam we realized we have to do things differently give them less direction. Need balance

Inquiry: More a discovery learning They have to figure things out. More complex tasks have a different approach

Michael

Active learning: I have to get them up out of their seats for maybe only 5 min. In general, chemistry makes it more difficult. Even then I have to think of something to get them out of their chairs.

Student Control

Madeline

Active learning: It was bring in a more hands on approach

Student Control: If you start with something very large they want to see how it's related to them. It can be a daunting task. They can relate more to it is it is more manageable. Designing a small bridge is easier to relate to.

Inquiry: If it's something that happens in the news. The oil; spill everyone had heard about. We did an experiment where we simulated an oil spill in a tub of water in the back and had to try to figure a way to contain the spill and clean it