# High School Science Teachers and Their Views on the Problem-Based Learning Approach: Barriers to Implementation

Jessica Godin

Department of Integrated Studies in Education

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## Abstract

In this research I examined the implementation of the problem-based learning (PBL) approach, an innovation implemented as a part of the science education reform that Quebec, Canada, underwent in the last ten years. Throughout my research, I explore various approaches that three high school science teachers take in implementing PBL into their own teaching of the science curriculum. This research is focused on three detailed case-study of these teachers which includes interviews, classroom observations, co-creation and implementation of PBL units, examination of their concerns about the reform using the Sages of concerns model, and reflective journals.

Four main findings emerging from the research are: (1) Teachers teach through some aspects of PBL but are unaware of the explicit mandate preventing them from creating lessons in accordance with this mandate. (2) Teachers are experiencing disconnect between the mandated PBL approach to teaching and the content-based mandatory final examinations. (3) Teachers cite a lack of proper financial resources, insufficient time and training as external barriers to the effective implementation of PBL. (4) Teachers cite personal resistance, lack of knowledge, training, and fear of the innovation as internal barriers.

The barriers that teachers encounter emerging in this research can help curriculum developers in Quebec to have a better understanding of how to structure future reforms to ensure they are understood by the teachers. Exams mandated in Quebec should be structured in a way, which is more reflective of the

curriculum currently employed, ensuring teachers see the value of the curriculum in relation to how the students will be evaluated.

**Résumé**

Dans cette recherche, j'introduis le concept d'apprentissage par la résolution de problèmes (ARP), une innovation appliquée comme faisant partie de la réforme en enseignement des sciences que le Québec, au Canada, a connu au cours des dix dernières années. Au fil de ma recherche, j'explore diverses approches qu'ont utilisées trois enseignants des sciences au secondaire pour l'implémentation de l'ARP dans leur propre enseignement du programme de sciences.

Cette recherche se concentre sur trois étude de cas détaillée de trois enseignants en sciences du secondaire, et comprend des entrevues, des observations faites en classe, la co-création et l'implémentation de modules d'ARP, des analyses *Stages of Concern* et un journal de bord contenant mes réflexions. Quatre découvertes principales ressortent de cette recherche : (1) Les enseignants intègrent certains aspects de l'ARP dans leur enseignement mais ne sont pas conscients du mandat explicite de cette approche, ce qui les empêche de créer des plans de cours conformes à ce mandat. (2) Les enseignants connaissent une certaine déconnection entre l'approche mandatée de l'ARP et les évaluations finales obligatoires de contenu. (3) Les enseignants mentionnent un manque de ressources financières convenables, de temps et de formation comme étant des obstacles externes à une implémentation efficace de l'ARP. (4) Une résistance personnelle au changement et une crainte face à cette nouvelle réforme incomprise sont mentionnées comme étant des obstacles internes.

Les obstacles auxquels font face les enseignants qui sont ressortis de cette recherche aideront les concepteurs de programmes d'études du Québec à mieux bâtir de futures réformes, afin de s'assurer qu'elles soient bien comprises des enseignants. Les évaluations mandatées au Québec devraient être structurées de manière à mieux refléter le programme actuellement utilisé. Cela ferait en sorte que les enseignants saisissent la valeur du programme en relation avec la manière dont les élèves seront évalués.

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# Chapter 1- Introduction

Over the last five years, I have been a secondary science teacher in the public Anglophone sector in Quebec, Canada. Recently, I have been interested in the role of science educators during a vital transitional period in the development of the new Quebec curriculum – often called "The Reform" by teachers, administrators, and provincial consultants belonging to the Ministère de l'Éducation, du Loisir et du Sport (MELS). As a classroom teacher who has encountered the changes in curriculum firsthand, I am interested foremost in a particular facet of this education reform – namely the systemic alteration in teaching styles from pure lectures and laboratories accompanied by direct testing (multiple choice, knowledge-based questions), to a new system of problem-based learning (PBL). With problem-based learning, students are asked to assess a scientific problem given a particular scenario, develop appropriate strategies and/or methods to solve the problem, and then test their hypotheses in either theoretical or experimental contexts to see if their solutions work. The basis for implementing a problem-based learning model in the Quebec science curriculum was to increase the autonomy of teachers, and to provide "students with challenges that will make them aware of the importance and usefulness of what the teacher is asking them to do" (Ministère de l'Éducation, du Loisir et du Sport, Education Reform, 2007). In other words, work is student-driven and creative.

Since the implementation of the Reform in 2005, teachers and students have been working towards full implementation of the provincial objectives including "elements that profoundly change Quebec schools…[i]nitiated in order to shape the school of the 21st century" (Ministère de l'Éducation, du Loisir et du Sport, 2005). The implementation strategy for the reform began informally as early as 1997 with the introduction of different strategies for renewing Quebec curriculum (Ministère de l'Éducation, du Loisir et du Sport, 2005). All elements of the reform, including a new basic school regulation, a renewed curriculum, and full standardized testing in Secondary IV (grade 10) history, science, and mathematics and Secondary V French and English, were fully implemented by the 2011-2012 school year. The Secondary IV science course was one of the last courses to achieve uniform examination status in 2011-2012, with the preceding two years in a testing phase for standardized provincial examinations in three areas: laboratory applications, technical applications (engineering and technical object construction), and theory (written examination).

The purpose of this study was to establish how Secondary Science teachers feel about the Science Education reform in Quebec, decipher the depth of their understanding of problem-based learning (PBL), and ultimately to identify the internal and external barriers each participants faces in the implementation of the curriculum. I also conducted this research in order to determine how Science teachers in English high schools in Quebec are implementing the new Science Education Reform. The aim of this research is to first and foremost establish how teacher's view the implementation of this reform; what teachers' views and perceptions about PBL are; and overall how their views and understanding have affected the use of this approach in their science classrooms.

This study serves an important purpose at a time in Quebec when the reform- now implemented- is being evaluated and altered. An analysis of teachers' understandings and opinions of the current reform can give insight into what kinds of changes need to be made in order to ensure the new reform better meets the needs of today's teachers looking forward.

This in-depth study creates a portrait of three classrooms evaluating how teachers are implementing the PBL approach into their teaching to ascertain the teacher`s specific use of PBL. As the reform is now fully implemented teachers are facing various barriers to the effective implementation of this new, problem-based learning (PBL) approach to the teaching of science. This approach consists of "a model for classroom activity that shifts away from the classroom practices of short, isolated, teacher-centered lessons and instead emphasizes learning activities that are long-term, interdisciplinary, student-centered, and integrated with real world issues and practices" (Asan & Haliloglu, 2005). PBL as a concept can be traced back to 1910 when John Dewey published his book *How We Think*. Dewey believed that "the native and unspoiled attitude of childhood, marked by ardent curiosity, fertile imagination, and love of experimental inquiry, is near, very near, to the attitude of the scientific mind" (Dewey, 1910, p. 3) Dewey contends that students need to see science as something that arouses the students' curiosity through real-life problems, the very idea behind PBL. He made it clear throughout his work that in order for learning in science to be effective it must be grounded in inquiry. Dewey states**,** "inquiry is a progressive determination of a problem and its possible solution" (p. 113). Although the MELS approach to science education is loosely grounded in Dewey's vision many notable barriers face teachers during the implementation process. According to Ertmer, Addison, Lane, Ross and Woods (1999) there are two kinds of barriers facing teachers:

> …external, or first-order barriers, include a lack of access to things such as computers, software, planning time, or administrative support. Internal barriers, called second-order barriers, relate to teacher beliefs about instructional technology, traditional teaching methodologies, and willingness to make changes in classroom practices (p. 2).

While the benefits of PBL have been clearly noted and established through past research, in Quebec at the Secondary level, PBL implementation issues for science teachers are substantial (Mensah, 2011). Gallagher, Stepien, Sher and Workman (1995) discuss barriers to implementing PBL in science such as:

> lack of concrete approaches for teachers, a disconnect between the ill-structured learning environments that promote PBL solving activities and the rigid focus of standardized testing and the struggle to create a student who is self-directed while somehow maintaining a semblance of cohesion in the classroom (p. 136).

Goodnough (2006) also identifies many barriers to implementation of PBL such as "teacher relinquishing control, adaptation of the PBL model to younger students and the lack of appropriate time allotment to develop the PBL scenarios" (p. 136).

### 1.1 Overview of the Inquiry

This study is driven by three research questions:

- How do high school science teachers feel about the PBL approach?
- What are the teachers' understanding of the PBL approach?

- What, if at all, are any internal and external barriers that high school science teachers face in the effective implementation of PBL in today's high school science classrooms?

The research participants in this study include one male high school Physics and Chemistry teacher named John (pseudonym), one male high school general science and chemistry teacher named Ian (pseudonym) and a female high school general science teacher named Amy (pseudonym). I first conducted semi-structured interviews (~35-40 minutes) with each participant at the beginning of the study in order to establish their views on the PBL approach and the Quebec science education reform. Subsequently, I observed each teacher's classroom for 6-8 hours and had many informal discussions with them about the implementation of the PBL approach in their classrooms. Based on the first interviews I saw that the teachers were lacked training and had limited knowledge about the PBL approach. Upon the teacher's request we researched resources about PBL and found reviewed information from LEARN Quebec [1] along with an article describing PBL (Goodnough, 2006). These resources described the facets of PBL and were used in order to guide their development of a co-created PBL unit. Following the implementation of these co-created units, each participant was given the Stages of Concern Questionnaire (SoCQ) adapted from the Concerns-Based Adoption Model (CBAM). The model is based on the idea that individuals' feelings and perceptions about an innovation can be assessed as concerns (Fuller,

[1] LEARN Quebec (Leading English Education and Resource Network) "is a non-profit educational foundation supported in part by funding from the Quebec-Canada Entente for Minority Language Education that: offers e-learning services and support to all English school boards, private schools, community organizations and the private sector in rural and urban settings; supports and promotes pedagogical collaboration and innovation using information technology, and works to model best practices; and publishes quality learning materials to support educators.

1969). The concerns-based model applies to individuals experiencing change. Usually these individuals are policy makers, teachers, parents and students (Hall & Hord, 1987). The model has seven stages of concerns that do not necessarily always occur in linear stages. The stages usually begin with the user becoming aware (stage 0) of the innovation and ending with the user having ideas about how to change the innovation at Stage 6 (refocusing). Once an awareness (stage 0) of the innovation exists the user usually begins to seek knowledge (stage 1) about it and develops personal concerns (stage 2). Following personal concerns the user may often struggle with management concerns (stage 3) such as preparation of materials. The final stages deal with consequences of the innovation (stage 4) for students, collaboration with fellow teachers (stage 5) and finally a refocusing (stage 6) occurs where new ideas about an even better innovation emerge. The questionnaires were then analyzed based on the resulting concern profiles. Each participant was also asked to reflect on their approach to PBL in a short four-question final reflective journal.

### 1.2 Overview of Chapters

*Chapter 2:* In chapter two, I frame this study and construct a conceptual framework drawing on the literature that is focused around the concept of problem-based learning. An in-depth analysis of the mandate for PBL teaching is Quebec is given. This mandate is then evaluated from a historical perspective of PBL, discussing where it originated and with what purpose. Incorporating the history of PBL and how it has been incorporated into the reform, I discuss previously reported research about the barriers teachers face while implementing a large curriculum reform.

*Chapter 3:* This chapter takes the reader through the process of my methodology I employed in my research. This chapter describes, in detail, the specific approaches I employed to identify how science teachers in Quebec feel about the PBL approach and the ways in which they have implemented it into their teaching. I then discuss my research, approach which is centered around participatory research, reflexivity, and the co-construction of knowledge that informed my inquiry with the teacher participants. This chapter concludes with an overview of the CBAM, which constitutes my analytical framework.

*Chapter 4*: In chapter four I create three individual cases, one for each teacher participant, detailing the results of the analysis that was performed during the research. This analysis includes a focus on the teachers' initial perceptions of PBL, their real-life approach to the teaching of PBL, the barriers they face in the implementation of PBL and finally an overview of their reported stages of concern about the reform. This chapter concludes with a cross-case analysis amalgamating the findings.

*Chapter 5:* I end the thesis with a conclusion. This chapter discusses my bias throughout the research as an experienced high school science teacher in Quebec and the ways in which my experiences influenced this inquiry, and reflect on the implications of this research for the future of science education in Quebec.

## Chapter 2 -Context

This chapter provides the context for the study and explains the various literatures I draw on to inform this study. Specifically, this study is situated within the constructivist learning model. I employ a constructivist framework as a lens to look at the recent science education reform and its implementation in Quebec. Since the current reform focuses on problem-based learning (PBL) as an essential constructivist approach to teaching and learning science, in this study I conducted an in-depth examination of how high school science teachers in Quebec feel about the problem-based learning approach and identify any barriers they face while implementing this innovation into their teaching. In this context I discuss the relevant literature on the problem-based learning model in this chapter. As this study centers on science teachers' response to and understanding of the PBL approach, I use the Concerns-Based Model (Hall & Hord, 1987) as an analytical framework to examine what the participant teachers are concerned about throughout the implementation of the reform.

PBL in of itself is considered a social constructivist approach to teaching, which aims to encourage students to think and solve problems; an application of their knowledge versus a reiteration of facts they have been taught. This apporoach has most notably been referenced by Vygostky where he refers to social constructivism as the importance of context in understanding what occurs in society and the idea of constructing knowledge based around this understanding.(Vygotsky, 1987) Piaget and Inhelder (1958) were also amongst the first to develop this idea of active construction of knowledge in education and they asserted that an individual at the basic operational level could understand and perform some logical operations, while an individual at a higher operational level would be able to find reason behind their operations. At this high stage, the individual could reason in a way that is close to ways commonly used in the PBL approach to the teaching of science (interpreting abstract models, applying their knowledge to solve a problem etc.) (Piaget & Inhelder, 1958). Constructivism and PBL are link together in that they both aim to creating active construction and application of knowledge through the solving of authentic problems.

In this chapter I begin describing the Quebec education reform, focusing on the innovations in the sciences. I will then summarize the history of PBL dating back to the early 1900's through to today. This history will provide a context for the research and provide a clear indication of how PBL has developed and why it is an appropriate teaching approach in high school science classes. Next, I describe a summary of previous studies about PBL and the barriers teachers have reported to its implementation to contextualize my research within the relevant literature. I conclude this chapter by identifying PBL advantages and critiques that have been previously reported. The majority of research supports PBL as an effective approach to teaching high school science although research also exists that critique the approach. Some research-based insights point to disadvantages of using the PBL approach at the high school level. Therefore, prior studies which reveal previously reported barriers faced by teachers implementing PBL are also discussed.

## 2.1 Quebec Education Plan (QEP): A Mandate for a New PBL Approach to the Teaching of High School Science

Quebec's education system has undergone a dramatic change in the last ten years when the newest reform was introduced that completely refocused the science curriculum to that of a problem-based approach. This reform has had many effects on the science teachers of Quebec and their approach to teaching. In the current movement to reform high school education in Quebec, many components of the curriculum and educational system are being altered. As a part of its reform, the Quebec government devised a set of elements that were geared to reform today's school and the teaching of various subjects. The Ministère de l'Éducation, du Loisir et du Sport (2005) states that students in the new reform are asked to "carry out learning activities" and "apply knowledge to [solve problems and] meet the subject-specific competencies". This approach to the teaching of science represents a constructivist approach to education, where in the learning at a high level involves the interpretation and application of knowledge. MELS (2005) points out, the reform was

> initiated in order to shape the school of the 21st century, the reform contains some elements that have been implemented at different times since 1997, others that are currently being implemented and still others that will be carried out progressively until the 2009-2010 school year (Ministère de l'Éducation, du Loisir et du Sport, 2005).

It was made clear that the goals of the reform were to be implemented over the course of many years and would ultimately result in a better schooling system. Most important for science education these elements include a competency-based approach to teaching science, which focuses on developing students' abilities to apply knowledge taught in order to solve problems and adopt effective work methods. (Ministère de l'Éducation, du Loisir et du Sport, 2005). Evaluation has a renewed focus on the learning accomplished by the student: gathering information by various means and subsequently processing this information (Ministère de l'Éducation, du Loisir et du Sport, 2005). The building of knowledge through a hands-on approach that PBL promotes is a constructivist approach to learning which ensures the students are exposed to practical examples of their constructed knowledge.

### 2.2 Problem-based Learning Approach: Advantages and Issues

The current reform in science education in Quebec mandate dictates that teachers should teach through a problem-based learning method which differs significantly from the lecture-based approach that existed previously. This project-based method of teaching is discussed on the LEARN Quebec website where it is described as "a model for…classroom activity that shifts away from the classroom practices of short, isolated, teacher-centered lessons and instead emphasizes learning activities that are long-term, interdisciplinary, student-centered, and integrated with real world issues and practices." (Asan & Haliloglu, 2005, p. 69).

Specifically in science, the Ministère de l'Éducation, du Loisir et du Sport (MELS) has a reform initiative which asks teachers to apply a project/problem-based approach (PBL) to teaching in order to "shift(s) away from the classroom practices of short, isolated, teacher-centered lessons and instead emphasize(s) learning activities that are long-term interdisciplinary student-centered, and integrated with real-world issues and practices.” (Learn Quebec, 2012).

Barriers to the implementation and delivery of PBL in the Quebec science education reform have not been previously studied. In order to ensure that this reform is properly implemented and that teachers are delivering it in the manner it was intended more research is needed to identify what barriers science teachers have faced and what their current understanding of the Quebec science education reform is.  This research begins with an overview of past and current research surrounding PBL in order to define and explain the term PBL and how it applies to this research. It is important to recognize and understand what barriers have been previously reported by teacher’s experience a reform of this type therefore an overview of these findings will also be discussed.

Before continuing with an overview of the MELS science reform, I address the various terms used when referring to an inquiry-based approach to teaching such as problem-based learning and project-based learning. Specifically, three terms are generally used, each of which have overlapping as well as distinguishable characteristics. Inquiry-based learning is defined by MELS in the Secondary English Language Arts (Ministère de l'Éducation, du Loisir et du Sport, 2007, p. 12-13) as:

> Learning moves the focus from the view of knowledge as ready-made and transmittable “as is” from teacher to student or from text to reader to an exploration and demonstration of how knowledge is really produced—how questions are asked, data accumulated and generalizations made. In projects such as ethnographic research, students follow these processes and apply these strategies to conduct original research in the school and community.

Many distinguishing features between problem-based and project-based learning exist, and Barron (1998) gives us clear visions of how they differ. Problem-based learning is usually given at the beginning of a lesson and uses a fictional scenario to engage the students while a project-based lesson is one that follows the initial problem and asks the students to apply the information they have learned through the initial fictional problem to a real life scenario. MELS uses the terms inquiry-based and project-based when referring to the open-ended style of teaching called for in the sciences. For the purposes of this thesis and research, PBL will be considered to mean problem-based learning and be viewed as a curriculum approach guided by a teacher facilitator who focuses on using an open-ended real world problem where students work in collaborative groups to make meaningful connections between school learning and learning for life (Torp & Sage, 2002).

This new reform, as any new policy [in education] does, conflicts with well-established institutional structures that have been in existence for a long period of time. This conflict gives rise to barriers in implementation of PBL for Quebec's high school science teachers. Only very recently in Quebec, over the last ten years, has PBL been formally introduced as a part of the high school curriculum and viewed as an effective way of teaching at the high school level. Although MELS see the PBL approach to the teaching of science as the most effective method, many gaps and barriers exist in the implementation of this new curriculum. Namely, MELS offers minimal to no professional development to teachers implementing PBL in their teaching. Although the website does offer the teacher with a resources section, it only begins to guide the teacher to an understanding of how to create effective PBL lessons. Some guidelines are given to the teacher as far as how to 'develop essential questions' and 'creating your own rubric' only a few samples are left to the teachers. Experienced teachers are unfamiliar with this new way of teaching and MELS does not provide them with sufficient practical resources to incorporate PBL into their teaching. When the reform was introduced to schools, it was also largely left on the shoulders of each school board to provide their teachers with the proper professional development they would need to effectively embrace the reform; this caused confusion and a lack of cohesiveness when trying to explain what exactly the reform was asking of them (Mensah, 2011). Furthermore, a discrepancy exists when one considers the QEP structure and emphasis on an open-ended investigative problem-solving approach to teaching and the multiple choice, content-based compulsory final exam that they put forth. Beginning in 2011, MELS began re-introducing multiple-choice, content-based questions into the science final exams. This year, 2012, represents the first year that MELS is requiring their final exam for the Secondary four science course as mandatory and it also includes the multiple-choice content-based section (See Appendix A). The QEP specifically states that in Secondary four the program is focused on "developing citizenship skills…intellectual potential… and scientific skills" (Ministère de l'Éducation, du Loisir et du Sport, 2007, Applied Science and Technology). Specifically, the program focuses on the development of three competences:

- Seeks answers or solutions to scientific or technological problems

- Makes the most of his/her knowledge of science and technology
- Communicates in the languages used in science and technology

Problem-based learning has a long history of development and in order to understand how MELS sees its role in high school science this history of development needs to be discussed and understood.

All three of these competencies shift the focus of the teaching from a lecture content-based approach to teaching to that which is focused on the methodologies used to solve scientific and technological problems and the skills necessary for students to engage in a hands-on approach to solving a problem (ibid). Given this method of teaching it should follow that students are also evaluated by using the same skills; not through a series of content-based multiple choice questions as is seen in the most recent compulsory exam released by MELS (Appendix A).

**2.3 A history of Problem-based Learning: Its Origins and Definition**

There is an immense amount of literature published about the concept of problem-based-learning in general. Beginning in the early 1900's, philosophers and educators were theorizing about PBL and its effectiveness as an approach to teaching.

PBL has a long history of development that needs to be understood if we are to grasp what the purpose of the current reform is and provide a context and rationale for my research. It is important to understand where PBL originated in order to grasp how it is understood today for this purpose, we need to go back to the beginnings in 1933 when John Dewey published his book *How We Think*.

Many researchers credit Dewey with being the founder of PBL (Koschmann, 2001). Dewey believed that “the native and unspoiled attitude of childhood, marked by ardent curiosity, fertile imagination, and love of experimental inquiry, is near, very near, to the attitude of the scientific mind” (Dewey, 1910). Dewey implies here that students need to see science as something that arises their curiosity through real-life problems; the very idea behind PBL. He made it clear throughout his work that in order for learning in science to be effective, it must be based in inquiry, “inquiry is a progressive determination of a problem and its possible solution" (Dewey, 1938, p. 113). He also advocated a connection between doing, thinking and learning that is supported in the PBL approach to teaching science. Dewey (1944) believed that learning “should give students something to do...and the doing is of such nature as to demand thinking or intentional connections” (Goodnough, 2006, p.154). Dewey established that the teaching of science needs to be engaging and based in inquiry. Although the Quebec education reform agrees with Dewey and asks teachers to teach through this PBL approach, its implementation, as the implementation of any new mandate in teaches can, has the potential to raise many barriers that need to be researched and addressed if students are to fully benefit from the PBL approach to the teaching of science.

Ward (2002) also investigated the origins of PBL and discussed the idea that it has “roots in Socratic inquiry and centuries-old apprenticeship training” (p. 17). Socrates used an approach to his teaching, which was focused on moderating and directing questions rather than lecturing to his class; he was one of the first to use a teacher-facilitator approach to education. "It can be observed in The Republic by Plato (360 B.C.E./1960) that Socrates guided his students through inquiry to answer their own questions, search out answers to problems, and relate their knowledge to life applications" (Ward, 2002).

It is also important to understand why there is now a need for change in the approach to teaching; a shift from that of a content-based approach to science education to a skills-based approach. As far back as 360 B.C.E it was noted that information was simply passed down from generation through word of mouth. As technology evolved, people began writing down the stories and information they gained. This shift gradually caused a shift in information from a practical sense to that of fact gathering (Ward, 2002). The amount of information accessible grew exponentially to a point where today students have access to an unlimited supply of information. The struggle is no longer lack of access to information but rather on of the students lacking the skills necessary to determine what information is relative to solve a problem, where to find this information and how to apply the information to the problem at hand. This is where Dewey's thinking and ideas about PBL meet a practical purpose.

A PBL based approach to teaching was then beginning to be seen as an approach to teaching that could aid students in this sorting and application of knowledge. PBL creates a positive learning environment that helps students to develop the process skills they need to achieve an efficient method of knowledge acquisition and application (Ward, 2002). Through a PBL approach "students explore content more deeply, making them more likely to develop an in-depth understanding of the science content being conveyed that would be sacrificed by focusing on breadth” (Hung, Harpole & Jonassen, 2003, p. 14). It is largely accepted that PBL does not create an increase in the content knowledge of a student but rather it helps the student to find, decipher and apply information that is available to them from books, the internet and other various sources of media and technology. PBL focuses on the use of open-ended questions and as seen in Akinoglus’(2007) article students’ responses to these open-ended questions contributed to their conceptual development of the students while also minimizing their misconceptions (Akınoğlu, 2007). Akinoglu (2007) argues that students’ opinions about PBL point to an increase in classroom participation and attendance. Students learning through a PBL approach were better able to relate the information to daily life.

PBL is now most commonly associated with science education as it was first brought into academia in at McMaster University Medical program (Ward, 2002). In this context, PBL was designed around a clinical framework where a problem is designed around the questions put forth by Gallagher (1995) such as: “what do I know, what do I need to learn, and how do I measure or describe the result” (Ward, 2002, p. 19). The teaching of science is most effective when it includes experimentation and these experiments can easily be framed around a PBL approach of questioning. A clinical experimental environment is very conducive to a student-directed teacher facilitated approach to teaching and learning (Ward, 2002). The evolution of PBL in medical school began when instructors began to notice that physicians in training were graduating with a wealth of information but without the necessary problem solving skills to use that information wisely (Gallagher, Stepien, Sher, & Workman, 1995). It then follows that there needed to be a shift in the way teaching occurred here to create students who not only had content knowledge but also had the skills necessary to apply and decipher what knowledge and information was relevant to various clinical cases. In 1969, McMaster University in Ontario founded what is known as the "McMaster Philosophy". The McMaster Philosophy assumes that learning should be

> student-centered and occur in small groups, teachers act as facilitators or guides, problems are the organizing theme for learning, problems are the means for the development of clinical problem-solving skills, and new understanding occurs through self-directed learning (Barrows & Kelson, 1995).

Gallagher *et al*. noted this philosophy and extrapolated from it three key features. They applied these strategies as the basis for an effective educational strategy: "initiating learning with a problem, making exclusive use of ill-structured problems, and using the instructor as a metacognitive coach" (Ward, 2002, p. 18). This philosophy has evolved into the educational strategy known today as problem-based learning (Ward, 2002).

When we consider how PBL has evolved throughout beginning Dewey's vision of science education through the McMaster Philosophy to the present Quebec education reform, we gain an understanding of how PBL in the high school science classroom came to be and why it is an effective way of teaching science. In line with Dewey's initial observations about the teaching of science, PBL is now defined as "an instructional approach where the focus is on learning in a meaningful way through a task" (Hmelo-Silver, 2004, p.236). In order for PBL today to be consistent with Dewey's vision of science education as well as that of the McMaster philosophy, it must be guided by aspects of each. Firstly, the PBL task assigned to the students' needs to be open-ended and have a real-life application. This idea is in line with the McMaster Philosophy, which was initially designed around a clinical approach to teaching, using real-life medical cases to teach students how to apply their knowledge. When students encountered a situation to which they can relate, they are more likely to be engaged in the problem and be motivated to solve the problem. Hmelo-Silver (2004) points out that students become active learners who use real-world problems as a basis for learning the concepts in science; by creating relatable problems students develop strategies to problem-solve in life as well as construct science knowledge.

The high school environment is rather different than the medical school environment the Quebec science reform is based on. The struggle in achieving a relatable PBL problem in high school is one that has been previously identified by researchers. Allen (1997) addresses this problem by asking; how does a teacher identify what is relative to a class full of students with diverse backgrounds, interests and aspirations? This barrier is something that the McMaster Philosophy does not address, and rightfully so. When it was designed, there was no need to consider these aspects since the target audience were all working towards the same goal of becoming a doctor, the clinical examples used were automatically ones of interest to this group of students. Teachers at the high school level must be able to identify a means of targeting larger groups of students who may all have very different interests and goals, a barrier to implementation which is not easily solved and also under-examined.

The McMaster Philosophy assumes that working in small collaborative groups allows the students to expand their knowledge base by sharing their ideas with classmates and the teacher is present in the classroom as a facilitator, there to guide the students' thinking and process. This teaching approach leads one to think that perhaps a solution to addressing the diverse interests of all students in a high school classroom may be to split the students into many smaller groups, each of which have a specific focus of interest. Using these interests, individual PBL scenarios can be developed that may be more relatable to each group of students and help "students identify relevant facts from a scenario and generate hypotheses about possible solutions (Hmleo, 2004, p. 236)". If they feel a connectedness to the problem at hand, the students may be more likely to be intrinsically motivated to solve the problem.

In order for PBL to be effective, the teacher facilitator must first be aware of what knowledge the students need to be able to solve the PBL problem. The prior knowledge of the students can be identified through many techniques such as quizzes, brainstorming, short answers and discussion. The goal here is for the teacher to gain an understanding of how to structure a PBL scenario so the students are provided with sufficient information to solve the problem, without giving them too much information and not allowing the problem to have the open-endedness a PBL scenario needs to have. If the problem is structured correctly, the students should discover various results to the same problem and sometimes may even reach a valid conclusion that is contradictory to the major paradigms present in science today. One of the major goals of PBL is to develop the life-long learning skills students need to thrive in their environment outside of school. In order to structure an effective PBL scenario, the idea of creating life-long learners should always be considered. In order to achieve their goal, a PBL scenario should follow a subset of goals, which have been identified by Barrows and Kelson (1995) stating that PBL is designed to help students:

1) construct an extensive and flexible knowledge base;
2) develop effective problem-solving skills;
3) develop self-directed, lifelong learning skills;
4) become effective collaborators; and
5) become intrinsically motivated to learn.

In order to accomplish these goals, the teacher facilitator must keep in mind that "flexible knowledge is more than memorizing facts but requires the integration of information across multiple domains" (Hmelo-Silver, 2004, p. 240). Although many aspects of PBL implementation and development have been identified here, the barriers such as lack of time and money, insufficient teacher training, insufficient material, teacher resistance to change, disconnect between mandated teaching approach and final examinations and management of large PBL units, which are suggested by current research are not all addressed by these suggestions. More research needs to be conducted to identify specifically what barriers teachers face in the implementation of PBL and how they believe these barriers should be best addressed. These barriers, and others, will be discussed in more detail in that section later in this chapter.

There are models that suggest ways PBL can be more effectively implemented, primarily laboratory work, real-life PBL units, hands-on building and analysis of technical objects and group work which promotes reflection and collaboration. Primarily, teaching PBL in high school science through laboratory work aids students in developing effective problem-solving skills, especially when they are placed in a scenario where they can use previous knowledge to aid in solving the new problem at hand. By involving students in a situation where they are engaged in the problem at hand, "students enjoy PBL instruction more when compared with the traditional instruction and their attitudes and opinions were more positive toward PBL approach" (Goodnough, 2006, p. 282). This creates an environment that is engaging for the students and therefore increases their motivation and participation. This increased motivation somewhat eliminates the teachers frustration at finding a topic of interest to every student in the classroom).

Intrinsic motivation, the inner desire to succeed, is a very important factor when introducing a PBL scenario. The inability of a teacher facilitator to facilitate a student's intrinsic motivation can pose a rather large barrier to the implementation of PBL. This type of motivation may occur in a student when they are presented with a scenario which touches on their own interests. Students become more motivated when they value what they are learning; the struggle arises when trying to identify what motivates a class filled with students of varying interests (Hmelo-Silver, 2004). A PBL scenario can be structured in a way which addresses many varying interests with the hopes of targeting many students' interests. This can be accomplished by ensuring that the problem being presented is open ended and creates room for the student to incorporate their own beliefs and experiences into the scenario.

The hands-on approach of PBL also fosters metacognitive skills which are vital to the development of self-directed learning. Students become aware of their learning and therefore develop skills such as:

> …knowing the goal of their learning, self-assessing how well they are doing with respect to that goal, understanding that revision is a natural component of achieving a learning goal, and recognizing the value of scaffolds, resources, and social structures that encourage and support revision (Barron, 1998, p. 273).

Although these skills are a positive outcome of effective PBL teaching, if a teacher facilitator in unable to develop these skills in a student, the effectiveness of a PBL approach may be severely lessened. Students must first be aware of what they do and do not understand and from there they can identify what areas of their learning they need to know more about. Students must also be able to identify their own learning goals and be able to assess at the completion of a project if their goals have been met (Hmelo-Silver, 2004). The development of problem-solving skills in students occurs through PBL as students are compelled to approach and solve a problem/scenario to which they feel an attachment. The use of higher order thinking skills employed by the students ensures they become independent, effective problem solvers (Hmelo-Silver, 2004).

In PBL, the facilitator is a vital part of the process and acts as a model for the skills and approaches used in effectively solving a problem while still remaining an expert in the content itself. The teacher is now being asked to play a dual role. In PBL, the facilitator steps away from the traditional role of a teacher and takes on less of an expert role and more that of a guide. The facilitator monitors group process and encourages students to justify their thinking, engage in self-reflection and identify reasons for their decisions throughout the process. The PBL scenarios, guided by the facilitator, ultimately give rise to high order thinking skills in the students (Hmelo-Silver, 2004).

Given all of the past and current research about PBL, its origins and development it can be seen that it is a promising method to the effective delivery of a high school science curriculum. The struggle now lies in identifying what barriers exist for teachers regarding the implementation of PBL and how these can be addressed in order to ensure that PBL is being implemented and approached in a manner which achieves the previously stated purposes. Despite its promises, the PBL approach to the teaching of science in Quebec has also been widely critiqued by science education researchers for a number of reasons, which are important to explore in researching potential barriers to PBL implementation.

**2.4 PBL Advantages and Critiques**

PBL has widely been studied as an effective approach to teaching at the University level, but its effectiveness at the secondary level has received only limited attention. While PBL has ultimately been found to be an effective way of teaching problem-solving skills, some researchers cite problems and drawbacks to this type of approach. It is important to acknowledge and address these critiques of PBL. In the Quebec reform the struggle arises when asking teachers to let go of their prior practices of “knowledge transmission” and assume a role as a facilitator present in the classroom to help their students become creative, independent, life-long learners.

Vernon and Blake (1993) investigate some of the advantages and critiques of PBL by conducting a meta-analysis of evaluative research that occurred prior to 1993. It is important to note here that although a meta-analysis of data can provide insightful information, once it is stripped from its context it does not necessarily apply. The purpose of this review was to synthesize all available evaluative research from 1970 through 1992 that compares problem-based learning with more traditional methods of medical education (Vernon and Blake, 1993). The comparative value of PBL is supported by data on outcomes that have been studied less frequently. Specifically, the focus of the review is on faculty and student attitudes, student mood, class attendance and academic process variables. Vernon and Blake state that in all studies that were found about student attitudes and analyzed, none were found that did not favor PBL to some degree. These findings were based on classroom attendance and student mood. When academic achievement was examined, it was found that overall there was no data that suggested a significant increase in academic knowledge when science is taught through a conventional lecture-based approach over a PBL approach to teaching. When looking at students’ academic process, that is, their ability to use various learning resources, Vernon and Blake (1993) concluded that “students in PBL programs place more emphasis on “meaning” (understanding) than on “reproducing” (rote learning and memorization), and that the opposite pattern prevailed among students in traditional programs."  Overall, this review concludes that overall the research generally supports the superiority of the PBL approach over more traditional methods (Vernon, 1993).

Norman (2000) argues that based on past research "findings lend credence to the conclusion that PBL is unlikely to make students learn more in the short term (although they may retain more)" (p. 721). The critiques of PBL stem from the argument that overall, PBL does not lend itself to an increase in cognitive outcomes in the students (Norman, 2000). It can be argued that PBL is achieving more than simply the cognitive abilities in a student as measured by a summative test or the like, but that it increases retention, understanding, problem-solving and analytical abilities in students; skills which are necessarily more valuable than short-term cognitive abilities and rote memorization.

The importance of practical experience in learning is discussed in detail by Hmelo-Silver (2004) in her article titled "Problem-based Learning: What and how do Students Learn?" (Hmelo-Silver, 2004). One critique to using PBL at the high school level, a setting with a larger and more diverse group of students compared to that at the medical school level, is the lack of a sufficient number of skilled facilitators. Classrooms have more students with more varying backgrounds than one person can easily facilitate, and learning to facilitate well is a challenge (Hmelo-Silver, 2004). Enhancing student motivation is purported to be a major advantage of PBL because learning issues arise from the problem (in response to students' need to know), intrinsic motivation should also be enhanced (Hmelo-Silver, 2004).

Another critique noted about PBL is that it is difficult for the teacher to shift from a teacher-centered classroom to a student-centered classroom with a facilitator (Mensah, 2011). The facilitator is a vital part of the PBL process and acts as a model for the skills and approaches used in effectively solving a problem rather than simply being an expert in the content itself. In PBL, the facilitator steps away from the traditional role of a teacher and takes on less of an expert role and more that of a guide. The facilitator monitors group process and encourages students to justify their thinking, engage in self-reflection and identify reasons for their decisions throughout the process. Since the high school science classroom consists of a large number of students, all with varying interests and goals, it is argued that one teacher facilitator may be unable to connect with all of the students backgrounds and therefore not be able to create a PBL centered classroom which ignites each student’s extrinsic motivation. Ultimately this causes a problem because in order for PBL to be effective the PBL scenarios, guided by the facilitator, should give rise to high order thinking skills in the students. (Hmelo-Silver, 2004) These higher order thinking skills can only occur if the students are engaged and connected to the subject matter, a hard task to accomplish in such a diverse setting.

### 2.5 Contextualizing my Inquiry: Research on Implementation of PBL in Secondary Science Settings

My research has a specific focus on the internal and external barriers faced by Secondary Science Teachers during the implementation of a PBL approach to their teaching. The following section summarizes prior research that has investigated barriers faced by teachers when similar reform programs in other parts of the world have been implemented. Specifically, the section will first discuss teachers' internal and external barriers and then I highlight important research that explored various curriculum barriers that have been previously identified in research. In noting these barriers here it will be easier to describe and analyze the barriers that my three participants will identify.

### 2.5.1 Teacher Specific Barriers to Implementation: Internal and External

While the benefits of PBL have been clearly noted and established through various past research, in Quebec at the Secondary level, PBL implementation issues for science teachers are substantial (Mensah, 2011). These issues give rise to significant barriers which impede the teachers' ability to properly and effective teach science through a PBL approach. Following is a summary of the past research which establishes what barriers to implementing PBL have been reported by teachers in previous research.

Allen (1997) discusses the challenges PBL brings to teaching in his article "Problem-Based Learning in Introductory Science across Disciplines". As earlier discussions of PBL's origins have shown, we have adopted a model which was originally developed to educate intellectually mature, highly motivated medical students using clinical case studies, and adapted it to fit undergraduate and high school courses (Allen, 1997). The adaptation of a model from medical schools to lower level high school science students leads to challenges, which need to be addressed such as class size, group dynamics, student maturity, sources of problems, and student supervision. Despite these challenges, problem-based learning has generated a large number of student and faculty advocates (Allen, 1997). Overall, Allen (1997) discusses that the problems with the teaching of PBL at a secondary science level arise specifically for the teacher when attempting to negotiate the constraints of implementing this new approach to teaching into their daily routine. My research is focused on the teachers' perceptions of the implementation of PBL into a high school science classroom and what barriers and constraints they face when going this.

In Gallaghers'(1995) article 'Implementing problem-based learning in science classrooms" she argues that there is a widespread agreement that an understanding of science is increasingly critical to effective functioning in a democratic society, as issues including nuclear power, balancing industry and the environment become a part of daily life (Gallagher, 1995). Clearly, schools, and teachers, must change their approach to science education to prepare citizens to make decisions on science-related issues. Problem-based learning provides the scaffolding to simultaneously achieve the goals of making students apprentice scientists, using realistic, ill-structured problems, and focusing on metacognitive skills (Gallagher, 1995, p. 136). Specifically, Gallagher (1995) discusses barriers to implementation such as: lack of concrete approaches for teachers, disconnect between the ill-structured learning environments and the rigid focus of standardized testing and the struggle to create a student who is self-directed while somehow maintaining a semblance of cohesion in the classroom (p. 136).

Goodnoughs' (2006) takes these ideas to the next step and begins to delve into the complexities of PBL, examining its feasibility as a curriculum and instructional approach in the context of high school science teaching and learning.

Goodnough (2006) also explores the concerns and issues that arise during design and implementation of PBL in this setting and the same issues were found in Barron's (1998) study such as, "inadequate material resources, little time to create new curricula, large class sizes, and over-controlling administrative structures that prevented teachers from having the autonomy necessary to implement progressive approaches". It is expected that many of these barriers may be shared by the teachers studied in my research. Goodnough (2006) stresses the concept that PBL is a more effective way to teach and should be implemented in a system where many components of the educational system are being targeted for change and improvement, since current reform initiatives require a substantive change in how science is taught (Goodnough, 2006). Quebec is currently undergoing a dramatic change where the entire education system is currently undergoing a major reform in its approach to teaching. Goodnough (2006) also argues that PBL is an effective teaching tool but does caution that more research needs to be done to determine how to effectively implement PBL, which is the focus of my own research. She stresses that in order for PBL to be successful, both the teacher and the student need to be prepared to be ready to tackle a new way of learning that often conflicts with the established practices (Goodnough, 2006). Issues such as; "teacher relinquishing control, adaptation of the PBL model to younger students and the lack of appropriate time allotment to develop the PBL scenarios" are the major barriers teachers reported when implementing PBL. Since Goodnough's (2006) study is focused on "examining PBL's feasibility as a curriculum and instructional approach in the high school science teaching and learning" (p. 280) it can be extrapolated that findings in my own research may yield fairly similar results, discovering that teachers face the same implementation barriers in the effective teaching of PBL to a high school science classroom. As Goodnough (2006) concludes her findings, she identifies that the struggle following the identification of barriers shifts to construct appropriate means to address and solve the implementation barriers. She points out questions that still need to be addressed such as: "what models of PBL K-12 education are most efficacious to promote student learning and what types of professional development (PD) approaches will be most effective in helping practitioners adopt PBL as a part of their regular instruction repertoires?" (p. 292). These questions are further explored in my study by probing teachers' views on the PBL approach and discussing their experiences in the adaptation of PBL to the high school setting. Teachers in my study will also be reflecting and critically analyzing the PD that has been offered to help with the implementation of PBL in their science classrooms; suggesting alternatives and ways to improve PD in the future.

Azer (2001) reports major challenges and barriers during curriculum preparation and implementation of PBL. These include: time constraints, difficulty in creating problems, substantial change in management and organizational structure, resource intensive, and student confusion about the goals of the PBL. These challenges are then used to critically evaluate the consequences of problem-based learning introduction and its educational outcomes (Azer, 2001). Also challenges issues such as prior knowledge, cognitive abilities, social factors, personal factors and difficulties in implementation from the views of both the students and the teachers are researched (Azer, 2001). The identified challenges are ones that can be assumed to be universal in teachers and are therefore ones that should arise from my own research as well.

Research done by Park, Lee, Blackman, Ertmer, Simons & Belland (2005) further investigates reported teacher barriers to the implementation of PBL by investigating the internal and external barriers teachers encounter when planning for and implementing problem-based learning in the middle school classroom (Park *et al.*, 2005). A distinction is made in this study between internal and external barriers; the same distinction is made in my own study. According to Ertmer, Addison, Lane, Ross and Woods (1999) "external, or first-order barriers, include a lack of access to things such as computers, software, planning time, or administrative support. Internal barriers, called second-order barriers, "relate to teacher beliefs about instructional technology, traditional teaching methodologies, and willingness to make changes in classroom practices" (p. 2). Barriers occurring in the middle school studied were defined through the use of classroom observations, teacher surveys, and interviews with teachers and administrators. Based on the results of data analysis, barriers such as lack of feedback, rewards and incentives for PBL implementation and misalignment of vision between teachers and administration created difficulties for teachers trying to plan and implement a PBL unit (Park *et al.*, 2005). From these results appropriate performance interventions were selected and proposed to help teachers overcome the internal and external barriers (Park *et al.*, 2005). For my study, teachers are asked to identify barriers they face in the implementation, these barriers can be identified as either internal or external barriers and possible solutions for each group of barriers will be developed. Teachers will then attempt to implement these solutions into their teaching and the outcomes of implementation will be analyzed through the teacher feedback and classroom observations completed by the researcher. Internal and external barriers that have been reported in previous research are summarized in Table 1 below.

**Table 1- Summary of previously researched barriers to implementation**

| | | |
|---|---|---|
| **Internal Barriers** | | • teacher struggle to create a student who is self-directed while somehow maintaining a semblance of cohesion in the classroom<br>• teacher inability to relinquish control<br>• lack of prior knowledge<br>• teacher resistance to change |
| **External Barriers** | **Teacher specific** | • Lack of concrete approaches for teachers<br>• disconnect between the ill-structured learning environments and the rigid focus of standardized testing<br>• Large class sizes<br>• Over-controlling administrative structures<br>• Lack of administrative support |
| | **Curriculum Specific** | • Inadequate material resources<br>• Little time to create new curricula |

## 2.6 Professional Development Approaches of Teachers

The previously reported barriers to implementation of a new innovation can be addressed through many ways, specifically, Ertmer, Lehman, Park, Cramer and Grove (2003) outlines the professional development activities that have been used in the past to support teachers' implementation of problem-based learning in their classrooms (Ertmer *et al.*, 2003). She discusses their effectiveness in dealing with previously identified barriers to implementation and teaching through a PBL approach to high school science teaching. Based on teacher interviews and PBL implementation data, she describes strategies that have worked, as well as those that have not, and outlines steps taken to confront the various barriers teachers encounter as they attempt to incorporate learner-centered pedagogies, supported by technology, within traditional classroom practice (Ertmer *et al.*, 2003). Ertmer identifies various implementation designs that have been successful in the past such as "effective models for professional development that combine multiple contexts such as a summer workshop wherein teachers learn new theoretical ideas, followed by ongoing support that helps them know how to integrate those ideas into the classroom" (Ertmer *et al.*, 2003, p. 1956).

Ertmer *et al.* (2003) also emphasize that a focus on the implementation of technology as an aid to the teaching of science with a PBL approach is effective. He states that "formal PD is not likely to have lasting effects unless it can provide continuity between what teachers learn and what goes on in the classroom" (Ertmer *et al.*, 2003). This continuity can be "achieved through professional development efforts that address teachers' changing needs in both powerful and flexible ways" (Ertmer *et al.*, 2003, p. 1957). In order to ensure the PD has lasting effects for the teachers it must be hands-on and approach the implementation of PBL into their teaching in a real-life way that allows teachers to develop tools they can use immediately upon the return to their classroom. Throughout my study teachers will identify their own barriers to the effective implementation of PBL and suggest what types of PD they believe would benefit them the most. This information will bring us one step closer to designing powerful PD that can truly aid the teacher on their quest to effectively incorporating PBL into their teaching at the high school science level

## 2.7 The Concerns-based Adoption Model (CBAM): How this Model Enriches my Research Analysis

The Concerns-based Adoption Model (CBAM) is used in the analysis of the findings because it is a powerful analytical tool that can be used to understand participating teachers' concerns about the PBL innovation. The model allows for the identification of concerns about any innovation being implemented by an individual. Specifically, the CBAM model, proposed by Fuller in 1969, is one that applies to anyone experiencing change (Fuller, 1969). For the purposes of my study, this model is used to analyze how the three teachers being studied are experiencing the change occurring as a result of the Quebec Education Science Reform. The CBAM notes that people considering and experiencing change evolve in the kinds of questions they ask as well as their use of whatever the change is. In general, teachers begin by asking questions that are more self-oriented such as What is it?  And How will it affect me? Once these questions are beginning to be resolved, the teacher moves towards asking questions, which are task-oriented such wondering how they will be able to implement the innovation and if they will have the time needed to accomplish this. When the teacher moves past these self- and task concerns, they begin to shift their focus on the impact they are having through the implementation of the innovation. Teachers ask: Is this change working for students? and Do I have ideas that will work even better? (Hall & Hord, 1987; Hord, Rutherford, Huling-Austin, & Hall, 1987).

The mandate delivered through the Quebec Science Education Reform was delivered in a top-down approach and "although top-down mandates are continuously criticized, they can work quite well." (Hall & Hord, 2006, p.12) In order for this reform to be successful it must be "accompanied by continuing communication, ongoing training, on-site coaching, and time for implementation, it can work" (Hall & Hord, 2006, p.12).

Specifically in my research, the CBAM model can help to understand why teachers seem to be resistant to fully implementing the reform and provides a rational for why teachers cannot move forward in the process.

> The first step is to determine the reason for the apparent resistance. The apparent resistance could really be the teacher working through the sense of loss for having to stop doing something that was comfortable. A second form of resistance is grounded in having serious questions about whether the change will really be an improvement (Hall & Hord, 2006, p.13).

The CBAM has been used in other research much in the same way I use it to analyze my data. Fuller's theory about stages of concern provides a useful framework for helping to understand why teachers are resistant to the adoption of the current reform. This approach was used to analyze data in Sanders (2010) *Addressing teacher's concerns about teaching evolution.* In this article, the authors use the model to determine what concerns were facing teachers and therefore what kind of professional development programmes were needed.

In my research, Fuller's theory of concern will be applied through his Stages of Concern Questionnaire (SoCQ) and used to analyze teachers "feelings and perceptions about the innovation and the change process. These can then sorted and classified in to what we call concerns" (Hall & Hord, 2006, p.134). Combined with the results of the initial semi-structured interview, the SoCQ results will be analyzed to determine at what stage of concern each individual teachers is at. After identifying the stage of concern pertaining to each teacher an analysis of what kinds of professional development are needed to encourage teachers in Quebec to move forward in the adoption of the Science Education Reform can occur.

When I consider the literature that has been previously published about PBL and apply it specifically in regards to its implementation in the Quebec Education reform many factors to be studied are evident. First and foremost it is important to establish how teachers currently view the application of PBL. Once this has been established it is important to determine if their views about PBL resonate with what the reform is asking of them. The teachers' application of PBL in their classroom will need to be established in order to compare the real-life approach they have to the application of PBL with the mandated approach. Finally, in order to explain the anticipated discrepancies between the mandated approach to the implication of PBL and the real-life approach the teachers take I will investigate what barriers, both internal and external, the teachers face while implementing PBL into their teaching.

# Chapter 3- Methodology

In this chapter, I begin with an overview of the specific research questions that are being addressed throughout my research. I then provide an overview of my research design and explain how I used the *co-construction of knowledge* and *participatory action research* approaches to conduct in depth case-studies with the three science teacher who participated in this the study. I then provide a detailed description of each part of the research design: (a) the materials required to complete the study, such as the research ethics board application, (b) the individualized profiles of the three selected science teacher participants, and (c) data collection instruments and process, which lasted from February 2012 until September 2012. I describe the concerns-based model and the stages of concern questionnaire in detail discussing how both helped inform my analysis and pull on previous research designs that have used this approach as an effective tool for analyzing the effectiveness of a recent innovation.

## 3.1 Overview of the Research Approach

This research was conducted in order to gain a better understanding of how high school science teachers view the Problem-based Learning (PBL) approach to teaching science and what issues have arisen during their attempts at implementing the PBL approach in the classrooms. The information gathered in the research can then be used in the future to help in designing proper support programs for teachers implementing the PBL approach in their science classrooms. My study is focused on studying high school science teachers in order to gather information that may answer the following questions:

- How do high school teachers feel about the PBL approach?
- What is the teachers' understanding of the PBL approach?
- What, if at all, are any internal and external barriers that high school science teachers face in the effective implementation of PBL in today's high school science classrooms?

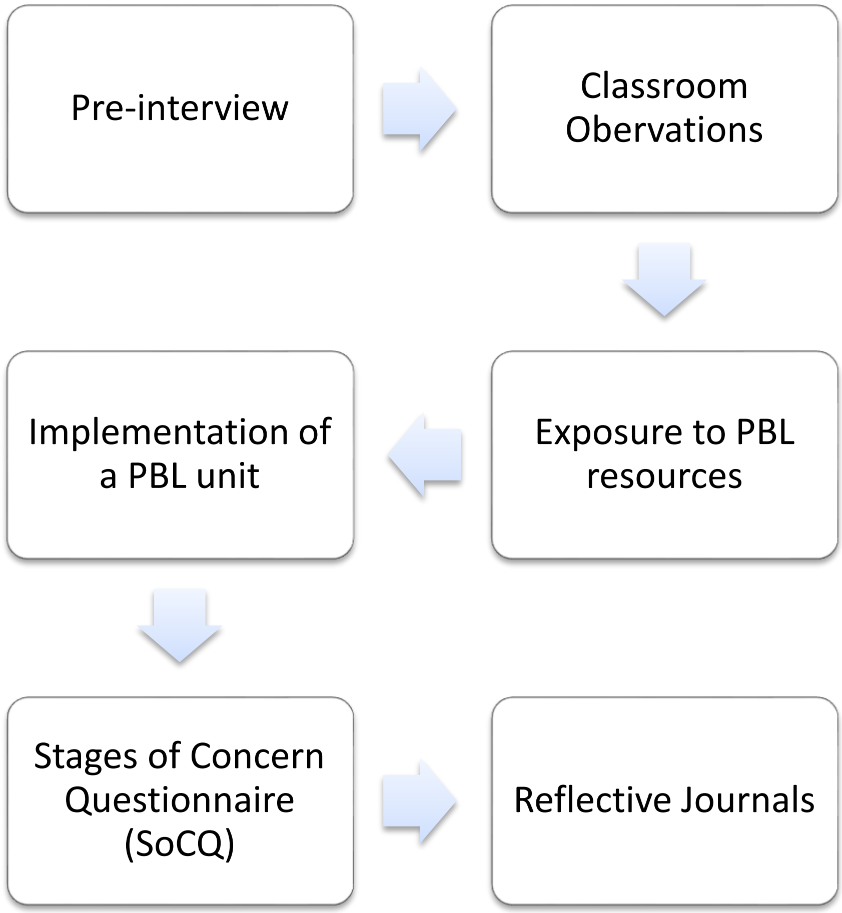
The specific goals of my research are to answer these research questions in a succinct and thorough manner, although many challenges may be encountered in attempting to do so. Goodnough's (2006) study showed that teachers might be resistant to addressing their real concerns about the reform for fear of repercussion from their principal. Further, teachers may not be aware of what PBL is and therefore might feel threatened when having their knowledge probed by me. Teachers might not be self-aware of the different kinds of barriers they face when attempting to implement the PBL approach into their teaching.

**3.2 Research Design Overview**

In order to collect a varied sample of data to determine what Quebec teachers' views are towards the PBL approach to the teaching of science and assess their level of concern with regards to the science education reform, three high school science teachers with diverse backgrounds were chosen to be a part of the study. These teachers represent a varied population and all have unique educational backgrounds and years of experience and these will be described later in this chapter.

Figure 1 describes the process I undertook in my research. I interviewed each participant to establish their views and opinions on the PBL approach. These interviews were completed using a semi-structured approach based on the questionnaire in Appendix F. Following this semi-structured interview lasting 30-40 minutes, I observed each teacher's classroom for 6-8 hours (about 7 classes each) in order to gather information about how they approach the teaching of science through a PBL approach. These observations were conducted in the classrooms as a silent observer. The teachers continued their teaching in the normal way and I was simply present to see how they were enacting the curriculum. In addition, I had several informal conversations (on average 3 per teacher) during this process to learn about their views about the reform. The research design is focused on a co-construction of knowledge approach between me and the teacher participants. I describe this co-construction process later in this chapter in section 3.5.2.

**Figure 1- Overview of Research Design**




Upon observing how teachers were implementing PBL they shared with me how uncomfortable they were with the process. During many informal discussions with each teacher participant they declared *the reform was never taught to [teachers] properly. It was just given to us as a book and they basically said good luck* (John, Interview 1). When I probed the teachers to ask what kind of support they needed, they asked if there were resources available that they could be exposed to in order to help develop their comprehension and knowledge about the PBL approach. Together, the teachers and I researched what resources were available from the Quebec government and then incorporated these resources into the planning of the PBL units.

Once I knew how the teachers were implementing PBL I shared with them some resources to aid in their thinking of how PBL could be used to teach science. We analyzed these resources and looked at previous lessons the teachers had implemented to determine what aspects were based in the PBL context. I then worked with each teacher to develop different PBL units, which the teachers subsequently implemented into their teaching. These units were co-created between each teacher participant and me, allowing for the teacher participants past experiences to inform the development of the unit while my expertise on PBL added another level to the units (eg. ability to construct authentic problems, and develop relatable LES's).

Teachers responded to the Stages of Concern Questionnaire and completed reflective journals in order for me to see the progressions of their thinking and implementation of PBL in their classrooms. This questionnaire allowed me to determine which Stage of Concern about the reform the teacher is currently more concerned with. Based on the results of these questionnaires a stages of concern profile was developed for each teacher. These profiles were then analyzed and linked to their interviews and reflective journals to ensure consistency in the data collection.

This study creates a portrait of each classroom studied and examines how the three teacher participants are implementing the PBL approach into their teaching using a co-construction of knowledge approach between the researcher and each teacher participant. The study involves three high school science teachers. The participants were selected based on references from colleagues and their innovative teaching and willingness to adapt to the science reform and change their teaching styles to include PBL activities. All three teachers also volunteered to be a part of my study.

### 3.3 Data Collection Methods

Based on the first interviews with the three teacher participants I saw that the teachers were unaware of what the PBL approach was. This became obvious during the interview when teachers were asked “How would you define problem-based learning?”. Answers varied amongst the participants but mostly included reflections such as:

> *Oh, ummm for me I guess giving the students a situation or some sort of, um, with some sort of background information and making sure that they have some prior knowledge or a way to research that and then having them come up with their own solution or as Ian states What do I think it is? Sounds like jargon to me!*

Although I was not initially planning on sharing any resources with the participant teacher, as I had assumed they would have all they needed from the MELS, upon revision of these quotes it was obvious that the teacher participants were unclear as to what PBL was. In particular, they were not clear about the MELS vision and understanding of PBL. Many conversations with the teachers and examination of past PBL units they had implemented reflected a lack of understanding on the teachers part on how to incorporate PBL efficiently into their teaching. The teachers opened up to me throughout the time I spent in their classrooms and informal conversations to reveal they needed more resources to better able understand PBL. Together, the teacher participants and I discovered what resources are available from the LEARN Quebec website. The teachers showed me what resources were given to them upon the implementation of the reform and I subsequently shared with them the Goodnough (2006) article discussion and defining PBL. These resources were helpful in guiding their development of a PBL unit. Together with each teacher participant we developed individual PBL units (discussed in the implications section of this chapter) that they felt a connection with and were comfortable implementing into their teaching over the next few months.

### 3.4 Setting the Scenes

The three teacher participants involved in this research are listed in Table 2 below along with a brief overview of each.

**Table 2- Teacher Participants**

| Teacher | Years of experience | Subjects Taught | Subject observed | Number of classroom visits |
|---|---|---|---|---|
| **John** | 10 | Secondary 3 Science and Math, Secondary 4 Science, Chemistry, Physics | Secondary 4 AST Science | 6 |
| **Ian** | 20 | Secondary 3 Science, Chemistry and Physics | Secondary 3 Science | 5 |
| **Amy** | 13 | Secondary 4 Science, Secondary 4 Math | Secondary 4 Science | 8 |

### 3.4.1 John: First Case

This first case study is located in a suburban public school in the southeastern part of Quebec. Everwood High (pseudonym) consists of approximately 750 students from grade seven (Secondary one) to grade eleven (Secondary five). It is situated in a small town with a population of 12,470 and is considered a significant industrial and economic center in the region. The school is an English speaking high school situated in a Francophone milieu and draws students from a wide area of over 5000 $km^2$. The staff at the school is composed of 65+ teachers and support staff where each student has the unique opportunity to use an Apple ibook every day to stay informed and enhance their learning.

John has been teaching since 2002. Before his teaching career began, John pursued many other pathways in education. His first degree after high school was a CEGEP degree in the pure and applied science program. His next educational endeavor was the completion of a BSc. in Psychology in 2000. After this degree John took some work as a replacement contractual teacher and began his career as an uncertified teacher but quickly realized that he wanted to pursue a career as an educator. This prompted him to pursue his Education degree and he completed a B.Ed. in 2005. John received his full time employment at his current school immediately following his graduation from University. He has taught many subjects including French, Math, Biology, Physics and Science all at the high school level. His teachable subjects are high school general Science and Language

Arts. He currently teaches secondary 3 and 4 science, secondary 3 math, and secondary 5 physics. I followed John as he taught his secondary 4 AST science class. This class has 24 students, although it is rare that all students are present. On average, this class has about 18-20 students present. I observed John’s class over two separate weeks; each week I spent about 4 hours in this Secondary 4 class.

### 3.4.2 Ian: Second Case

Ian works in a small community high school West of the downtown Montreal center. Waterview High (pseudonym) has students in attendance from many suburbs in the area, including an aboriginal reserve. The immediate surrounding community has a population of about 40,000 and 62% of this population is French with the remaining percentage (28%) being English. Waterview High was founded in 2001 when two schools amalgamated into one. This school has a culturally, ethnically and socio-economically diverse population. This school also offers three academic programs: International Baccalaureate Middle Years Program, French Immersion and English. Students at this school are also involved in a wide range of community service projects.

Ian, a veteran teacher of 20 years has a diverse background in Education. He grew up with two primary teachers as parents and coached a fair amount of sports before entering into formal teaching. Ian holds an HND (Higher National Diploma) in applied biology and an honors degree in Microbiology. This degree is roughly equivalent to a Masters degree in Canada. All of these degrees were completed in Manchester England. In 1991 Ian completed his teacher training with a post graduate certificate in Education, a professional qualification and he has been teaching ever since. Ian has always taught science, with occasionally a few periods of physical education. The schools he taught in have varied from a deprived area of an industrial town for 7 years to the only school in a small market town (3 years) to his current position at Waterview (10 years).

In England, high school science is usually taught as a combined science course; the separate subjects are not often offered. The science departments are generally highly collaborative with a paid head of department, so colleagues routinely share best practices. At Ian's second school the students were slightly older so he taught both senior high school science and A level Biology (CEGEP type courses). He also taught a new more practical qualification called GNVQ Applied Biology and a low level science course for students with special needs.

In Canada, Ian has only taught science. Specifically, Ian has taught the Secondary IV Physical Science program and the Secondary V Physics and Chemistry programs. He has also taught a modified Secondary III course, one year of Secondary V Biology and a Secondary II course, although the majority of his teaching in Canada has been in the Secondary IV and V classes. I observed Ian with his Secondary 3 class which has 23 students. I observed this class over the period of two weeks, with an average of 4 hours spent in the class each week.

### 3.4.3 Amy: Third Case

Amy works in a very different setting than the first two participants. Amy (pseudonym) teaches at a high school in a much more urban setting. Wintergreen (pseudonym) High is located in a suburban area of the island of Montreal, which is largely residential in character, but is also the site of a lot of economic activity, including for example: retail activity, light manufacturing, various corporate offices, and a hospital. The population of the area is about 30 000 spread over 35 $km^2$. The population of the area consists of English as the first language (57%) followed by French (24%) and the majority of the population is white (88.06%). Students attending Wintergreen come from middle class families. Wintergreen has approximately 100 staff members and the student population is around 1500.

Amy is a teacher of 13 years. Her educational background includes a DEC in Early childhood Education from a Quebec CEGEP (1994) and a B.Ed. in 1999. Amy was initially certified as an elementary teacher but she has been teaching high school science for many years now. In 1999 Amy began her career as an educator at the an alternative school in Quebec. Here, Amy worked with students in secondary 3 and 4 who had many personal problems but were very motivated to learn. She taught there for six years teaching all high school subjects. Amy moved to Wintergreen high school in 2005 where she started with teaching secondary 4 Math and Science.  Amy currently teaches CST math ST science and AST science. Amy is certified to teach Elementary and High School Science. I observed Amy's Secondary 4 AST class over the course of four weeks. This class had 26 students present. I spent on average 3 hours in her class each week for a total of 12 hours of observation. During this time, I was engaged with the students while they completed many hands-on PBL units.

## 3.5 Methodology and Methods

In this research, I began by conducting semi-structured interviews with each participant. These interviews were structured in a way that allowed for each teacher to give feedback and change the direction of the interview based on what they felt was important to share with me in relation to particular their views, feelings, and experiences related to PBL. Based on the teachers views and opinions that emerged in these interviews I gained some valuable insights into their understandings of the PBL approach. Learning that these teachers felt they needed more information about the approach allowed me to explore what available resources were available to them and together we co-constructed a new view of what the Quebec Science Education Reform is asking of its Science teachers when referring to the PBL approach.

### 3.5.1 The Co-Construction of Knowledge: A Constructivist Approach to Research

Throughout the process of conducting any qualitative research with people a relationship emerges between the researcher and the participants. In my study, this relationship developed into one of co-construction of knowledge, allowing both the teachers and me to contribute to and inform the process of developing a deeper understanding of the PBL approach and implementing it together. This process was conducted using a constructivist approach to the research assuming "multiple realities where the knower and respondent co-create understandings of the natural world" (Denzin & Lincoln, 2005, p. 24). Collaboration is beneficial in any research setting (Ellis, Klahr, & Siegler, 1993). My research reflects this collaborative view as the teacher participants made many comments about how they *felt more comfortable opening-up to me about their fears* (Amy, a secondary science teacher) when teaching through a PBL approach. Likewise, Ian notes this comfort level is a result of *having [me] collaborate with [her] and share [my own] concerns about teaching through a PBL approach* (Ian, a secondary science teacher). I collaborated with each teacher participant to co-create individualized PBL units that were then implemented into their teaching. Collaborative learning in this sense is sometimes considered to be a process of convergence. During this process people tend to gradually converge on an understanding and achieve a shared goal (Roschelle, 1992). I was able to help the teachers focus their PBL units towards the specific mandate that the MELS asks for (open-ended activities that help students reach the subject-specific competencies). The teacher participants each showed me engaging, original ways in which they had previously implemented PBL into their teaching. When the teachers shared these innovative approaches with me my own understanding of PBL began to change. The teacher participants were using PBL approaches that incorporated real-life news and field trips to engage the students, an approach I had not previously considered. The teacher participants also shared with me PBL approaches that involved the students directing their own learning through a PBL unit. Amy believed that by truly allowing the students to *guide the lesson, their imaginations run wild and their engagement in the subject increases dramatically*. Teacher participants sharing of these new and innovate approaches coupled with my understanding of PBL allowed us to co-construct new knowledge about how PBL activities can be structured and implemented. This sharing of knowledge and resources allowed us to create PBL units that were not only met the MELS mandate for PBL teaching but were engaging and relatable for the students. In the analysis I will discuss the knowledge we co-created together to our conversation and implementing some PBL units. Overall, this co-construction of knowledge approach showed me new and innovate ways to structure PBL units that engage students.

### 3.5.2 Participatory Research

This type of research takes a step back from the traditional approach of gaining knowledge for understanding and causes a shift in the purpose of research towards that of knowledge for action (Cornwall, 1995). Although this type of research is seen as a source of considerable contention Rahman and Fals-Borda (1991) agree that research strategies emphasizing participation are gaining more respectability within mainstream research. In my own research, I set out to create a framework with my participants that allowed us to share knowledge that would ultimately lead to creating a change in the application of the Quebec Education Science Reform. This sharing of knowledge is another example of the co-construction of knowledge discussed in section 3.2, page 40 above. In order to ensure that a participatory research setting was established a lot of thought was placed on creating a space for pursuing this participatory approach with the teachers. This environment was fostered by allowing the teachers to guide the number of classroom visits I went to and also decide what classes they wanted me to attend. By allowing the teachers to decide when the visits took place a level of trust and respect was established. Once the classroom observations were over for the day each teacher participant and I had many informal conversations during their off-periods from teaching. These informal conversations seemed to put the teachers at ease, allowing the teachers to feel at ease and be candid about their reflections on PBL and the reform. This research relationship based on mutual trust and respect allowed us to co-create knowledge and understanding of how PBL can be incorporated into science teaching as an effective approach.

### 3.5.3 Using Reflexivity in a Participatory Setting

> Once we abandon the idea that the social character of research can be standardized out or avoided by becoming a `fly on the wall` or a `full participant,` the role of the researcher as active participant in the research process becomes clearer (Atkinson & Hammersley, 2007 , p. 17).

My research was conducted through a qualitative lens that placed me in a complex relationship with those with whom I worked, making me the instrument of research. Reflexivity occurs when the researcher engages in explicit self- aware meta analysis (Finlay, 2002). Qualitative research assumes a relationship between the research and the participants that in undeniable. The research cannot be fully independent of my opinions as a qualitative researcher since I am creating the context within which the research will be conducted and the questions that will be asked. Examining how the researcher and participants transform, has been an important part of the evolution of qualitative research. The individual must engage in some critical reflection, which can allow reflexivity to monitor the research process. This allows for a certain level of transparency to the research process wherein personal experience becomes public and accountable knowledge (Coffey and Atkinson, 1996).

Relationships in qualitative research are often developed between the researcher and the participants. It is important to acknowledge this relationship because “the relationship you establish can facilitate or hinder other components of the research design such as sampling and data collection methods” (Maxwell, 1996, p. 67). In my research volunteer participants were chosen based on referrals from colleagues. Choosing participants this way allowed me to ensure I had interested teachers to research, they were keen to be a part of my study and offer their advice on improving the reform, it also has an effect on the overall validity of the sample of participants. After all, do these chosen participants offer a true reflection of the population of Quebec teacher’s who have participated in the reform? The participants were viewed by their colleagues as expert teachers with a willingness to improve their teaching and understand the reform.

In current research the need for critical reflection by the researcher on the self as a research instrument is now viewed as more important than attempting to all together eliminate the impact of the researcher’s subjectivity (Guba & Lincoln, 2008). It is important to acknowledge that I do not believe in the research and participants as being separate entities. Instead, I see them as individuals who come together to construct realities through their participation in social interactions with each other. I also acknowledge that my lived experiences have an effect on my research approach and through reflexivity I can critically reflect on my lived experience’s influence over my research creating a stronger context within which to complete my work. I began my research with what I thought was a clear and complete understanding of the PBL approach. Throughout my research, as the teacher participants shared their own innovative PBL activities my outlook changed. I began to realize that PBL could be interpreted and applied through many useful approaches. My new outlook allowed me to take a step back as a researcher and learn from the teacher participants. This process allowed me to use a co-construction approach in my research (as described earlier in section 3.5.1 on page 50) by forming a "conscious experience of the self as both inquirer and respondent, as teacher and learner, as the one coming to know the self within the process of research itself" (Giardana & Newman, 2011, p. 124).

### 3.6 Research Methods

This section entails a detailed description of the research methods employed in my study. The materials used to complete the study are first described, followed by a detailed description of the initial interview process. The process I undertook during the classroom observations are then described, focusing on the number of visits and the focus of my observations. The reflective journals completed by the teacher participants are explained and the focus questions provided to the teachers for these journals are described.

### 3.6.1 Materials

Before beginning to conduct my research many steps were taken to address ethical issues and considerations in relation to this study. Initially in September 2011 I submitted an application to conduct research to the Research Ethics Board (REB) of McGill University. The REB application was approved under file number 132-1011 on November 8, 2011 and research involving humans was approved to be conducted until November 7, 2012. The research study was approved under the title “High School Science Teachers and Their Views on the Problem-based Learning Approach” (Appendix B).

Following the approval of my research from the REB, approval needed to be granted from the individual school boards in which I would complete my research. Approval was further granted from both school boards involved in the study in January 2012 (Appendix B).

**3.6.2 Interviews**

I began my research in February 2012 and completed data collection in September of the same year. I began with a semi-structured interview with each participant. These interview questions (Appendix C) focused on establishing each teacher’s views and understanding of the PBL approach to teaching, their opinions regarding the implementation of the PBL science education reform in Quebec and the major internal and external barriers they face in this implementation. Specifically, the interviews were structured in a manner that would direct the teachers to answer the research questions for this study. By asking open-ended questions such as “What is problem-based learning?” and “Do you believe you are teaching through a PBL approach?” I examined and answered my research questions and learned about “How high school teachers view the PBL approach?”  In order to address the second research question and determine “What are the teachers’ understanding of the PBL approach?” more open-ended questions about PBL were asked such as: “How would you define PBL?” and “Do you believe you are teaching through a PBL approach?” In order to determine what internal and external barriers the teachers are facing in the implementation of the reform, and answer my final research question that asks “What, if at all, are any internal and external barriers that high school science teachers face in the effective implementation of PBL in today’s high school science classrooms?” A last of set of open-ended questions were asked during those interviews. These questions were focused on their use of PBL in the classroom, asking teachers if they “wish they could teach through this approach more often” and “what kind of support would they need to teach more effectively through the PBL approach” (Appendix C).

After the completion of these interviews I transcribed each one and proceeded to go through each interview and perform open coding identifying any and all important information. This process involved reading over the interview transcriptions and identifying any and all information that was relevant to my research questions. This first round of coding was followed by a second coding process where I began to identify emerging salient themes and concepts and classify the previously noted important information into themes. Main concepts were identified and the interviews were reviewed using the research questions as a guide. The three research questions I used as a focus in this stage of the coding and I was looking for teachers reflections about: (a) How they view about the PBL approach (b) What is their understanding of the PBL approach (c) What, is at all, are any internal or external barriers teachers face in the implementation of PBL? The fourth time I coded the interviews following the CBAM stages of concern in order to indentify where the participants place themselves according to the stages of concern. The interviews were shared with a PhD. candidate colleague and a second open-coding was conducted on a separate occasion. This colleague is considered a leader in education in Quebec who has completed research on the reform and its implementation in Quebec.

### 3.6.3 Observations

After the initial interviews were conducted, I observed each teacher's classroom over a period of two months. I spent between 6-8 hours in each classroom and had the chance to see how each individual teacher approached implementing PBL into their teaching. These observations, coupled with the initial interviews that were collected, allowed me to gain important insights to how PBL is being implemented. Using this knowledge I gathered some PBL resources (Appendix D) and articles that I brought to discuss with the teachers. These resources allowed for reflection and brain-storming with each teacher that resulted in the development of individualized PBL units for each teacher's classroom. In this research I mainly observed the implementation of these co-created PBL units. The teachers then reflected on the implementation of these units in their reflective journals, described in the next section.

### 3.6.4 Reflective Journals

The last step of the research was for each teacher to submit a reflective journal where they were able to express how their thinking and opinions about the PBL approach to the teaching of science, and their views of how the Quebec education science reform have developed and changed. These journals were meant to help the teachers recognize the social environment within which PBL was being implemented in their classrooms and alter their position when thinking about PBL's place in the curriculum. Overall, the journals offered a place for reflexivity. The questions asked of the teachers in these journals are detailed in Appendix E. This reflective journal was completed at the same time as the SoCQ that was then used to assess each individual's stage of concern in the implementation of the Quebec science education reform. The resultant "Stage of Concern" profile for each individual was compared with codes from their first interviews to compare and contrast the data from the interviews with data from the SoCQ (Figure 1).

### 3.7 Description of Implemented PBL Units

The next sections describe individual cases that explain the co-created units implemented between each teacher participant and me. These cases are explained in terms of the format, the classes they were implemented in, the criteria given to the students and an explanation why each specific class was chosen for the PBL unit.

#### 3.7.1 Case 1: John's Project: Electrical Mazes

John and I chose to use his smallest class for this project as we felt that the PBL approach to teaching science is most effective with a smaller group of students. I was present in the class and helped the students through the unit. The class was asked to construct a small electrical maze. The electrical system was provided to them in the form of a circuit diagram and all the required tools were available. The students had to come up with their own procedures and methods for assembly and presentation. The task is problem-based in that the students had to decide what an appropriate order of assembly would be given the large number of specific tasks and that several parts overlap in the circuit system. The Circuit could be assembled in any number of methods provided the final diagram was respected, but certain tasks would be significantly easier if performed before others. In this way the students are required to make specific decisions with regards to the process and outcome of the task.

### 3.7.2 Case 2: Ian's Project: Genetic Diseases

Ian and I decided to do a cross-curricular project from Ian's grade 9 science students around the theme of genetic diseases. The students were introduced to genetically inherited diseases by traditional teaching methods but then choose a specific example of relevance to them. They are asked to produce a "zine" aimed at teenagers who either are suffering from the disease or have family affected. The work is assessed in science for the content, in English for the literacy aspects and was used as a cross-curricular piece in our IB program.

The aim of this approach was to move away from the traditional "chalk and talk" approach to try and make the topic more relevant and personal to the students. We also aimed to break down some of the more artificial barriers that the traditional subject demarcations impose. The students worked in groups of 2 or 3 and need to work together to research, design, produce and present their "zine".

The main adaptation from the teachers' point of view was to let go of the minutiae of precisely what is covered and allow the students to take more ownership. It does not matter if groups end up with different examples as long as they could understand the gist about how genetic diseases are transmitted and an understanding of the issues involved in making decisions around them. This unit was implemented and the outcomes are discussed later in the results chapter.

### 3.7.3 Case 3: Amy's Project: Windmills

Amy and I decided to try out the McGill's Science Education (WOW) Lab windmill project. The McGill WOW Lab Science and Education R&D project is a joint initiative between the Faculties of Science and Education at McGill University. The lab aims to develop engaging open-ended science and math teaching technologies. Our goal with the windmill project was to show that one can generate an electric current strong enough to charge a mp3 player or make a light bulb work. The students had to bring the majority of the materials and that is always a struggle to have them be responsible for such things. The project involved "creating a power-generating wind-farm out of pop bottles in the classroom" (WOWLab). In this activity, students engineer a windmill out of everyday materials and link them together as a class to make electricity. They can measure the amount of electricity generated by connecting all of the windmills together and even use them to light LEDs and charge an iPod. Through this PBL activity, students learnt about factors that influence the amount of power a windmill generates and then attempted to try to optimize the efficiency of their own pop bottle windmill. Students also explore series and parallel circuits by assembling the wind farm in different configurations and measuring the different resulting voltages. This was a hands-on practical demonstration of the relationship between mechanical and electrical energy.

### 3.8 Stages of Concern Questionnaire

Following the implementation of these units, each participant was given the Stages of Concern Questionnaire (SoCQ) from the Concerns-Based Adoption Model (CBAM). The concerns-based model applies to teachers who are implementing a new innovation although it could apply to any individual undergoing a change (Hall & Hord, 2006). The model (and other developmental models of its type) holds that people considering and experiencing change evolve in the kinds of questions they ask and in their use of whatever the change is. In general, early questions are more self-oriented using “me” and “I” such as: How will I organize my class? Where do I park my car? “These expressions indicate concerns about teaching, but with a focus on themselves rather than on the act of teaching or the needs of the children” (Hall & Hord, 2006, p. 135). After these self and task concerns were dealt with, teachers begin to be able to focus on the impact the innovation is having. They begin to reflect on improving student outcomes. The model has 7 stages of concerns, displayed in table 3 below. These concerns begin with the user becoming aware of the innovation. Once an awareness (stage 0) of the innovation exists, the user usually begins to seek knowledge (stage 1) about it and develops personal concerns (stage 2). Following personal concerns the user will struggle with management concerns (stage 3) such as preparation of materials. The final stages deal with consequences of the innovation (stage 4) for students, collaboration with fellow teachers (stage 5) and finally a refocusing (stage 6) occurs where new ideas about an even better innovation emerge. These stages are summarized in the chart below. The CBAM was used as an analytical tool to guide the analysis of the data.

**Table 3 - Stages of Concern according to the CBAM**

| **Stage of Concern** | **Expression of Concern** |
|---|---|
| 6. Refocusing | I have some ideas about something that would work even better |
| 5. Collaboration | How can I relate what I am doing to what others are doing? |
| 4. Consequence | How is my use affecting learners? How can I refine it to have more impact? |
| 3. Management | I seem to be spending all my time getting materials ready. |
| 2. Personal | How will using it affect me? |
| 1. Informational | I would like to know more about it. |
| 0. Awareness | I am not concerned about it. |

Hall and Hord (2006) state that “the SoCQ is a 35-item questionnaire that has strong reliability estimates and internal consistency” (p. 147) and is therefore a great tool to use when attempting to determine teachers concern about a new innovation. In my study the questionnaire was used to assess where each participant was in the implementation of a new reform. The questionnaires were then analyzed based on the resulting concern profiles. After a concern profile was established for each participant the resulting profiles were compared with the data collected from the initial interviews. Specific quotes were extracted from the interviews that reinforced the profiles that were developed allowing me to clearly establish individual stages of concern for each participant.  The last tool of analysis that was used was a reflective journal. The questions asked in this reflection were: (1) Describe the PBL activity you chose to implement into your teaching for the purpose of this research. (2) Referring to the MELS website, do you think a clear indication of how the teaching of science should be approached is given? (3) Referring to the Goodnough article you were supplied, do you agree or disagree with the barriers listed? and (4) What do you think needs to happen in the future in order for teachers to understand the MELS vision for the reform? Each participant was asked to reflect on their approach to PBL implementation in this short four-question final reflective journal.

**3.9 Analysis of Data**

After the completion of the interviews, I transcribed each one and reviewed each interview performing open coding and identifying any and all important information. This first round of coding was followed by a second coding process where I began to identify emerging salient themes and concepts and classify the previously noted important information into themes. Main concepts were identified and the interviews were once again re-coded using the research questions as a guide. These data collection methods allowed me to gain insight into the teacher participants' views about the PBL approach in a more informal, real-life manner. Observing their teaching over many classes ensured that the teachers were not changing their teaching styles to accommodate me. The three research questions were used as a focus in this stage of the coding and I was looking for teachers reflections about: (a) How they feel about the PBL approach (b) What is their understanding of the PBL approach? (c) What, if at all, are any internal or external barriers teachers face in the implementation of PBL? The fourth time I coded the interviews following the CBAM stages of concern in order to indentify where the participants place themselves according to the stages of concern. The interviews were shared with a PhD Candidate colleague and he completed a second open-coding on a separate occasion. Each individual interview was analyzed alone and subsequently the interviews went through a cross-analysis to ascertain the salient patterns emerging from the three cases.

The SoCQ results were analyzed according to the framework suggested by Hall and Hord (1987) and the results were substantiated with quotes from the interviews to concretely assess each teacher's stage of concern. In this framework, the SoCQ can be hand-scored, especially useful when there are only a small number of questionnaires being scored. Hall and Hord (1987) explain that "the 35 statements in the questionnaire were carefully selected to represent seven fundamental areas of concern", as displayed in Table 3 on page 63. The questionnaire is organized to represent items in each scale that represent concerns prominent at that Stage of Concern, according to the concerns model (ibid). In the questionnaire each stage is represented by 5 separate questions. Each question is ranked on a scale of 1-7 by the participant. The representation of the scores is shown in Table 4.

**Table 4- SoCQ Scoring Interpretation**

| **Score Value** | **Meaning** |
|---|---|
| 0 | Irrelevant |
| 1-2 | Not true of me now |
| 3-5 | Somewhat true of me now |
| 6-7 | Very true of me now |

Once the teachers have answered the questionnaire the "raw scores" (the sum of the responses to the five statements on that scale) are converted to percentiles. The questions and their corresponding statements are shown in Appendix F (Figure 1). The sum of the seven raw scores is the total score for that Stage of Concern and is converted to a percentile score using the conversion table in Appendix F, Figure 2. These percentile scores are then plotted on a graph to produce the participants SoCQ profile. Certain profiles are common amongst users of an innovation and these profiles are called 'classic profiles' and are used to compare with other, unique user profiles. The methods and instruments used in the analysis of all the data in this research are summarized in Table 5 below.

**Table 5 – Methods and Instruments Used**

| **Questions** | **Data** | **Analytic Techniques** |
|---|---|---|
| How do high school science teachers feel about the PBL approach? | Informal interactions and conversations<br>Pre-interview<br>Classroom observations | Interview coding with identification of emerging themes. |
| What is the participant teachers' understanding of the PBL approach? | Pre-interview<br>Classroom observations<br>Study of the QEP and MELS approach to PBL | Comparison of QEP and classroom approaches |
| What, if at all, are any internal and external barriers that high school science teachers face in the effective implementation of PBL in today's high school science classrooms? | SoCQ<br>Classroom observations<br>Reflective Journals | Self-identified barriers<br>Stages of concern profile analysis |

# Chapter 4- Findings and Analysis

> *I was just coming in [when the reform was implemented]. The kind of PD that was given to teachers was here are some project ideas. There were no courses, or packages of information about what the goals are of the reform. We were lost.*
>
> (John, a secondary science teacher)

## 4.1 Overview of Results

In this section I present the findings of the salient themes that surfaced throughout my research. These findings emerged through a variety of approaches to the collection of data. Interviews were conducted with each teacher participant in order to establish three key points in relation to questions; (1) their understanding of the PBL approach, (2) their views about this approach to the teaching of science and (3) any internal or external barriers that they faced while implementing the curriculum. This chapter is organized in various sections that are aimed at engaging the reader to discuss curriculum implementation of the PBL approach to high school science in Quebec. Data collection methods included semi-structured interviews, classroom observations, a PBL unit implementation, reflective journals and the Stages of Concern Questionnaire (SoCQ) (these methods are discussed in detail in Chapter 3).

For each teacher participant findings are presented that explain what their initial perceptions of PBL were prior to this inquiry. These perceptions were discussed in the pre-interview and were evident throughout classroom observations. Following this initial perception of PBL overview, I present data that explores each teacher's initial understanding of the Quebec science curriculum as shown in the Quebec Education Plan. This constructivist curriculum framework is used as a model to assess each teacher's understanding of the implementation of PBL. Using the classroom observations, each teacher's real-life approach to PBL teaching is explored in the next section. In order to address the last research question and establish "What, if at all, are any internal and external barriers that high school science teachers face in the effective implementation of PBL in today's high school science classrooms?" data from the interviews, classroom observations and the SoCQ is combined, analyzed, and key findings are presented in this chapter. Finally, the development process of each co-created PBL unit is described along with the methods of implementation. I then explain how they PBL units were implemented and barriers the teacher participants faced throughout the teaching of each unit.

### 4.2 Individual Case Analysis

I followed three teachers implementing the PBL approach to the teaching of science mandated by the Quebec reform. The data collected for each individual case is first presented and then a cross case analysis is performed to discuss patterns of similarities and differences across the three cases. This cross-case analysis was conducted across the three participants in relation to all three research questions to research trends that appear in the results. Key themes identified from the interviews and classroom observations are presented that appear across all three cases. These initial themes, identified as sub-sections below in each case analysis, answer the first research question "How do high school science teachers feel about the PBL approach?"

#### 4.2.1 Case 1: John

**4.2.1.1 Initial Perceptions of PBL and the Curriculum:** The first interview with John gave rise to many themes that allowed me to gain insight into how John initially viewed the PBL approach in terms of his teaching style and the curriculum. When asking John to consider my first research question, "How do high school teachers feel about the PBL approach?", his experience shines through his many insightful answers. John completed his Education degree at a critical point in the implementation of the Quebec Science Education reform, he was fortunate to be exposed to the reform in an educational setting at McGill University and had the opportunity to see the overall goals of the reform as a whole when they were first implemented. John has a good understanding of what the PBL approach entails, stating that

> I like to think of problem-based learning more along the lines of solution based. Um, because they give the old [story] of the situational problem, which shows up in science, shows up in math, shows up here, shows up there, the situational problem is inevitably and unanswerable question which just leads to more problems.(February 28, 2012)

Here John identifies a common problem faced by teachers when they are first tackling the implementation of a PBL unit. All too often teachers become stuck on the management aspect of an innovation and do not see how to tackle issues dealing with the overwhelming aspect of a true PBL unit.

This become obvious when John suggests his solution to this common problem:

> I like giving them something that has a set of solutions. So, for example, one of my favorite opening tasks in my classes is I give them a small set of materials and say good now mount this on the wall. So I'll give them something like a matchbox, a couple of candles, one pushpin and 2 matches and say mount the candles on the wall. Now, that's only got a limited number of possible solutions. A truly open-ended question is very difficult to deal with, I prefer something that gives them a few very simple solutions but you don't necessarily give them exactly what they need to get there, you give them a chance to figure it out. (February 28, 2012)

Here, John explains that he allows the students to use their creativity and imagination without becoming overwhelmed with trying to manage a class full of students all attempting to solve a problem their own unique way. In restricting the materials made available to the students John realizes that although PBL units have an advantage at creating innovative thinkers they must be limited in the context of a real-life classroom to ensure they are manageable. John realizes that although the mandate for the PBL approach to the teaching of Science has many great advantages, it needs to be adapted to work within his own teaching philosophy. When attempting to answer my second research question, "What are the teachers' understanding of the PBL approach?" John again reflects on his own experiences and application of the approach in his own teaching stating that "PBL in the Quebec reform asks teachers to teach through relatable, practical situations." John realizes that he is being asked to change his teaching style from one of pure teacher-talk to one that is "solution-based with a limited number of possible answers that encourages students to think laterally." Although John offers great insights into his opinion about what he believes PBL to be, I am only presenting a small excerpt of his most notable statements throughout this section. John is very accepting of this change in the curriculum as he has seen firsthand in his students how engaged they become when their learning is self-regulated. John also notes that PBL is an effective way to teach when it is controlled and the possible solutions are limited, this control allows for students to find a possible answer and encourages them to find as many solutions as possible.

John offered great insights into his opinion about what he believes PBL to be during the formal interview and several informal conversations that we had during this study. Overall, it seems that John has a good understanding of PBL teaching that is on par with what the Quebec science education reform has mandated. John understands that PBL is a solution-based approach that allows the students to engage in their learning and develop their own unique, hands-on solutions to open-ended problems.

**4.2.1.2 Teacher Real-life Approach to PBL Teaching:** John's real life approach to the implementation of PBL in his science classroom was evident in many incidences. When first observing John teach his class clearly he always tried to approach each lesson with an open-ended question that would guide the students thinking towards possible correct answers. This clarity was evident in one of the first lessons I observed in John's Secondary 4 AST science class. He began the class by having the students discuss how they would hang matches on the wall given only a limited amount of materials such as: one match, two push pins, one board.  John set limits on this open-ended question by only allowing the students a certain list of materials to accomplish the task but still allowing them to find their own unique solution to the problem at hand. John stresses in his interview that “it is important for the students to feel they have control over the problem presented to them without giving them too many possibilities and leaving them feeling overwhelmed.” While John wants to give the students the opportunity to be successful with an open-ended PBL question he notes that “a truly open-ended question would have an infinite number of possibilities and this is not a realistic scenario for students at this level.” Throughout my classroom observations with John (6 in total) I noted many times that he would present the students with an open-ended problem-based question but immediately would set limits on the problem (type of material, amount of material, time to complete the task). If absolutely no limits are set on the problems students will may choose to solve the problem too many ways, thus creating a management nightmare for the teacher. John also points out that that if students are given an unlimited amount of choices to solve a problem they become overwhelmed and discouraged. Giving them limitations allows them to gain confidence solving a problem on their own while ensuring they are engaged in their learning.

**4.2.1.3 Internal and External Barriers:** John points to many significant barriers that he has experienced in the past and continues to experience attempting to successfully implement the PBL reform into his teaching. The barriers he articulates address my last research question; “What, if at all, are any internal and external barriers that high school science teachers face in the effective implementation of PBL in today’s high school science classrooms?”

When delving into the complex barriers that John experienced in his own implementation, he shifts his thoughts more towards the internal barriers faced by his colleagues rather than reflect on his own by stating that “Teachers are not clear about what the problem-based approach to the teaching of science called for by MELS entails”. John blames the lack of effective implementation of the reform by his colleagues on this confusion. Instead of discussing his own internal barriers, John focuses on the external barriers that plague all teachers attempting to implement this reform. Even when probed about his own internal barriers John steers towards external barriers that he faces, stating that “[he] has a good understanding of PBL and how to teach that way, it’s the other ‘stuff’ that [he] can’t control”. John believes that not only does “MELS not provide teachers with sufficient effective practical situations” but he also believes that what the QEP and the government say they want and what they ask for as proof have very little in common”. When John mentions “proof” here he is pointing towards the disconnect that exists between the government mandate to teach through open-ended practical situations and the mandatory final exams which are often heavily reliant on multiple-choice questioning. John believes that this has resulted in a “misguided message being delivered to teachers in the process of implementing the PBL reform”. John feels he was lucky to have completed his Education degree at a crucial time, when the reform was first introduced. He feels that this is rare, and although he had special direct access to the people who designed the reform, most “teachers do not have direct access to the people who were designing the reform and therefore are confused about what is being asked of them”. Another poignant external barrier that John identifies is that “evaluations have changed every year and teachers are left confused about what approach they should be using to teach the content”. The “lack of communication between the Ministry and the board and subsequently to the schools and teachers” has resulted in every teacher having their own misguided interpretation of how the reform should be implemented.

John noted many barriers to the implementation of PBL that he faces in his classroom. The most notable of these barriers include:

- Teachers are not clear about what the problem-based approach to the teaching of science called for by MELS entails.
- MELS does not provide teachers with sufficient effective practical situations.
- Misguided message was delivered to teachers in the implementation of PBL
- Teachers do not have direct access to the people who were designing the reform and therefore are confused about what is being asked
- Evaluations have changed every year and teachers are left confused about what approach they should be using to teach the content
- Lack of communication between the Ministry and the board and subsequently to the schools and teachers,

After John notes the barriers he has faced he offers one fairly simple solution. John states that “teachers need to be informed of what the final evaluation will look like at the beginning of the year and need to stay consistent for many years in a row." By doing this it will be easier for teachers to guide their teaching throughout the year to prepare the students for the type of evaluation they will face at the end of the year.

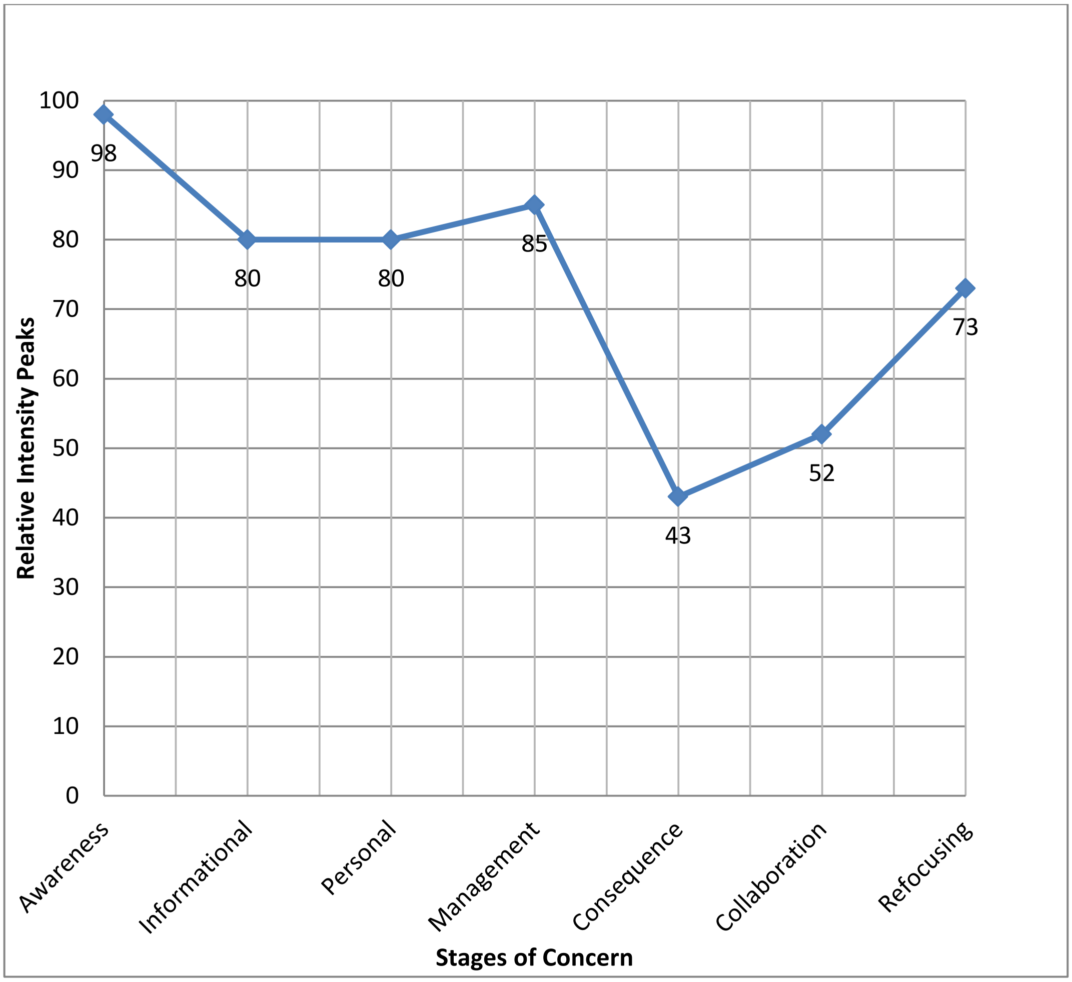
**4.2.1.4 Co-creation of a PBL Unit**: John and I decided to use his smallest class to implement a PBL unit. We had decided to have the class design and build a small electrical maze. This unit was created with a very open ended approach since the students needed to decide how to use the materials provided, including a circuit diagram, to create an appropriate procedure for the assembly of the circuit. Although some students found it very easy to develop an appropriate procedure for the assembly of the circuit, other students struggled with where to begin. Another major issue that arose was the students' inability to interpret the diagram and understand what materials given related to what part of the circuit diagram. John reiterates these points in his reflective journal stating that

> *organization was the major issue in this task as there could be any number of different activities happening simultaneously, given one student may be soldering while another could be cutting wire of cutting the base, it could get a little difficult to manage.* (June 15, 2012)

Here John identifies one of the most common management issues of any PBL unit, management. This management issue can be overcome in many ways. The help of a laboratory technician in a classroom is crucial in order for many PBL units to be successful. John is identifying that he sees the classroom management aspect of the PBL approach to be a significant one for him. This trend is repeated when we look at his SoCQ profile in Figure 2, where he has a fairly high management percentile score of 85.

**4.2.1.5 Stages of Concern Profile Analysis:** The SoCQ, used in this research as a method of analyzing the teachers' Stages of Concern, "is a 35-item questionnaire that has strong reliability estimates and internal consistency" (Hall & Hord, 2006, p. 147) and is a great tool to use when attempting to determine teachers levels of concern about a new innovation. The concerns, displayed in Table 3 on page 63, are related to awareness of the innovation (awareness); what kind of information one would like to receive about the innovation (*informational*); how would it affect one's practice (*personal*); managing and preparing for the innovation (*management*); impact of the innovation (*consequence*); working with other colleagues while implementing the innovation (*collaboration*); exploring more universal benefits from the innovation, including alternatives (*refocusing*) (Hall & Hord, 2006, p. 140). The questionnaire is used to develop a Stages of Concern profile. These profiles are developed using the process identified in section 3.9 on page 64 of this thesis. This profile shows John's percentile scores according to each of the seven stages of concern.

**Figure 2 – John's Stages of Concern Profile**




John's profile, seen in Figure 2, most closely resembles a "one/two split" with tailing up" (Hall, George & Rutherford, 1977) seen in Figure 1 in Appendix G. When we look at analyzing John's profile, we can approach it from many different ways. One of the most common ways to analyze a stages of concern profile is to focus on the peaks of the profile and conclude that the two highest peaks on the profile represent the individual's highest areas of concern about the innovation. Hall *et al.* (1977) defines this approach as the peak stage score interpretation. In John's case the highest two peaks occur at stage 0 (awareness) and stage 3 (management) with respective percentile scores of 98 and 85.

“Interpretation of the high scores is based directly on the Stages of Concern about the innovation definitions presented in table 6. Stages of concern displayed in John’s profile are directly related to the stage definitions with “the relative intensity of concern being indicated by the percentile score” (Hall *et al.*, 1977, p. 40). A high stage 0 concern on John’s profile indicates that he “lacks concern about the innovation” (Hall *et al.*, 1977, p. 40). John is a user of the innovation who lacks concern about it. John’s high percentile score of 85 on stage 3 indicates an “intense concern about management, time, and logistical aspects of the innovation” (Hall *et al.*, 1977, p. 40). These high Stage 3 concerns indicate that John is very concerned with various tasks around the innovation. These tasks can include “the processes of the tasks of using the innovation, the best use of resources and issues relating to efficiency, organizing and managing demands” (Hall & Hord, 2006, p. 140).

The last part of John’s profile that is significant is the “tailing-up” that is seen at the end, specifically for the last stage of concern revolving around refocusing. When focusing on the overall shape of John’s profile we see that it resembles a classic negative “one/two split” with tailing up (Appendix G). The tailing up of the profile at Stage 6 (refocusing) indicates that John “has other ideas about that he sees as having more merit than the proposed innovation” (Hall *et al.* 1977, p. 52). This tailing up is seen as a significant one since it is more than 10 points above the lowest previous point (collaboration). This severe tailing up is most significant since it indicates the potential for John to be quite resistant to the innovation itself (ibid). Throughout my discussions with John I did sense a resistance to the reform. He often pointed out ideas he had to "improve the reform, make it more feasible as a teaching approach and ensure the needs of the students are being met". John's reflections about the reform indicate that he has implemented the reform into his teaching but wants to change some aspects of it such as: creating smaller PBL units which are feasible to teach, ensuring all teachers understand the PBL approach and creating final examinations that reflect the mandated PBL approach.

### 4.2.2 Case 2: Ian

**4.2.2.1 Initial Perceptions of PBL and the Curriculum:** During Ian's initial interview and throughout my classroom observations many of his perceptions about PBL and its place in the curriculum emerged. During the pre-interview with Ian he was very clear about how he felt about PBL and its place in the curriculum. When asked how he feels about PBL and what he thinks it is Ian explains:

> *What do I think it is? Sounds like jargon to me! I would guess it is the kids are supposed to have a certain level of knowledge to begin with, you then give them a relevant, hopefully real world situation where they have to apply their knowledge to solve this problem. In science I would imagine a lot of it would be practical based. I think there's a place for it but it's certainly not the be all and the end all. The kids have to have a certain level of knowledge before these things can become relevant.* (September 20, 1012)

Here Ian makes it very clear that he does not completely understand what the point of PBL is. He states that it sounds like jargon to him and proceeds to guess what its purpose is. Although Ian states he does not clearly understand what the purpose of PBL is, his next statement gives a fairly accurate portrayal of the intentions of PBL as a teaching approach in the sciences. He points out that it must be based on prior knowledge, practical-based and involves a situation.

Ian takes his discussion about PBL even further when he begins to reflect on its implementation into his teaching in relation to MELS stating:

> *I thought they [MELS] had some really good ideas in terms of what they wanted to put into the curriculum and the way that some of them sort of linked together. Instead of it being isolated facts [they should have] base[d] it around a topic, you do your teaching around that topic and you give the kids some sort of context for what they're learning. That I thought was fine. If they could have built a coherent curriculum around that then I think a lot more people would be still on board with that today. (September 20, 2012)*

Here Ian reflects on where the problem arises when he considers how the reform was implemented in the curriculum. He feels that it was not clearly explained to teachers that the curriculum should be taught around a central topic that links all the content together. If this had been done, Ian would be more on board with the PBL mandate.

**4.2.2.2 Teacher Real-life Approach to PBL Teaching:** Ian's experiences throughout his teaching career with the implementation of various reforms and teaching innovations gives him insights that he taps into when reflecting on the Quebec science education reform and how he incorporates PBL into his own teaching.

This is evident when Ian reflects on his priorities about implementing PBL into his lessons. As he explained:

> *I guess a lot of the time it's got to be kid first, subject second. So you try and make connections with the kids whatever way you can, usually by knowing a little bit of something outside of school. That then tends to make them want to be on your side, want to learn the science, so I go at it that way.* (September 20, 2012)

Ian believes that although a PBL unit is a great way to engage the students by "making connections" with them and be able to use real-life relatable examples to teach them, the implementation of PBL was not done in the most effective manner by the MELS. Ian demonstrates this belief when he states this when he says that you need to "[know] something outside of school [about the students]". He realizes that by connecting with the students they are more likely to "be on your side [and] want to learn science."

**4.2.2.3 Internal and External Barriers:** Ian noted many barriers that he faces while implementing PBL into his teaching. Of these barriers Ian specifically discusses major ones as being:

- Student absence
- Lack of access to computers and research materials
- Sensitivity of topic
- Time is always a major concern.
- Students' literacy skills
- Lack of practical materials to better explain the concepts

These barriers were elaborated on by Ian as he describes how each barrier affects the teaching of a PBL unit. Student absences, a common occurrence, hinder a whole group and can lead to social problems in the teams when they teammates begin to blame one another for not doing their share of the work throughout a large PBL unit. The lack of access to computers and research materials meant in a school or for the students at home creates issues when coupled with the first barrier of absences. When absences occur a lot of the work has to be done outside of school which proves to be difficult when many students do not have access to the necessary materials or computers at home.

Time is also noted by Ian as being a major concern when working through any large PBL open-ended project. Ian knows that "ideally the projects would be done in class time over a 2 week span with access to computers and the library throughout. This is simply unfeasible as too much content needs to be covered already and the computers are already over-booked."

The last external barrier noted by Ian concerns the diversity of the students he sees in his class. "In most science PBL units the students need to reflect on real-life problems. This becomes problematic when one considers all of the various lived experiences the students in the classroom have." In order for the students to gain insight into how science in the real world works, Ian feel that an outside speaker would have been of great value, and though this was attempted the people approached were rarely able to come to speak. Students' poor literacy skills coupled with the above mentioned barriers create a situation where students struggle with completing PBL units. Ian notes that it would have been beneficial to introduce some practical element into the PBL unit but lack of time and insufficient equipment prevented this from being a possibility.

Other notable barriers that Ian explains are evident throughout his interview. Ian experiences many internal barriers to implementing PBL into his teaching and tends to relate to the students a lot, causing him to struggles with how to balance the PBL approach to science mandated in the curriculum with the needs of his students. He mentions that:

> *I tend to be bored fairly easily, very much like the kids. The kids now are the same so they didn't push themselves because they didn't have to. The standards were dropped very quickly. I mean we can talk high ... educational philosophy all we like, kids don't give a stuff, they want to know if they graduate or not.* (September 20, 2012)

Here Ian is placing himself in the shoes of his students, noting that he gets bored easily with repetitive tasks, just as his students often do. He realizes that it is human nature to only push yourself when its demanded of you by the task. By allowing the students to achieve a successful grade in a course without them feeling challenged Ian believes that these lowered standards have created students who expect high grades with little effort.

Although Ian's own internal barriers are part of the reason why he finds it difficult to implement PBL into his teaching he points out many more external barriers related to the management and implementation of these PBL units. Ian believes that "LES's are too many, too big, too long, too expensive, kids didn't have the basic knowledge to do them in the first place and it ended up just being the teacher telling them what to do if they were going to get anywhere."

Ian also struggles with many management and logistic problems when teaching a PBL unit such as attendance, managing student participation and accurately grading the LES units.

These issues are evident when Ian states:

> *Attendance becomes an issue. You try and put kids together and one kid's off for 2 or 3 classes, they're way behind, they come back, they don't have a clue what's going on. You can't really help them because it's supposed to be their work. There's just so many logistical problems.* (September 20, 2012)

When considering the issues of student participation Ian remarks that "you don't have a clue, really, who's done what. So, I mean by observation you know what students worked and which ones didn't, but they hand stuff in and it has all four names on it what are you supposed to do?"

**4.2.2.4 Co-creation of a PBL Unit:** Ian and I decided to do a cross-curricular project with his grade 9 science students around the theme of genetic diseases. The students were introduced to genetically inherited diseases by traditional teacher-talk methods and then chose a genetic disease that they find relevant to their own lives. They are asked to produce a "zine" aimed at teenagers who either are suffering from the disease or have family affected. A zine is a "a noncommercial often homemade or online publication usually devoted to specialized and often unconventional subject matter" (Merriam-Webster, 2012). The work completed by the students was then assessed in regards to the science content it contained and in English for the literacy aspects and is used as a cross-curricular piece in the school's International Baccalaureate program. The aim of this approach was to move away from the traditional teacher-talk approach to try and make the topic more relevant and personal to the students. They were asked to solve many issues that arise throughout this task such as problems with the technology being employed, decisions on how to approach the open-ended approach and use their prior knowledge of genetic diseases. This task is considered a problem-based task as it requires students to engage themselves in a problem (how do we educate the public about genetic diseases) while tapping into their prior knowledge to solve the problem. We also aimed to break down some of the more artificial barriers that the traditional subject demarcations impose such as isolating science content from English. We wanted the students to realize that material they cover in other classes applies to all their classes. The students worked in groups of 2 or 3 and needed to work together to research, design, produce and present their "zine". The zines students created were information pamphlets of sorts explaining the genetic diseases and possible cures for the diseases. The task required the students not only gather and analyze information about the diseases but they also had to apply their knowledge to find possible solutions to the diseases.

The main adaptation from the teachers' point of view was to let go of the minutiae of what is covered and allow the students to take more ownership of their learning. In taking ownership the students have a free pass to apply their own knowledge and creativity to the task, considering it is an open-ended task with many possible solutions. It does not matter if groups end up with different examples as long as they get the gist about how genetic diseases are transmitted and an understanding of the issues involved in making decisions around them.

From the students' point of view a number of students stated they were unclear about exactly what was expected from them. This confusion mostly stemmed from the students having to distribute the work between themselves and gave rise to some friction in certain groups. On reflection this appears to be a part of the student's development of team skills and will be a healthy thing for them in the long run, a possibly positive outcome of the PBL approach.

The zines the students produced varied a lot in quality. Those groups which worked well together and had a true interest in the project produced high quality work. Those not so engaged produced adequate pieces but just enough to get marks. These varied results made it difficult to mark the zines since it was difficult to determine which students were responsible for what work.

**4.2.2.5 Stages of Concern Profile Analysis:** Ian, like John, completed the SoCQ and his results were analyzed to produce a stages of concern profile, seen in figure 3. When analyzing Ian's profile we see that it does not fit one classic example of a concern profile and must therefore be analyzed from the multiple peak aspect. This method of analysis assumes that the Stages of Concern with the highest percentile scores are the Stages that concern the participant (Hall *et al.*, 1977). Ian clearly expresses high levels of concern at stage 0 (awareness), stage 4 (management) and stage 6 (refocusing). Please refer to the process of producing the Stages of Concern Profile detailed in section 4.4.1.5 above. The process will be the same for Ian's data.

**Figure 3- Ian's Stages of Concern Profile**

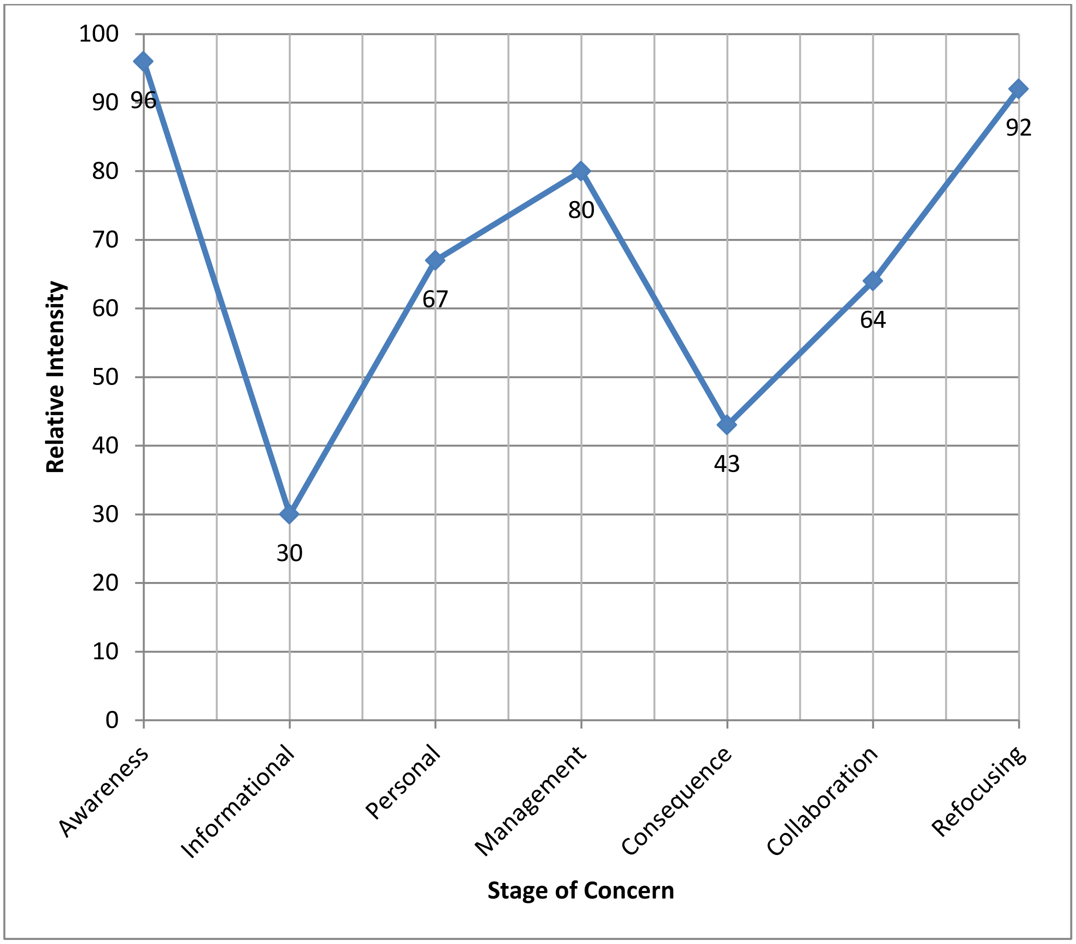



Table 3 on page 63 explains what each stage of concern represents. In the first interview Ian makes many statements which can be interpreted to determine what his greatest levels of concern about the PBL innovation were. Ian makes several statements that confirm, as his stages of concern profile show, that he had a high level of concern in regards to awareness about the Quebec Science Education Reform (Level 0) Ian lacks some awareness about what the innovation is trying to achieve as explains that PBL "sounds like jargon. I would guess it is the kids are supposed to have a certain level of knowledge to begin with, you then give them a relevant, hopefully real world situation where they have to apply their knowledge to." Here Ian seems frustrated when attempting to decipher what MELS is mandating with the reform.

Ian also expresses a rise in level 3 personal concerns. He feels that the reform allowed students to become over-confident with their abilities when "the standards were dropped." Ian shows an internal struggle here with how to manage the new lower standards the students have for themselves while maintaining a high level of teaching that reaches the requirements of the reform. Ian points out that "the kids now are the same so they didn't push themselves because they didn't have to." Along with these management concerns Ian notes that money distribution when completing a PBL unit is a big issue to manage because even if you are "only dealing with dollar store stuff, suppose it's 4$ a group and you've got 12 groups in one class and you've got 5 or 6 classes, you're talking big bucks. We're not in a particularly privileged area, so there's not a chance on the funding."

Management concerns for Ian are very high in his stages of concern profile, expressed at an 80$^{th}$ percentile score. Ian not only struggles with his own internal personal concerns about PBL but acknowledges that all PBL units and assignments are "so difficult to mark. You don't have a clue, really, who's done what. So, I mean by observation you can see who has done work in class and who hasn't, but they hand stuff in and it has all four names on it what are you supposed to do?" .

Ian also notes that he struggles to manage students who are not in class often, therefore attendance becomes an issue. As Ian explained in his reflective journal:

> *You try and put kids together and one kid is off for two or three classes, they're way behind, they come back, they don't have a clue what's going on. You can't really help them because it's supposed to be their work but also they're part of a group that's supposed to be working independently and the teacher is just a facilitator. There's just so many logistical problems we have to give out kids the best chance possible.* (December 12, 2012)

All of Ian's concerns about the Quebec Science Reform have resulted in him developing new ideas about how the reform should have been implemented and what would make it more effective. Ian believes that PBL"has its place [in the curriculum], but it's not a big place because then it takes away from the regular business." When Ian is referring to the "regular business" here he is referring to the content aspect of the course. Ian feels that the reform has shifted too far away from the content teacher-talk of teaching and allowed the students to be successful in science while meeting much lower standards.

Ian points out that he "thought [MELS] had some really good ideas, in terms of what they were wanting to put into the curriculum and the way that some of them sort of linked together." Ian acknowledges the positive aspect of the reform as an "alternative approach to it being isolated facts base it around a topic, and that you do your teaching around that topic and you give the kids some sort of context for what they're learning." He points out that he thought "that was fine". The problem arises when looking at how the curriculum was introduced into schools and teacher s and he suggests that "if they could have built a coherent curriculum around [the approach] then I think a lot more people would be still on board with [it] today.

### 4.2.3 Case 3: Amy

**4.2.3.1 Initial Perceptions of PBL and the Curriculum:** During my 6 hours of classroom observations with Amy many of her perceptions of PBL and its place in the curriculum were evident. During the pre-interview Amy explained her understanding of PBL when she said

> *I guess giving the students a situation or some sort of with some sort of background information and making sure that they have some prior knowledge or a way to research that and then having them come up with their own solution.* (March 16, 2012)

Amy believes that the PBL approach to teaching science is when the teacher gives the students a situation and the students are responsible for coming up with their own solution to the problem. According to Amy, this type of approach includes the teacher as a person to guide the students' learning and ensure they have access to all materials and background information needed. Amy also states that it is important to correctly frame the introduction to a PBL unit by

> *…telling them next to nothing and them saying well 'Miss what about this?' and then you're like 'oh really? That's an interesting thing you brought up' well let's talk about that. I like that.* (March 16, 2012)

In this quote it is evident that Amy likes introducing a PBL unit without giving the kids too much information and allowing them to guide how the lesson will go. This ignites the students' curiosity and makes for a richer lesson. This approach is evident in Amy's real-life teaching style, discussed in the following section.

**4.2.3.2 Teacher Real-life Approach to PBL Teaching:** Amy is very clear about her approach to implementing PBL into her teaching. She states that she tries to

> *...focus on the parts of the curriculum that are important and the parts [she] think[s] are [the] most cross curricular, in many different branches of science [the students will] see [things] repeatedly like the periodic table is almost in every world that you discuss so I try to focus a lot on that and the mechanisms and the technology, you see it in everything, so even let's say you are talking about mining, well you can talk about the machines they use and why they use that and try to relate it all together all the time.* (March 16, 2012)

Here Amy is stating that when she implements PBL into her Science teaching, she always tries to ensure she is approaching the problem in a cross-curricular way. She feels this is important for the students so they can make connections between the individual concepts that they learn. When Amy relates the various units in the science curriculum through one concept it allows the students to see science as a whole rather than a sum of many small parts. It is important for Amy to "make it relevant to something recent, either in the news or something that [the students] used before or something that they've heard." By doing this Amy ensures that the PBL units and LES's are relevant to the students' lives, creating a learning environment using "a variety of medias, [including] talking to them, showing them a video, showing them an animation, filling out a sheet or having them read about it."

Amy also likes to try many “different activities [with the students] where they’re building things, where they have to design something and they have to chose a design based on what they have learned.” Amy chooses to teach this way to allow the students to use their imagination to develop their own unique solution to an open-ended PBL unit. Amy notes it is important to ask “them why things were designed in a particular way [so] they can work backwards and figure out well scissors have two holes because your need your two fingers to make them work, that kind of thing.” Although Amy recognizes that approaching PBL in a variety of way is usually the best way to teach it she acknowledges that it “doesn’t always work!” She tries to reach as many students as possible but some students, no matter the approach being used to teach PBL, are not able to apply themselves to solve an open-ended PBL scenario.

**4.2.3.3 Internal and External Barriers:** Amy doesn’t seem to experience many internal barriers when considering the implementation of PBL into her teaching. She only notes that “it’s hard, you really have to balance between the theory part, because they do have to know the theory and the time it takes to do something it always takes longer but in the long-run they do learn more.” Here Amy acknowledges she has an internal struggle with balancing between teacher-talk approach and PBL open-ended hands-on approach. She realizes that the students need the content knowledge to pass the final exam but the reform asks her to approach her teaching in a practical manner. This conflict is a reflection of the mandated approach to teaching science and the content-driven final examinations.

Amy reflects on many external barriers that she faces in the implementation of PBL into her teaching. She first points out that “it takes time to create those activities, get the materials, predict what the kids are going do and want to do because you don’t have an unlimited amount of time; you need to keep on track.” Amy repeatedly discusses the lack of time necessary to properly prepare, organize and teach a PBL unit. She would need more time to develop appropriate activities and the ones already developed require more class time to implement. She also finds that “another big barrier is that a lot of the students have a big gaps in their learning.” These gaps in learning are amplified “when you give them a situation and half the students had teacher A last year and teacher A wasn’t maybe comfortable teaching that and they have no idea so they’ve never explored these topics and they’re looking at you like what are you talking about and then the other half of the class is like “oh! We did this already.” When this happens the time issue becomes even more pronounced because “you’ve got to stop figure out what they do know and then you got to figure out okay what do I have to fill in and then you know it’s difficult balancing that cause they do have an exam in the end.” The content-driven final exam causes Amy to be torn between teaching through a PBL open-ended approach or a teacher-talk content approach that might better prepare the students for their final exam. The last external barrier Amy raises is money. She would “like lots of money! Lots of money! [Laughs] To buy all these sort of cool things and I need a store right next door to the school

**4.2.3.4 Co-creation of a PBL Unit:** Amy and I created and implemented a PBL lesson for the students focused or creating windmills. In this activity students create a power-generating wind-farm out of pop bottles in the classroom. Students each engineered a windmill out of everyday materials and configured them together as a class to make electricity. They then were able to measure the amount of electricity generated by the wind farm and use this electricity to light LEDs or charge an iPod.

Amy notes that from the diagrams and activity instructions the build looked easy enough, but when it came to doing the circuit she was lost. We realized as we started the activity that the motor voltage was not on the WOWLab activity instructions and so we were not sure if the motor we were using was the correct type. Upon investigation and testing we were able to determine the motor was in fact not strong enough and did not produce sufficient electricity to light up the LED. We were however able to build the windmills and as we had set them up the students were the ones trying to figure out why they weren't working. They were checking connections and reattaching various cords to try and fix the problem. They did enjoy watching them all spin and knew that it was possible they could generate enough current to charge an mp3 player. This activity was only tried with Amy's Applied Science and Technology (AST) class as she was running out of time in her Science and Technology (ST). There is more material to be covered in ST so it leaves little room for long building projects. Amy notes that she feels the biggest problem encountered was her lack of electrical engineering knowledge to troubleshoot the circuit issue. She was able to see a model at the WOW lab at McGill which helped to problem solve and chose the correct motor for the windmills.

**4.2.3.5 Stages of Concern Profile Analysis:** Amy's SoCQ was analyzed in the same way it was for John and Ian's cases. The method used for this analysis is described above in section 4.2.1.5 on page 76. When this analysis method is applied to her questionnaire answers it is evident that Amy exhibits some classic signs of the profile of a typical nonuser as seen in figure 2 of Appendix G. Amy's SoCQ profile in seen below in figure 4. "Overall this profile suggests and reflects the interested, not terribly over-concerned, positively disposed nonuser" (Hall *et al.*, 1977, p. 45). Since Amy is using the reform in her teaching, this profile suggests that she is interested in the reform and somewhat aware of and concerned about it (high Stage 0). The profile also shows that "she is interested in learning more about the reform from a positive proactive perspective." (Hall *et al.*, 1977, p. 45) The only discrepancy in Amy's profile and that of a typical nonuser is that classically a nonuser profile shows a lower level of level 3 management concerns where as Amy's profile expresses a high level of management concerns. Amy does however follow the nonuser profile with low Stages 4 and 5, indicating a low level of concern about the reform's consequences for students (Hall *et al.*, 1977). "The tailing-off Stage 6 score suggests that the individual does not have other ideas that would be potentially competitive with the reform" (Hall *et al.*, 1977, p. 45).

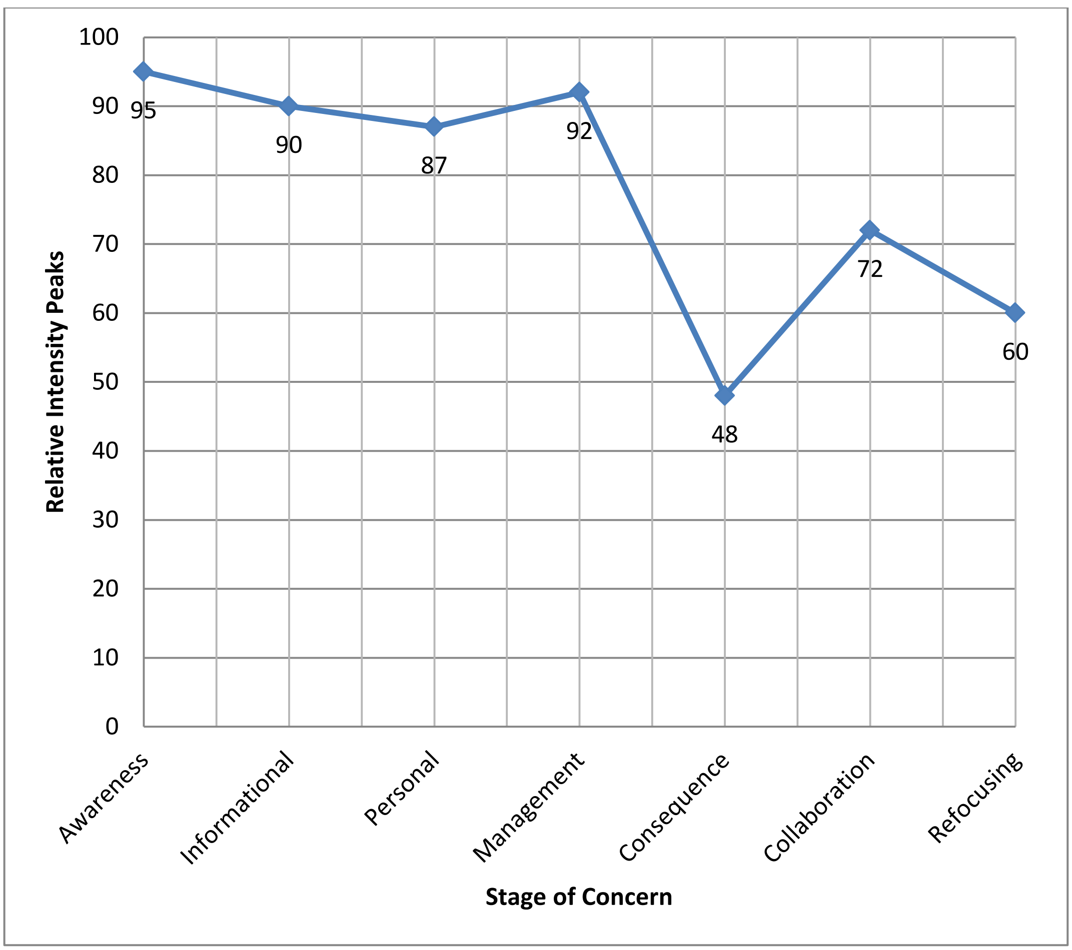
Overall Amy's concerns are higher in Stages 0 through 3. These concerns all fall into the self and task sections of concern. As described by Hall & Hord

(2006, p. 140) high concern in these stages defines a user who has the following characteristics:

- Is aware of the innovation and interested in learning more about it
- Is interested in the effects and requirements of the innovation
- Is uncertain about the demands of the innovation and their role
- Is focused on the processes and tasks of using the innovation

Amy exhibits these concerns through her teaching and the interview I conducted with her, as stated above.

**Figure 4 - Amy's SoCQ Profile**



### 4.3 Cross-Cases Analysis

#### 4.3.1 Participants' Initial Perceptions of PBL and the Curriculum

Although each teacher described a variety of their own perceptions about PBL a lot of overlap occurs, showing that some concerns experienced by one teacher are also experienced by other teachers.

For example, John Ian and Amy describe PBL as being a combination of three main themes:

- Solution-based
- Open-ended
- Relatable problems

A solution-based problem is one that offers the students an introduction to a concept, sets parameters for the solution and asks the students to apply their previous knowledge about a subject to solve the problem at hand. These types of problem are considered open-ended since more than one solution is possible. Students are only able to apply their prior knowledge to the problems as needed if they teacher ensures the problem at hand is one that is relatable to students and their lives. All teacher participants noted that the three themes listed here are of utmost importance for all teachers to consider when they are designing or implementing any PBL unit.

#### 4.3.2 Teacher Real-Life Approach to PBL Teaching

When describing how they incorporate PBL into their teaching, all three participants pointed to many of the same methods, notably:

- Setting limits of the possible number of answers (limit management issues)
- Using hands-on scenarios
- Employing a variety of teaching techniques (practical and content)

### 4.3.3 Internal and External Barriers

All three teacher participants cited only a few internal barriers to the implementation of PBL. Namely, they focused on the lack of clear communication between the Ministry and teachers about what the reform was actually meant to accomplish, leaving the teachers confused about what they were to be doing. All three teachers also state that they have a lack of appropriate knowledge about the PBL approach, and do not posess the proper skills necessary to understand how to implement these open-ended problems into their teaching. Teachers also noted that they are unclear about how to access and use any available resources. They seem overwhelmed with the amount of resources given to them from MELS and need guidance on how to use them.

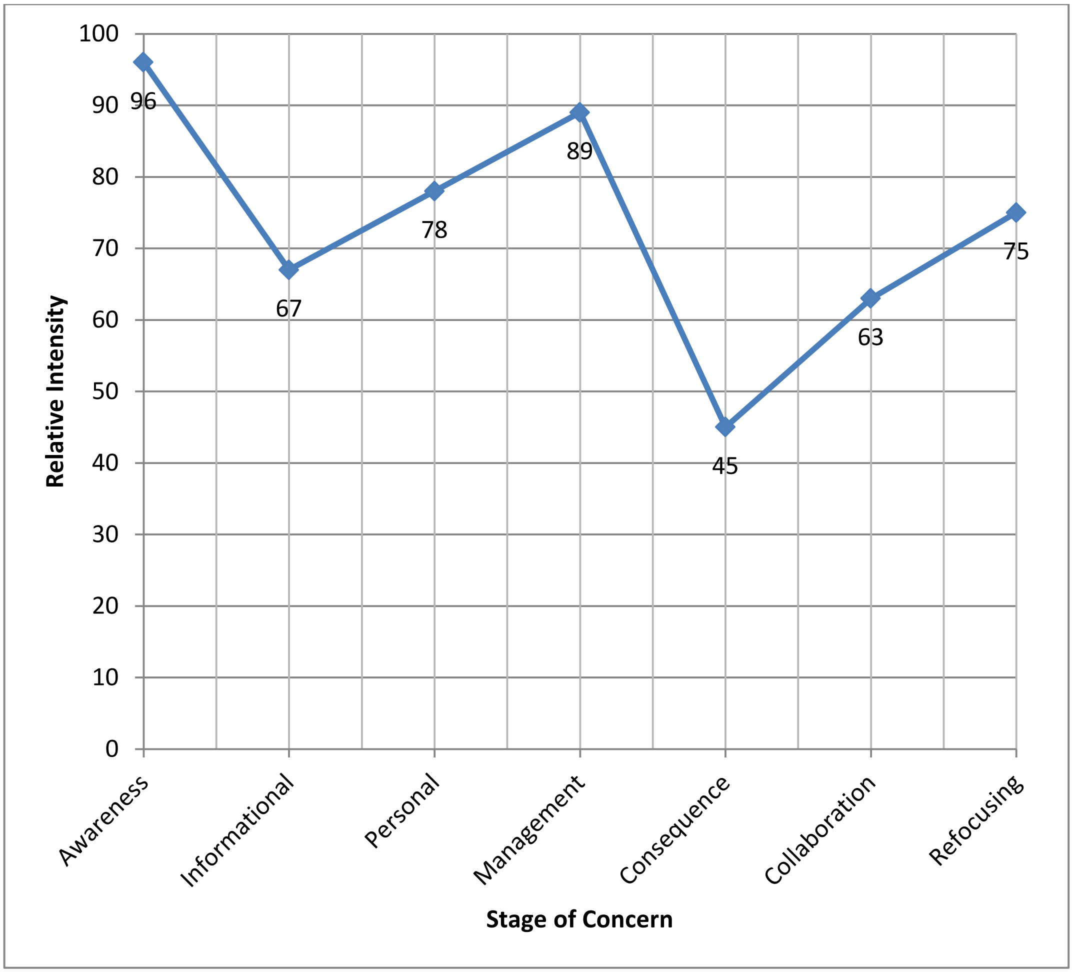
All three teachers also noted many common external barriers such as the lack of appropriate resources, shortage of money to buy the equipment and insufficient time to complete all the PBL activities mandated while still covering the content material of the courses.

Ian pointed out some external barriers that were not considered by John and Amy. He points out that student absences, sensitivity of the topic and student poor literacy skills are major contributing factors to the difficulty he experiences in implementing PBL into his Science teaching. Although Amy and John do not specifically point to these factors as being barriers they hint at it when reflecting on their units and stating such facts as "it was difficult to finish all the LES's because there was always someone from the group missing" (Adam, Reflective Journal, June 10, 2012). Amy also experiences weak literacy as an external barrier. I noticed this while observing her classes. Many students would approach her to ask what a term in the directions meant or they could not understand the next step in a long procedure to build something. Therefore it seems that upon deeper analysis the barriers explicitly mentioned by Ian are experienced by all three teacher participants.

### 4.3.4 Stages of Concern Profile Analysis

The SoCQ can be summarized for groups of individuals by reporting the means for each stage (Hall *et al.*, 1977, p. 35). If this is done for John, Ian and Amy the resulting concern profile is as seen in Figure 5. This profile needs to be analyzed according to the multiple peaks approach since it does not fit any of the classic profiles (Hall *et al.*, 1977). A classic profile is considered a profile which has a high rate on re-occurrence across many teachers. As a group, these teachers express high concerns at Stage 0 (awareness), Stage 4 (Personal) and Stage 6 (Refocusing) although the highest concern is expressed at Stage 0, as seen in Figure 5.

**Figure 5- Cross Case Stages of Concern Profile**




High Stage 0 concerns indicate that as a group these teachers lack concern about the innovation. Although they are using the reform in their teaching, they are confused about exactly what is being asked of them. Each teacher offers a slightly different definition of what PBL is. If all teachers were completely aware of the reform and its mandate they would all define PBL in a more consistent manner in accordance with the QEP's vision and meaning of this reform. A high Stage 3 score is indicative that teachers struggle with many management issues in their teaching. All three teachers expressed issues relating to managing their time, the available money they had and the scheduling and timing of the PBL units. These concerns are on par with what Hall & Hord (2006) describe as management concern when they state that teachers with high Stage 3 concerns have "issues related to efficiency, organizing, managing, scheduling, and time demands" (p. 140).

The three teacher participants expressed a fairly high percentile score at Stage 6 (refocusing). These concerns are a result of the teachers implementing the reform as they interpreted it and subsequently developing their own opinions about what would work better. Teachers with high Stage 6 concerns tend to "focus on the exploration of more universal benefits from the innovation" (Hall & Hord, 2006, p. 140). Refocusing helps to inform an innovation and ensure it is being critiqued by the user, these critiques ensure that any reform is always been tweaked and refined. This is evident when Ian reflects about how the reform was implemented and that they should have "put more emphasis on the cross-curricular coherent approach centered around a topic" that they were trying to accomplish. Furthermore, all three participants have "definite ideas about alternatives to the proposed or existing innovation" that they are already including in their own teaching. John shares these ideas when he talks about his own teaching methods and how he has chosen to not teach truly open-ended questions but instead sets certain limits on these problems to guide the students.

This analysis revealed interesting trends and useful insights about teachers' views on the implementation of PBL approach that inform the science education community in Quebec about limitations the current reform has. The following chapter will illuminate these insights and offer some suggestions not only about the implications this research has for the reform but possible steps that can be taken to move forward to effectively implement it.

# Chapter 5 – Discussion, Conclusion and Implications

## 5.1 Discussion and Conclusions

Through the case study analysis of the three teacher participants many significant findings were revealed. The teachers' initial understandings about PBL were not always on par with what is mandated by MELS. As described by LEARN Quebec, MELS has asked teachers to

> shift away from the classroom practices of short, isolated, teacher-centered lessons and instead emphasizes learning activities that are long-term, interdisciplinary, student-centered, and integrated with real world issues and practices (Asan & Haliloglu, 2005, p. 69).

Although Amy and Ian pointed to the idea of MELS wanting them to use more projects in their teaching, they did not completely describe the reform as an approach that is related to real-life and is interdisciplinary. John, on the other hand, seems to have an understanding of PBL that is more in line with what MELS is describing, stating that the reform asks him to "teach through hands-on, real-life problems that bring in elements from all subjects."

Teachers have a general understanding of the PBL approach mandated by MELS; they realize that their teaching should be approached in a manner that allows for open-ended questions wherein the students take charge of their own learning. The discrepancies between the MELS and the teachers' understanding arise when we focus on the implementation of the PBL reform. Teachers do not understand how to incorporate the large PBL unit put forth by MELS into their teaching; they do not see these units as an addition to the content approach to teaching they currently have but rather as a stop in their teaching. MELS asks teachers to “build knowledge through a hands-on approach that constructs student knowledge.” Althought this approach is centered around PBL, it does not exclude teacher-talk traditional methods. Teachers must learn how to adapt their traditional teaching methods to include more hands-on activities to reinforce the concepts being taught. Teachers view these PBL activities as something separate from the content teaching they must accomplish and feel that there is no time to ‘add’ these to their teaching. The PBL activities need to be viewed as something to be incorporated into their teaching that reinforces the content being taught. This skewed understanding contributed to the lack of knowledge and management of the PBL units in the classroom.

Teachers’ reported many internal and external barriers that need to be dealt with in order for the reform in science to be successful. Notably, teachers cited a lack of proper training and knowledge of PBL when the reform was first introduced; this internal barrier causes the teachers to lack the confidence necessary to change their teaching styles. In order for the teachers to feel confident about teaching through a PBL approach the need more hands-on, real-life training and exposure to this idea. That could be accomplished through workshops or off-site visits to schools which have successfully incorporated PBL into their science teaching. The notable external barriers teachers reported in my study were a lack of sufficient time, money and resources to complete the activities. These barriers were also cited in previous research by Mensah (2011), Goodnough (2006) and Allen (1997). Although all barriers reported in this study were previously reported in other studies, they have not before been identified in the context of the Quebec reform. Time is considered a problem for the teachers because many of the PBL activities given require too much time to complete given all the content that needs to be covered throughout a course. This barrier can be tackled by ensuring that the PBL activities developed cover a wide range of topics, therefore incorporating many facets of the curriculum into one activity. Money is a constant source of frustration for teachers as there is often not enough to buy the necessary materials. Specifically, Barron (1998) identifies “the little amount of time given to teachers for preparation” as one of the major barriers to the effective implementation of PBL. Creating PBL activities which require little consumable items is a good way to ensure the repeat cost to complete the activity is kept low while ensuring the students are still exposed to a hands-on real-life problem. The internal and external barriers reported in this research resonate with the barriers that emerged in my study (discussed in Chapter 2). Finally, Gallagher (2005) points out the disconnect between problem-based learning environments and the “rigid focus of standardized testing” (p. 136).

These barriers were also reported by the participants in this research. All three teacher participants pointed to a disconnect between the hands-on approach of PBL teaching mandated and the content-based, multiple-choice mandatory final examinations. Additionally, external barriers such as: “inadequate material resources, little time to create new curricula, large class sizes,” were previously reported by Barron (1998) and are mirrored in this research as well. All three teacher participants noted that they lack the necessary resources to complete the PBL units, they said that they need more time to implement them.  The large class sizes create many management issues (such as large groups with many absences). Azer (2001) also reports these time management concerns along with issues with the organizational structure and difficulty in creating good problems for students. The major management concerns reported by Azer and the teachers in my study are “the classroom organization, the role of the teacher and the time management concerns.” In this example, teachers are concerned with the time necessary to complete an open-ended PBL scenario while ensuring they are covering the entire mandated curriculum. All three teacher participants noted that they found the overall structure of the PBL units confusing, but they lacked the time necessary to develop more appropriate units.

Overall, when comparing teachers concerns with the CBAM, the teacher participants showed higher concerns about the reform at Stages 0 (awareness), Stage 3 (Management) and Stage 6 (refocusing). These concerns mirror the barriers the teachers reported. For instance, they are aware of the reform and seek to have a better understanding of its overall goals, objectives, and processes; this is a reflection of their high Stage 0 concerns. This awareness and willingness to learn about the reform is encouraging; it points towards a teacher population ready to support the implementation of the reform if given the tools to do so (training, money, time). Management issues arise when teachers discuss lack of time, money, student absences and insufficient resources; these issues are connected to the teachers’ external barriers. Management issues as well as the teachers’ need to learn more about the reform are both barriers that were reported in earlier studies of the PBL approach. Gallagher (1995) specifically points to a classroom where teachers “need to understand the PBL approach and its goals in order to ensure the student becomes self-directed all the while somehow maintaining a semblance of cohesion in the classroom.”

Finally, all three teachers point to ways in which they feel the reform could be improved to better meet their own needs and the needs of their students. They state that it needs to be more centered around a topic; the PBL units need to be more relatable for students and the final examinations need to reflect the open-ended approach taken in the PBL units. The relatability of a PBL unit has also been previously identified by teachers as a barrier to effective implementation. Hmelo-Silver (2004) discusses this importance noting that “students will only become motivated to learn when they can relate to the PBL problem at hand.” The ideas articulated by the teacher participants indicate a Stage of Concern at level 6 (refocusing) (Hall & Hord, 2006). Concerns at this stage focus “on the exploration of more universal benefits from the innovation” (Hall & Hord, 2006, p. 140). In other words, they can refine and further develop their ideas about the innovation allowing teachers to refocus their concerns at other stages by developing possible alternatives that would alleviate these concerns. These suggestions for change offered by the teacher participants indicate that they have taken an active role in the implementation of the reform. Throughout their implementation they have noticed room for improvement and are now suggesting ways for the reform to be a more effective approach to teaching. They do not want to completely dismiss the reform but are offering ways to improve it.

### 5.2 Researcher Background and Influence

Throughout my career as a science educator I have developed my own thoughts and opinions about how science should be taught, PBL's place in the curriculum and how the Quebec Education Reform was implemented. From my experience I believe that science is a subject that is best taught in a manner that allows the students to recognize how it applies to their lives. Using real-life open-ended examples to engage the students in their own learning provides an environment for the students to apply knowledge. PBL in high schools has a place alongside the traditional methods of teaching to solidify the knowledge being taught. Although I believe that the PBL approach to the teaching of science renders itself to creating students who retain more practical knowledge and have a higher motivation for learning, this method can only be accomplished when the students have a firm grasp of the underlying topic. Therefore, the PBL approach needs to be reinforced with some teacher-talk traditional teaching. My opinions inevitably have an effect on how I analyzed the data collected in this research. I have always thought that a hands-on, problem-based approach to the teaching of Science was the best. As I began my research, I noticed that most teachers shared this view but were still hesitant to fully incorporate it into their teaching. John, Ian and Amy all spoke about the downfalls of the PBL approach, stating "class sizes are too large to manage" (John, reflective journal, June 10, 2012) and "the students lack the basic knowledge required to be able to fully engage in an open-ended problem" (Ian, reflective journal, December 15, 2012). It wasn't until further investigation that I began to realize why this resistance was present.

Although PBL was viewed as beneficial, teachers felt the pressure to meet the requirements for the standardized exams the students are given and did not see how this would be possible if they were to teach through PBL instead of a content-based teacher-talk approach.

This was the turning point for me; my views about PBL and its implementation began to change for me. As I engaged within my own research I began to change my views and opinions about PBL; a topic I had previously believed I had a solid understanding of. I had always assumed that my understanding of the PBL approach was shared by all my science colleagues, we were, after all, teaching in the same educational setting. Upon reflection, I saw that my understanding was only a result of my own independent research on the topic, and not a result of my teacher training. This research and insight into the inner-workings of PBL and the reform was a direct result of my time spent at McGill completing my Masters degree and my employment at the WOW Lab during this time. These experiences allowed me to be exposed to many approaches to PBL currently being implemented throughout the province. Working for the WOW Lab gave me the opportunity to present students with real-life, open-ended PBL activities and see first-hand that the mandate put forth by the MELS truly does create a learning environment for students which is relatable and hands-on. Since most science educators may not have had the same experiences as me, they might not have the same understand of PBL that I do. I realized that although teachers believe in the approach, they were never explained how to implement it, how the exams reflect the curriculum and the overall goal of the reform. Without this over arching view, these teachers felt lost. When I exposed them to the PBL documents, upon their request, and explained the purpose of the reform, many of the teachers were much more receptive to the PBL approach. The change in teacher attitude was clear when I began developing the PBL units with each one. As we looked over each curriculum goal set out by the MELS and saw how each one could be incorporated into an effective PBL activity, the teachers became excited about motivating students by incorporating this new approach into their teaching.

**5.3 Implications for the Future**

In order for Quebec's PBL science reform to become an effective approach to teaching the internal and external barriers faced by teachers need to be addressed and overcome. Major barriers that have been identified are:

- Disconnects between the hands-on approach to teaching mandated and the multiple-choice, content emphasis of the mandatory exams
- Lack of training and experience of teachers
- Lack of resources and time to complete the PBL activities
- Inconsistent approaches with significant changes in the reform mandate every year

These barriers are significant and need to be addressed if the reform is to be implemented successfully province wide. Some changes to the reform can begin at the board level. School boards can offer teacher training. The boards can also ensure the complimentary final exams they are in charge of reflect the open-ended PBL approach of the reform. Other barriers must be addressed by the MELS;

spefically, MELS must give more resources such as money and laboratory technicians in order to ensure the activities are being implemented fully. The MELS must also implement a reform that remains consistent for a period of time to allow teachers to adjust.

Possible solutions to these barriers include:

- Final examinations that are in line with the hands-on PBL approach to teaching
- Training and constant school-based support for teachers to increase their comfort level with new technologies, and knowledge about the specific and overall goals of the Quebec science reform
- A consistent implementation of the reform over many years

Only once the identified barriers teachers face are addressed can the Quebec Science Education reform begin to truly flourish as an effective approach to the teaching of science. This development and change needs to be facilitated by many people. Firstly, teachers need to be receptive to the change. This change needs to also be accepted and promoted by school principals. When principals take a leadership role teachers are more apt to accept the change. Science consultants in Quebec become invaluable assets in order to create change and consistency across the province for the PBL approach. Since these consultants are responsible for many schools within a region they are able to see how many teachers are implementing PBL. Upon review, a consultant can identify which schools are implementing the reform in the most effective and appropriate manner. They can then use this school and its teachers as models for the other schools to see.

Teachers from various schools should be invited into these model schools in order to see how a real-life PBL classroom runs efficiently.

**5.4 Limitations**

My study marks one of the first and only focusing on the most recent Science Education Reform in Quebec therefore making it an invaluable and important contribution to the research. Members of the Quebec educator community may benefit from this research by gaining an understanding of the necessary steps to be implemented in the high school science community to refine the Quebec science reform and ensure it is being implemented in the most effective manner. In order for PBL to become a teaching approach in all science classes it needs to first be understood by teachers, meaning the implementation of it into schools needs to be done with care in ensuring the message and overall goals of the approach are understood.

While this study is invaluable and represents a much need area of research in Quebec, it presents with certain limitations. It is a rich study of three teachers using the PBL approach in their high school science classes but this does not mean the data is representative of what is occurring in all high school science classes across Quebec. The detail provided in this study is only applicable within the context of the specific teachers discussed and the information cannot be stripped from the context within which is taken. The three teacher participants were purposively selected based on their reputations for being leaders in the field of PBL and volunteered for the study; this motivation to learn and adapt to PBL as a new way of teaching is not necessarily an attitude that would be found in the majority of teachers in Quebec.

Furthermore, the study may have been enriched if student opinions and motivation was also researched. Merging the students' attitudes towards PBL with the teachers may provide a rich additional to this study in the future. Future studies could also include a larger sample of teachers in order to gain more insight into what the majority of teachers feel about the PBL approach.

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## Appendix A: MELS 2011 Exam Content Example

The examination, which consists of 25 questions worth 4 marks each, is divided into three parts:

• Part A consists of 15 multiple-choice questions worth 60% of the examination mark. These questions evaluate students' mastery of and ability to use knowledge relating to the compulsory concepts in the four areas of the program.

• Part B consists of six constructed-response questions worth 24% of the examination mark. The concepts considered in this part of the examination are associated with three of the four areas of the Science and Technology program. The questions in this part of the exam do not pertain to The Technological World.

• Part C consists of four questions on the technological analysis of a technical object and is worth16% of the examination mark.

## Appendix B: Parent/Guardian Information Letter

I am a second year graduate student in the Department of Education at McGill University. In order to complete my research I will be observing your child's teacher over the next few months. Following is a description of my research. This letter is intended to simply inform you of my presence in your child's classroom. Your child is not the focus of the study and no data will be collected with regard to your child.

**Purpose of the research study:** To study high school science teachers and answer the following questions: How do high school teachers feel about the PBL approach? What is the teachers' understanding of the PBL approach? What, if at all, are any internal and external barriers that high school science teachers face in the effective implementation of PBL in today's high school science classrooms?

The objective of this project is to gather enough data to determine what the primary barriers these teachers face in the implementation of PBL are in order to later construct a workshop to help these teachers overcome these barriers. This research will therefore benefit both the teachers and the students. The teachers will benefit by gaining access to innovative ways to teach and implement PBL and the students will be benefit from a new way of learning that has been shown to be more effective. The results will be analyzed and used to write my thesis which I will then publish in a scientific journal.

Thank you,

Jessica Godin

jessica.godin2@mail.mcgill.ca

**TEACHER RESEARCH CONSENT FORM**

McGill University

**Title of Research**: *High School Science teachers' and views on the problem-based learning approach*

**Researcher**: Jessica Godin , Masters Student Supervisor: Dr. Anila Asghar; tel: 514-398-5327

**Department:** Integrated Studies in Education, Curriculum Studies

**Contact Information**: Tel : 514-398-5327; email: jessica.godin2@mail.mcgill.ca

**Purpose of the research:** To study high school science teachers in order to gather information that will solve the following questions: How do high school teachers feel about the PBL approach? What is the teachers' understanding of the PBL approach? What, if at all, are any internal and external barriers that high school science teachers face in the effective implementation of PBL in today's high school science classrooms? The objective of this project is to gather enough data to determine what the primary barriers these teachers face in the implementation of PBL are in order to later construct a workshop t help these teachers overcome these barriers. This research will therefore benefit both the teachers and the students. The teachers will benefit by being access to innovative ways to teach and implement PBL and the students will be benefit from a new way of learning that has been shown to be more effective. The results will be analyzed and used to write my thesis which I will then publish in a scientific journal.

**What is involved in participating**: I will begin with a short interview with you to discuss your current methods of teaching. Following this initial interview**, I will be present in your classroom to observe your teaching.** The number of observations to occur will be discussed and be based on your level of comfort. You will also be asked to keep a log of your teaching as you implement PBL activities into your teaching. Subsequent interviews will also occur throughout the period of study. The method, time and length of these interviews will be at your own convenience. The interviews will be recorded and these recordings will only be used for transcription purposes and be reviewed solely by the researcher. The information gathered will be kept in a secure place for a year by the researcher and could be used in a future study.

Your participation is entirely voluntary and you can choose to decline to answer any question or even to withdraw at any point from the project. Anything you say will only be attributed to you with your permission, otherwise the information will be reported in such a way as to make direct association with yourself impossible. My pledge to confidentiality also means that no other person or organization will have access to the interview materials and that they will be coded and stored in such as way as to make it impossible to identify them directly with any individual (e.g. they will be organized by number rather than by name)

**Research Ethics Board Contact Information:**

If you have any questions or concerns about your rights or welfare as a participant in this research study, please contact the McGill Ethics Officer at 514-398-6831.

**Consent:** I would like my real name to be used in the report ____YES ___NO

I have read the above information and I agree to participate in this study

Signature: ___________________

Name: _______________________

Date:________________________

Lester B. Pearson School Board

Commission scolaire Lester-B.-Pearson

# CONSENT TO CONDUCT RESEARCH

_______________________________ Principal of ______________________________

*(Principal's name)* (*School name)*

Grants permission to_____________________ of_________________________

*(Name of researcher)* *(Name of University)*

For the purpose of conducting research related to the approved project entitled

"***High School Science teachers and views on the problem-based learning approach***"

**The project was approved by the School's Governing Board on:_____________**

*(Date of Governing Board Meeting)*

__________________________ ________________________________

*(Principal's signature)* *(Date)*

*Note to researcher: Once the location(s) for your research have been determined, it is the responsibility of the researcher to ensure that a separate form be signed by the Principal of each of the schools at which the research is to be conducted. The form(s) must be returned to Michael Chechile – Director of Educational Services at the Lester B. Pearson School Board.*

**Eastern Townships School Board Research Approval Email**

Hello Jessica,

I agree that concentrating your research at [school name] will be simpler. Given that Mr. [X], Mr. [Y], Mr. [Z] and Ms. [X] have agreed to work with you and after having reviewed once again the Ethics Board approval and your research proposal regarding the PBL approach, you do now have permission from the ETSB to go ahead.

Best of luck.

Sincerely,

Gilles Ribaux
Assistant Director General &
Director of Pedagogical Studies
Eastern Townships School Board
101, du Moulin, Magog, QC J1X 6H8
Tel: 819 868 3111
Fax: 819 868 2286

## Appendix C: Interview Questions

1. How would you define your overall style of teaching? What approach do you use in your teaching? What is your focus?
2. What do you think is the best way to ensure that the majority of your students are learning within a context they can apply to the rest of their lives?
3. What method of teaching Science does the QEP call for?
4. How would you define problem-based learning?
5. Do you believe you are teaching through PBL? (examples)
6. If you are not currently teaching this way, have you ever taught this way?
7. Do you wish you could teach more often using the problem-based approach? If yes, why don't you, if not, what are your reasons?
8. What kind of support would you need to teach through PBL effectively?
9. Do you believe that PBL is the best approach to teaching science? Why or why not?

**Appendix D: PBL Resources Website Excerpt**

# Welcome to the Project Based Learning section of the IDC website!

This section was designed to help educators understand Project Based Learning (PBL) and the implications it has for classroom teaching and learning. Coming hot on the heels of Québec's curriculum reform, the PBL section offers a concise introduction to new strategies and theories and thus equips educators for the challenges of teaching in the new millenium.

"Project-based learning (PBL) is a model for classroom activity that shifts away from the classroom practices of short, isolated, teacher-centered lessons and instead emphasizes learning activities that are long-term, interdisciplinary, student-centered, and integrated with real world issues and practices."

*San Mateo County Office of Education*
http://pblmm.k12.ca.us/PBLGuide/WhyPBL.html

**Theory**
This section provides an introduction to the theory behind Project Based Learning - from brain theory to multiple intelligences.

**Practice**
In the Practice section, you will find pathways to beginning PBL in your classroom. Stay tuned for sample projects from the field!

**Rubrics**
The Rubrics section focuses on evaluating Project Based Learning by creating and applying rubrics.

**Resources**
Find tools to help you get started in your classroom and websites to broaden your PBL horizons.

**http://www.learnquebec.ca/en/content/reform/bestprac/pbl/**

## Appendix E: Reflective Journal Questions

1) Describe the PBL activity you chose to implement into your teaching for the purpose of this research. Include any reflections you noted throughout the activity, things that needed to be adapted, what the goal you had in mind was and finally if the product the students produced achieved the goals the project set out to meet. What barriers were holding you back when implementing this activity? What situation/materials/resources would have made it easier to implement? (please compare and discuss the difference in implementing a PBL problem in AST, ST or an option course ex. Forensic science, if that applies to you)
2) Referring to the MELS website, do you think a clear indication of how the teaching of science should be approached is given? Are there sufficient resources given? What would need to be added? Does MELS give an overview of what the goal of the science reform is and the overall vision they have?
3) Referring to the Goodnough article you were supplied, do you agree or disagree with the barriers listed? Please comment on the article. Do you relate to it?
4) What do you think needs to happen in the future in order for teachers to understand the MELS vision for the reform? What does MELS need to do, what do teachers need to do, what is the next step (s).

## Appendix F: Concerns-based Adaptation Model, SoCQ and Scoring

### Stages of Concern Questionnaire

Name:

---

The purpose of this questionnaire is to determine what people who are using or thinking about using various programs are concerned about at various times during the adoption process.

The items were developed from typical responses of school and college teachers who ranged from no knowledge at all about various programs to many years' experience using them. Therefore, many of the items on this questionnaire may appear to be of little relevance or irrelevant to you at this time.

For the completely irrelevant items, please circle "0" on the scale. Other items will represent those concerns you do have, in varying degrees of intensity, and should be marked higher on the scale.

For example:

This statement is very true of me at this time. 0 1 2 3 4 5 **6 7**

This statement is somewhat true of me now. 0 1 2 **3 4** 5 6 7

This statement is not at all true of me at this time. 0 **1 2** 3 4 5 6 7

This statement seems irrelevant to me. **0** 1 2 3 4 5 6 7

Please respond to the items in terms of your present concerns, or how you feel about your involvement with this innovation. We do not hold to any one definition of the innovation so please think of it in terms of your own perception of what it involves. Phrases such as "this approach" and "the new system" all refer to the same innovation. Remember to respond to each item in terms of your present concerns about your involvement or potential involvement with the innovation.

Thank you for taking time to complete this task.

| | | | |
|---|---|---|---|
| 0 | 12 | 345 | 67 |
| Irrelevant | Not true of me now | Somewhat true of me now | Very true of me now |

1. I am concerned about students' attitudes toward the innovation. 0 1 2 3 4 5 6 7

2. I now know of some other approaches that might work better. 0 1 2 3 4 5 6 7

3. I am more concerned about another innovation. 0 1 2 3 4 5 6 7

4. I am concerned about not having enough time to organize myself each day.

0 1 2 3 4 5 6 7

5. I would like to help other faculty in their use of the innovation. 0 1 2 3 4 5 6 7

6. I have a very limited knowledge of the innovation. 0 1 2 3 4 5 6 7

7. I would like to know the effect of reorganization on my professional status.

0 1 2 3 4 5 6 7

8. I am concerned about conflict between my interests and my responsibilities.

0 1 2 3 4 5 6 7

9. I am concerned about revising my use of the innovation. 0 1 2 3 4 5 6 7

10. I would like to develop working relationships with both our faculty and outside faculty using this innovation. 0 1 2 3 4 5 6 7

11. I am concerned about how the innovation affects students. 0 1 2 3 4 5 6 7

12. I am not concerned about the innovation at this time. 0 1 2 3 4 5 6 7

13. I would like to know who will make the decisions in the new system.

0 1 2 3 4 5 6 7

14. I would like to discuss the possibility of using the innovation. 0 1 2 3 4 5 6 7

15. I would like to know what resources are available if we decide to adopt the innovation 0 1 2 3 4 5 6 7

16. I am concerned about my inability to manage all that the innovation requires. 0 1 2 3 4 5 6 7

17. I would like to know how my teaching or administration is supposed to change. 0 1 2 3 4 5 6 7

18. I would like to familiarize other departments or persons with the progress of this new approach.

0 1 2 3 4 5 6 7

19. I am concerned about evaluating my impact on students. 0 1 2 3 4 5 6 7

20. I would like to revise the innovation's approach. 0 1 2 3 4 5 6 7

21. I am preoccupied with things other than the innovation. 0 1 2 3 4 5 6 7

22. I would like to modify our use of the innovation based on the experiences of our students.

0 1 2 3 4 5 6 7

23. I spend little time thinking about the innovation. 0 1 2 3 4 5 6 7

24. I would like to excite my students about their part in this approach.

0 1 2 3 4 5 6 7

25. I am concerned about time spent working with nonacademic problems related to the innovation.

0 1 2 3 4 5 6 7

26. I would like to know what the use of the innovation will require in the immediate future.

0 1 2 3 4 5 6 7

27. I would like to coordinate my efforts with others to maximize the innovation's effects.

0 1 2 3 4 5 6 7

28. I would like to have more information on time and energy commitments required by the innovation.

0 1 2 3 4 5 6 7

29. I would like to know what other faculty are doing in this area. 0 1 2 3 4 5 6 7

30. Currently, other priorities prevent me from focusing my attention on the innovation.

0 1 2 3 4 5 6 7

31. I would like to determine how to supplement, enhance, or replace the innovation. 0 1 2 3 4 5 6 7

32. I would like to use feedback from students to change the program. 0 1 2 3 4 5 6 7

33. I would like to know how my role will change when I am using the innovation. 0 1 2 3 4 5 6 7

34. Coordination of tasks and people is taking too much of my time. 0 1 2 3 4 5 6 7

35. I would like to know how the innovation is better than what we have now. 0 1 2 3 4 5 6 7

Please complete the following:

1. How long have you been involved with the innovation, not counting this year?

Never ___ 1 year ___ 2 years ___ 3 years ___ 4 years ___ 5 or more ____

2. In your use of the innovation, do you consider yourself to be a:

non-user ___ novice ___ intermediate ___ old hand ___ past user ____

3. Have you received formal training regarding the innovation (workshops, courses)?

Yes ____ No ____

4. Are you currently in the first or second year of use of some major innovation or program other than this one?

Yes ____ No ____

If yes, please describe briefly:

Thank you for your help!

## Figure 1 – SoCQ Scoring Table

| | Individual Item Response (fill in the blanks with average of other item on that scale) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Stage** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| B | 3 | 6 | 7 | 4 | 1 | 5 | 2 |
| | 12 | 14 | 13 | 8 | 11 | 10 | 9 |
| | 21 | 15 | 17 | 16 | 19 | 18 | 20 |
| | 23 | 26 | 28 | 25 | 24 | 27 | 22 |
| | 30 | 35 | 33 | 34 | 32 | 29 | 31 |
| Raw Score Total C | | | | | | | |
| Percentile Score E | | | | | | | |

## Figure 2 – Percentile Score Conversion Table (Hall & Hord, 2006)

| Five Item Raw Scale Total Score | Stage | | | | | | |
|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| 0 | 10 | 5 | 5 | 2 | 1 | 1 | 1 |
| 1 | 23 | 12 | 12 | 5 | 1 | 2 | 2 |
| 2 | 29 | 16 | 14 | 7 | 1 | 3 | 3 |
| 3 | 37 | 19 | 17 | 9 | 2 | 3 | 5 |
| 4 | 46 | 23 | 21 | 11 | 2 | 4 | 6 |
| 5 | 53 | 27 | 25 | 15 | 3 | 5 | 9 |
| 6 | 60 | 30 | 28 | 18 | 3 | 7 | 11 |
| 7 | 66 | 34 | 31 | 23 | 4 | 9 | 14 |
| 8 | 72 | 37 | 35 | 27 | 5 | 10 | 17 |
| 9 | 77 | 40 | 39 | 30 | 5 | 12 | 20 |
| 10 | 81 | 43 | 41 | 34 | 7 | 14 | 22 |
| 11 | 84 | 45 | 45 | 39 | 8 | 16 | 26 |
| 12 | 86 | 48 | 48 | 43 | 9 | 19 | 30 |
| 13 | 89 | 51 | 52 | 47 | 11 | 22 | 34 |
| 14 | 91 | 54 | 55 | 52 | 13 | 25 | 38 |
| 15 | 93 | 57 | 57 | 56 | 16 | 28 | 42 |
| 16 | 94 | 60 | 59 | 60 | 19 | 31 | 47 |
| 17 | 95 | 63 | 63 | 65 | 21 | 36 | 52 |
| 18 | 96 | 66 | 67 | 69 | 24 | 40 | 57 |
| 19 | 97 | 69 | 70 | 73 | 27 | 44 | 60 |
| 20 | 98 | 72 | 72 | 77 | 30 | 48 | 65 |
| 21 | 98 | 75 | 76 | 80 | 33 | 52 | 69 |
| 22 | 99 | 80 | 78 | 83 | 38 | 55 | 73 |
| 23 | 99 | 84 | 80 | 85 | 43 | 59 | 77 |
| 24 | 99 | 88 | 83 | 88 | 48 | 64 | 81 |
| 25 | 99 | 90 | 85 | 90 | 54 | 68 | 84 |
| 26 | 99 | 91 | 87 | 92 | 59 | 72 | 87 |
| 27 | 99 | 93 | 89 | 94 | 63 | 76 | 90 |
| 28 | 99 | 95 | 91 | 95 | 66 | 80 | 92 |
| 29 | 99 | 96 | 92 | 97 | 71 | 84 | 94 |
| 30 | 99 | 97 | 94 | 97 | 76 | 88 | 96 |
| 31 | 99 | 98 | 95 | 98 | 82 | 91 | 97 |
| 32 | 99 | 99 | 96 | 98 | 86 | 93 | 98 |
| 33 | 99 | 99 | 96 | 99 | 90 | 95 | 99 |
| 34 | 99 | 99 | 97 | 99 | 92 | 97 | 99 |
| 35 | 99 | 99 | 99 | 99 | 96 | 98 | 99 |

## Appendix G: Classic SoCQ profiles

**Figure 1- Negative "One/Two Split" with Tailing-up 6**

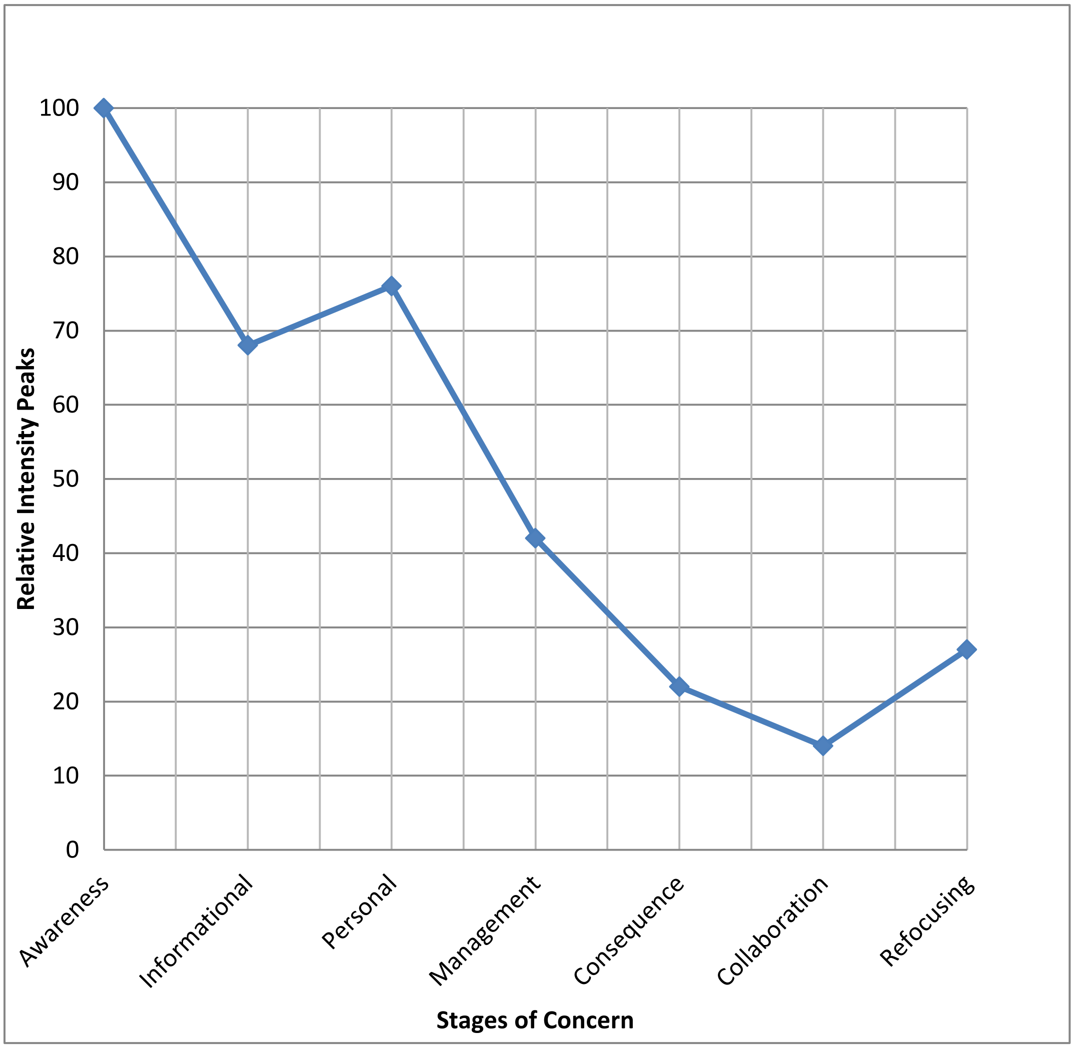

**Figure 2- Typical Nonuser SoCQ Profile**