Technology-enhanced inquiry approaches and benefits in secondary science classrooms

By
Natalie Urbanc

A research paper submitted in conformity with the requirements
For the degree of Master of Teaching
Department of Curriculum, Teaching and Learning
Ontario Institute for Studies in Education at the University of Toronto

Copyright by Natalie Urbanc, April 2017
Abstract

There are a variety of teacher practices related to how technology is used in the science classroom. However, of the technology used in the classroom, studies have shown that student-centered technologies were almost non-existent in pedagogical practices (Hechter & Vermette, 2014; Chen, Gallagher-Mackay & Kidder, 2014). This research study aimed to look at how teachers use technology to support or enhance inquiry as well as the outcomes. A qualitative research methodology was employed, including three semi-structured interviews. From thematic analysis, the themes that emerged were practices related to technology-enhanced inquiry, benefits of technology and, challenges of technology-enhanced inquiry. The research findings demonstrated that teachers need to dedicate class time to introduce new technologies and that there is a preference for teacher scaffolds (e.g. prompting, design conversations, creation of diverse groupings) over technology scaffolds (e.g. embedded scripts in technology) in technology-enhanced inquiry. Furthermore, technology use was dependent on the school context and if challenges could be overcome. The patterns of technology use indicated support for the investigation and communication steps of the inquiry process and could enable students to overcome failure narrative and gain metacognitive skills. Overall, this has broad implications for the educational community including considerations of emphasizing process over content in the science curriculum and classroom, school funding for training and better technological equipment, and access to online professional development.

Keywords: inquiry-based learning, technology, TPACK, technology-enhanced inquiry student-centered pedagogy
Acknowledgements

Firstly, I would like to thank my mother for her constant support in my academic pursuits at the undergraduate and graduate level. Thank you to my father, who helped me develop my passion for science and technology.

I am grateful to all the staff at OISE who helped me write this MTRP. Special thanks goes to Dr. Cristina Guerrero, who provided very detailed feedback and suggested edits to increase the quality of my MTRP. Thank you to Dr. Arlo Kempf for helping me in the beginning stages of my writing.

To my fellow classmates at OISE and cohort IS-233, many thanks for your help in editing my MTRP, giving me suggestions on how to improve my writing and for inspiring me to be a better educator.

Finally, this research would not be possible without my three participants. I am grateful to these educators for sharing their expertise and experiences with me through their interviews.
Table of Contents

Abstract 1
Acknowledgements 2

Chapter 1: Introduction
  1.0 Introduction and Research Context 5
  1.1 Research Problem 5
  1.2 Research Purpose 6
  1.3 Background of Researcher 7
  1.4 Overview 8

Chapter 2: Literature Review
  2.1 Scientific Inquiry and Inquiry-Based Learning 9
  2.2 Inquiry-Based Learning Process 9
  2.3 Why Inquiry-Based Learning? 10
    2.3.1 History and purpose of inquiry-based learning. 10
    2.3.2 Benefits of inquiry-based learning. 12
  2.4 Challenges to Implementing Inquiry-Based learning 14
    2.4.1 Teacher perceptions and willingness of teaching science as inquiry. 14
    2.4.2 Scaffolding inquiry-based learning. 16
  2.5 Challenges and the role of technology in secondary classrooms 17
    2.5.1 Technology scaffolds 17
    2.5.2 Preconceptions and challenges of technology use in the classroom. 17
    2.5.3 The role of technology in the classroom using TPACK. 19
  2.6. Technology-enhanced inquiry 20
    2.6.1. Technologies to aid scaffolding or enhancement of inquiry. 20
    2.6.2 Examples and outcomes of technology enhanced inquiry. 22
    2.6.3 Pedagogical model for technology-enhanced inquiry. 26
  2.7 Conclusion 28

Chapter 3: Research Methodology
  3.0 Introduction 30
  3.1 Research Approach and Procedures 30
  3.2 Instruments of Data collection 31
  3.3 Participants 32
    3.3.1 Sampling criteria. 32
    3.3.2 Sampling procedures. 33
    3.3.3 Participant biographies. 34
  3.4 Data Analysis 35
  3.5 Ethical Review Procedure 36
  3.6 Methodological Limitations and Strengths 37
  3.7 Conclusion 37

Chapter 4: Research Findings
  4.0 Introduction 39
  4.1 Practices related to technology-enhanced inquiry 40
    4.1.1 Introducing technology use in the classroom. 40
    4.1.2 Examples of technology-enhanced inquiry. 42
4.1.3 Scaffolding technology-enhanced inquiry.

4.2 Challenges of Technology-Enhanced Inquiry

4.2.1 Challenges of implementing technology for inquiry.

4.2.2 Balancing the practical inquiry skills and technology skills.

4.2.3 Challenging the Failure Narrative in Science.

4.3 Benefits of Technology

4.3.1 Benefits of Specific technologies.

4.3.2 Metacognition skills gained with technology.

4.4 Conclusion

Chapter 5: Conclusion

5.0 Introduction

5.1 Overview of Key Findings and their Significance

5.2 Implications

5.2.1 The educational community.

5.2.2 My professional identity and practice.

5.3 Recommendations

5.4 Areas for Further Research

5.5 Concluding Comments

References

Appendices

Appendix A: Letter of Consent for Interviews

Appendix B: Interview Protocol


Chapter 1: Introduction

1.0 Introduction and Research Context

There has been a paradigm shift in education moving away from a traditional, passive, lecture-style teaching, towards active student-centered learning in which students must self-regulate their learning. In science education, there are various types of active student-centered learning including: inquiry based learning, project-based learning, and discovery learning. As a result, the “new pedagogy” as described by Fullan (2012) emerged, shifting the fundamental role of teachers from instructors to learning partners. This new way of teaching and learning can be supported by the acceleration of technology (Fullan, 2012).

We live in an advanced technological era, where student have increased digital skills, access to new technological tools and a plethora of resources on the web. In the Canadian context (New Brunswick), “the 21st Century School Initiative has recently begun and has as objectives to define, promote and focus upon 21st century skills; create innovative learning environments; and to provide ubiquitous access to technology in classrooms” (Ananiadou & Claro, 2009, p. 12). In addition, the acquisition of technology skills, a 21st century skill, is a highly-esteemed goal in the Ontario curriculum. It is integrated into the Science, Technology, Society and Environment (STSE) component for science courses. As a result, there is significantly more interest in developing technology-enhanced learning environments that enhances inquiry-based learning in the science classroom. Evidence of this type of teaching and learning is scarce and there is little research on how to enact or scaffold this type of learning in the real classroom contexts (Kim & Hannafin, 2011).

1.1 Research Problem
Although there is a high emphasis on the integration of technology into science education through the Ontario curriculum and to encourage the development of 21st century skills, teachers are still reluctant to use technology in meaningful ways to engage students in inquiry-based activities. A few frameworks have been suggested to support student learning with technologies including scaffolding hypermedia to cultivate self-regulated learning, metacognitive scaffolds embedded in software for online inquiry and epistemic scaffolds to guide technology-supported inquiry (Kim & Hannafin, 2011). However, it was found that all teachers did not implement these frameworks in a consistent manner (Kim & Hannafin, 2011). This demonstrates the need to learn how to create technology-enhanced learning environments to enhance inquiry.

1.2 Research Purpose

In view of this problem, the purpose of my research is to learn how teachers enact technology-enhanced inquiries in the science classroom. More specifically, I would like to analyze: the role of technology in the science classroom, what kind of technology and teacher scaffolds are used, the challenges faced in enacting this pedagogy and the benefits of technology on the inquiry process.

Through this research, I hope to inform other science educators’ pedagogy to learn how to integrate technology in the science classroom in a meaningful way to enhance the inquiry process. This would allow teachers to improve their pedagogy and learn from current science educators that engage in technology-enhanced inquiry.

The primary research question that this study seeks to answer is: How do teachers use technology to enhance inquiry and what are the outcomes?

To gain more insight from this research, the following sub-questions are considered:
• What kinds of technology and teacher scaffolds are used to support technology-enhanced inquiry?

• What challenges do teachers encounter in implementing technology-enhanced inquiry in the science classroom?

• What are the benefits of technology integration on inquiry?

1.3 Background of Researcher

In my high school experience, I did not have many opportunities to do authentic inquiry-based activities. The labs that we typically engaged in were confirmatory labs that involved confirming already known scientific phenomenon. Although there is nothing wrong with confirmation labs, these labs were often too guided and did not get me to think critically. I was simply given a procedure, which I followed and answered some analysis questions to assess my understanding of the concepts. This was the extent of my science experience.

In university I gained a better understanding of the scientific inquiry process because we participated in some open-ended inquiry projects. This enabled me to authentically go through the scientific process as scientists and asking a question that was relevant to my interests. However, even though I participated in a few inquiry projects I still don’t feel confident in my abilities to lead inquiry-based activities.

In my Masters of Teaching program, I had the chance to learn about various technological tools that facilitate communication, interactive environments, data collection, and sharing information in multiple formats. Furthermore, we learned about online websites that helped guide students through inquiry-based activities. With all this information, I became interested in how technology could be used to enhance inquiry-based learning. Personally, I
have not always been comfortable with technology. However, I believe that technology is valuable in the educational system because it facilitates many tasks and helps to get students engaged. Currently, technology is rapidly evolving and could potentially revolutionize the science classroom. I hope to get my students engaged in my science classroom by doing authentic inquiry tasks and using technology. I believe that technology-enhanced inquiry could help students develop 21st century skills such as higher order thinking skills and technology skills. However, this can only happen if I learn to use technology in a meaningful way. From this research, I learned about how teachers interact with both technology and students to enhance inquiry-based learning.

1.4 Overview

To respond to the research questions, I conducted a qualitative research study using purposeful sampling to interview three teachers about their instructional strategies used for technology enhanced inquiry-based inquiry in science secondary classes. In chapter two, I review the literature in the areas of technology enhanced inquiry-based learning within the science classroom, including perceptions of technology use, challenges to implementing inquiry-based learning, scaffolding inquiry-based learning with and without technology and a pedagogical model of inquiry. Next, in chapter three I elaborate on the research design. In chapter 4, I will analyze the results by categorizing the data into themes and sub-themes. Chapter 5 will include all relevant implications of my research.
Chapter 2: Literature Review

2.1 Scientific Inquiry and Inquiry-Based Learning

Scientific inquiry as outlined by NSES refers to the process of providing explanations about the natural world based on evidence, essentially taking on the role of scientists. Inquiry learning as a result is defined by activities that allow students to build their knowledge and understanding of scientific ideas as well as learn about the nature of science (NRC, 1996). The National Research Council (1996) states that:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results (p.23).

2.2 Inquiry-Based Learning Process

There are countless inquiry cycles and steps to achieve inquiry-based learning. Bell, Urhahne, Schanze & Ploetzner (2010) summarized ten research articles on inquiry learning approaches from science education experts into nine main inquiry steps in no particular order (see Table 2). These steps were used for the purposes of this study. It is important to note that many of the studies referred to in the rest of the literature review may use different inquiry learning processes.
Table 1: Synthesis of 10 approaches to inquiry learning from science education experts (Bell et. al, 2010)

<table>
<thead>
<tr>
<th>Nine steps of inquiry</th>
<th>Brief description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orienting and asking questions</td>
<td>Observe scientific phenomena and formulate questions</td>
</tr>
<tr>
<td>Hypothesis generation</td>
<td>Coming up with relations between variables</td>
</tr>
<tr>
<td>Planning</td>
<td>Designing an experiment to test hypothesis with appropriate lab techniques</td>
</tr>
<tr>
<td>Investigation</td>
<td>Empirical aspect of inquiry as it involves the use of tools to collect data, conduct experiments and organize data</td>
</tr>
<tr>
<td>Analysis and interpretation</td>
<td>Making claims based on empirical data</td>
</tr>
<tr>
<td>Model</td>
<td>Exploration and creation of scientific models (e.g. free sketches &amp; mathematical model)</td>
</tr>
<tr>
<td>Conclusion and evaluation</td>
<td>Conclusion can be drawn from data in combination with theories and other research. Evaluation is used to judge the research and results.</td>
</tr>
<tr>
<td>Communication</td>
<td>Collaborative part of inquiry learning which can span the entire scientific inquiry process involves presenting research question and reporting results</td>
</tr>
<tr>
<td>Prediction</td>
<td>Statement about the values of dependent variables under the influence of an independent variable</td>
</tr>
</tbody>
</table>

2.3 Why Inquiry-Based Learning?

2.3.1 History and purpose of inquiry-based learning. As a former science teacher, Dewey realized that there was a high emphasis on rote learning and memorizing facts rather than developing thinking and habits of mind for science (Barrow, 2006; Dewey 1910). Consequently, he suggested the inclusion of inquiry into grade K-12 curriculum. Firstly, he encouraged the implementation of inquiry with a rigid scientific method, which he revised to include reflective thinking in 1944 (Barrow, 2006; Dewey, 1944). The scientific method included: the presentation of the problem, formation of a hypothesis, collecting data during the experiment, and the
formulation of a conclusion. In this way, students get involved in active learning, while teachers take the role of a facilitator or guide (Barrow, 2006; Dewey, 1944).

In the 1990s, inquiry-based learning was the preferred pedagogy based on major curricular associations such as the National Research Council (NRC) (Shore, Chichekian, Syer, Aullus & Frederiksen, 2012). The NRC (1996) stated, “inquiry into authentic questions generated from student experiences is the central strategy for teaching science” (p.31). The main purpose of this pedagogy was to guide students towards scientific literacy such that students can critically evaluate important scientific information, make informed decisions and problem-solve (NRC, 1996). Although the National Science Education Standards outlined by NRC suggested teachers guide students through the inquiry process, there was confusion as to what inquiry involves. As a result, clarifications were addressed in the Inquiry and National Science Education Standards in 2000 by providing five essential components of inquiry learning: 1. Scientifically oriented questions that will engage the students; 2. Evidence collected by students that allows them to develop and evaluate their explanations to the scientifically-oriented questions; 3. Explanations developed by students from their evidence to address the scientifically-oriented questions; 4. Evaluation of their explanations, which can include alternative explanations that reflect scientific understanding; and 5. Communication and justification of their proposed explanations (Barrow, 2006; NRC 2000). Although this reform originated from the United States, inquiry is deemed important in precollege science curricula all over the globe (Abd-El-Khalik, Boujaoude, Duschl, Lederman, Mamlok-Naaman, Hofstein & Tuan, 2004).

For instance, the Ontario Secondary Science Curriculum has a section dedicated to scientific investigation skills outlining four stages outlined in Table 1. Thus, demonstrating the wide-ranging impact of the scientific educational reform. The Science, Technology, Society and
Environmental (STSE) goals in the Ontario Science curriculum were “designed to promote the development of critical, scientifically and technologically literate citizens capable of understanding STSE issues” (Pedretti et. al, 2008, p.219). Critical thinking is an essential component of inquiry learning, which is a 21st century skills that falls under the active student-centered learning strategy.

Table 2: Four Broad Areas of Scientific Investigation outlined in the Ontario Secondary Science Curriculum (Ontario Ministry of Education, 2008)

<table>
<thead>
<tr>
<th>Investigation Skills</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiating and planning</td>
<td>Forming questions or hypotheses about scientific phenomena and planning investigations to answer those questions</td>
</tr>
<tr>
<td>Performing and Recording</td>
<td>Gathering information, conducting inquiries safely to collect and record data</td>
</tr>
<tr>
<td>Analyzing and Interpreting</td>
<td>Evaluating if the data is adequate based on evidence and theory and drawing conclusions</td>
</tr>
<tr>
<td>Communication</td>
<td>Developing appropriate methods of communicating scientifically e.g. graphical representation</td>
</tr>
</tbody>
</table>

2.3.2 Benefits of inquiry-based learning. There is a plethora of positive outcomes on student learning when they engage in various inquiry-based activities. In the sciences, many of these activities involve performing inquiry laboratories. However, this is not the only way of achieving inquiry-based learning in science. Inquiry laboratories enable students to practice how to do science and learn about the nature of science. Before participating in inquiry-based laboratories or activities, researchers have found qualitatively and quantitatively that students have the conception that science boils down to the search for the right answer (Szott, 2014; Sandoval & Morrison, 2003). Through inquiry-based activities, studies have found that students can change their conception about the nature of science (Sesen & Tarhan, 2013; Walker & Molnar, 2013). As a result, inquiry-based activities can be quite a transformative learning experience A study
reported that students who participated in inquiry activities developed new understandings of scientific inquiry, which included that scientific knowledge is built over time and through many experimental trials. Although some experiments lead to interesting results, students also learned that some experiments produce uninteresting results (Walker & Molnar, 2013).

A few other studies also indicated that students benefited from inquiry activities by gaining refined scientific investigation or process skills such as formulating hypotheses, posing scientifically oriented questions as well as designing experiments; which are all part of the inquiry steps (see Table 1) (Hofstein, Shore & Kipnis, 2004; Lati, Supasorn & Promarak, 2012; Sesen & Tarhan, 2013; Szott, 2014). Furthermore, two studies noted that the types of questions students asked changed with inquiry-based activities (Szott, 2014; Hofstein et. al, 2004). For instance, in one study that had students do open-ended physics laboratories, students started asking questions to enhance their ability to discover new information, which they wanted to discover for themselves (Szott, 2014). Many studies have found that there was an increase in engagement due to inquiry-based activities as well as a change in attitude towards science (Gani, Safitri & Saminan, 2016; Sesen & Tarhan, 2013). One specific example that demonstrates the multifold benefits of inquiry activities includes an evolution outreach program based in Ontario, Canada for grade 11 biology, which involves exploring dandelions in fields. The study analyzing the results of this program reported that students were engaged and made appropriate predictions directly related to the concepts of natural selection.

From all these studies, inquiry activities have been conducted in a variety of science contexts, including chemistry, physics and biology units respectively (Gani et. al, 2016; Jacobs, Bender & McAdam, 2015; Lati et. al, 2012; Sesen & Tarham, 2013; Szott, 2014). Although, it is important to note that some topics were better addressed in inquiry activities than others. For
instance, in chemistry, topics of determination of reaction rates resulted in gains in the post-test achievement scores, while not as successful for energy, reaction progress and collision theory (Lati et. al, 2012). Finally, it has also been demonstrated that the level of inquiry exposure had significant impacts on outcomes of student learning competencies, personal motivation and student role. From student questionnaires, higher levels of inquiry resulted in students expressing increased confidence in reaching learning competencies, increased personal motivation and it was associated with an autonomous student role (Saunders-Stewart, Gyles, Shore & Bracewell, 2015).

2.4 Challenges to Implementing Inquiry-Based learning

2.4.1 Teacher perceptions and willingness of teaching science as inquiry. Teaching science, as inquiry, is a challenging process for teachers and its enactment can be influenced by various factors. A qualitative study which involved fourteen beginner science teachers, outlined that the five major constraints to teaching science inquiry includes an understanding of the nature of science and scientific inquiry, content knowledge, pedagogical content knowledge, teacher beliefs and class management (Roehrig & Luft, 2004)

Firstly, according to Crawford (2005) preservice teachers with degrees in science have been found to have uninformed understanding of the nature of science. For instance, the preservice teachers that participated in the study were unable to create meaningful graphs and make evidence-based arguments. However, in terms of enactment, Windschitl (2003) has found that preservice teachers with undergraduate or professional experience with authentic science research used more guided and open inquiry styled activities during their practice teaching sessions.
In terms of content knowledge, Crawford (2005) found that preservice teachers had a poor understanding of evolutionary concepts and as a result could not understand the curriculum. In terms of enactment, Crawford (2007) found that teachers who had low subject matter expertise had more difficulty teaching science as inquiry.

Pedagogical content knowledge and teacher beliefs also impacts enactment of teaching inquiry as science. Roehrig and Luft (2004) found that teachers who held student-centered beliefs about pedagogy were the ones who successfully did ‘science as inquiry’, while those with more structure inquiry lessons had fewer student-centered beliefs. In addition, an interesting finding from Crawford (2007) was that all prospective teachers in the study had professional development about how to teach inquiry. However, it was enacted in many different teaching strategies from traditional, lecture driven lessons, to innovative, open, full-inquiry projects. This suggests that beliefs and teacher perceptions can influence a teacher’s decision on how to implement inquiry.

Teacher’s perception of students also has an influence on teaching science as inquiry. Teachers who perceived students as having low ability or motivation seemed to have difficulty implementing ‘science as inquiry’ (Saunders-Stewart, Gyles, Shore & Bracewell, 2015). In fact, teachers reported that the nature of high school learners (i.e. lazy, uninterested etc.) made inquiry an inappropriate teaching strategy (Lati, Supasorn, Promarak, 2012). Finally, depending on a teacher’s level of inquiry experience, it has been found to influence a teacher’s reflection on the challenges of inquiry. Teachers with less inquiry experience were more concerned about the time, how the inquiry fits into the curriculum and with materials. However, those with extensive inquiry experience focused on the challenge of scaffolding student’s knowledge (Szott, 2014).
2.4.2 **Scaffolding inquiry-based learning.** Scaffolding inquiry-based learning is a challenging endeavour. As a teacher, you neither want to give too much guidance or too little guidance. Kirschner, Sweller and Clark (2006) suggested that minimal guidance instruction is ineffective since it ignores human cognitive architecture and evidence from empirical findings. Kirchner et. al (2006) stated that guided instruction is superior unless students have high levels of prior knowledge. The question is: how do teachers know how much guidance to provide during inquiry lessons? In the end, it is essential to provide guidance for students as they go through the inquiry process. The following quote summarizes the problems found when trying to guide students with scaffolds:

> The cost of scaffolding is that it is a crutch that students know they can fall back on, and so they may become dependent on it. The benefits of scaffolding are that it helps students to accomplish difficult tasks, providing focused help at critical times and only as much help as needed. It is, in fact, easier in designing learning environments to provide scaffolding than to provide the kind of coaching described next. Ideally, the scaffolding would be faded as students become more expert (Collins, 1996, p.6).

Although theoretically, scaffolding is recommended to engage students in inquiry-based learning; realistically, there are not many practical examples of using scaffolding effectively. It is known that scaffolding can come in many different forms and there exists a form of synergy that enables students to reach or fail to reach the objectives of the inquiry activity.

In a study exploring inquiry lessons on plate tectonics, they investigated three different inquiry lesson designs with different scaffolding strategies. The most successful scaffolding strategy in terms of understanding plate tectonics and evidence-based reasoning was the inquiry lesson design including an advanced organizer, deconstruction of complex tasks and reflection
on the whole inquiry cycle at the end of the lesson. The curricular scaffolds enabled teachers and students to work on achieving the common goal of completing the task and the advanced organizer included reminders in headings at the beginning of the activity and reflective questions at the end of the worksheet (Hsu, Lai & Hsu, 2015). This is one of the very few studies looking at scaffolding without technology; many other studies suggest that scaffolding inquiry-based learning can be aided through technology or the use of technology scaffolds.

However, before embedding technology into inquiry tasks, we will explore the challenges and roles of technology within the science classroom.

2.5. Challenges and the role of technology in secondary classrooms

2.5.1 Technology scaffolds. In this study, technology scaffolds will be defined by the literature. In literature, technology scaffolds refer to prompts embedded in learning technologies to help students self-regulate their learning in an activity such as an inquiry or problem-solving task. Hints, suggestions, reminders or openers to questions can be displayed on a screen to help students activate their cognitive processes and improve learning for individual students (Raes, Schellens, De Wever & Vanderhoven, 2012).

2.5.2 Preconceptions and challenges of technology use in the classroom. Technology can be used as a scaffold to help inquiry-based learning, once you learn how to integrate technology into the classroom. Both teachers and students have preconceptions about using technology in the classroom. According to Chen, Gallagher-Mackay and Kidder (2014), only 44 percent of principals across Ontario reported that most or almost all teachers use videos or YouTube to support their instruction. This means that not all teachers are using technology in schools across Ontario, albeit it is highly encouraged by the educational reform and the Ministry
of Education in Ontario. Furthermore, 87.3 percent of high school students like using technology and think that it could produce effective learning (Li, 2007). Technology skills are considered part of the 21st century skills as Li (2007) reported that 24 percent of students deemed that technology could help them prepare for the future. From this, it is evident that students want technology incorporated into their classroom to help them learn and prepare them for the future.

When interviewing teachers, Li (2007) discovered that the two main concerns teachers had with integrating technology was the fear of students having limited experience with technology and the cost of technology. Furthermore, some teachers held beliefs that only strong students should use technology in the classroom, weak students should simply focus on the basic skills. On the other hand, Groff and Mouza (2008) suggest that students need to be familiar with the technological tools needed for a project before starting the project. Therefore, technology needs to be scaffolded so that students in the classroom can learn to use it effectively, for its purpose.

However, technological challenges can be a barrier to frequent technology use in the classroom. According to a Canadian report, the three key challenges schools face with regards to technology integration is the lack of effective training for educators, infrastructure complications and the lack of time to adopt new methods (The Learning Partnership, 2015). In the context of technology-enhanced inquiry, technological challenges can be a limiting factor. Approximately 56 percent of teachers, who were recruited to implement technology-enhanced inquiry modules for a study, had technological challenges including outdated software or hardware and networking challenges (Varma, Husic & Linn, 2008).

Of the technology used in the classroom, in Ontario and Manitoba, studies suggest that student-centered technologies (e.g. handheld devices, online discussion boards, social media)
were almost non-existent in pedagogical practices. The most popular uses of technology included Youtube, external websites, interactive whiteboards, Powerpoint and Excel (Hechter & Vermette, 2014; Chen, Gallagher-Mackay & Kidder, 2014). This could have implications with regards to doing technology-enhanced inquiry lessons, since inquiry-based instruction is meant to be a student-centered pedagogy. Sun, Looi and Xie (2014) found that two teachers enacted Collaborative Science Inquiry (CSI) lessons using the CSI web-based platform differently. One teacher had student-centered beliefs, which facilitated the inquiry process while the other teacher held on to traditional, teacher-centered pedagogy. It was found that the amount of student and teacher control, in terms of inquiry seemed to be a key in student motivation for inquiry. This can make us question the role of technology and teachers during the inquiry lesson.

2.5.3 The role of technology in the classroom using TPACK. The role of technology in the classroom is an important consideration before including it in a teacher’s pedagogy. The technological, pedagogical content knowledge (TPACK) framework, described by Mishra & Koehler (2006), includes understanding the connections between content, pedagogy and technology knowledge. Technology knowledge is described as challenging, since it always changing. However, teachers need to recognize when technology can assist or impede achievement of a goal. Technological content knowledge includes the understanding that technology can allow for newer, varied representations or put restrictions on content. Some technologies are best suited for certain subject-matter learning. Furthermore, technological pedagogical knowledge demonstrates that teaching and learning can change when specific technologies are used. Teachers must reconfigure technology for pedagogical purposes. Altogether, technological pedagogical content knowledge helps teachers use technologies constructively, in such a way that the technology could facilitate learning of difficult concepts.
Furthermore, this knowledge should include how to build on students existing knowledge and help them develop new or improved epistemologies (Mishra & Koehler, 2006).

The TPACK framework can help teachers reflect and evaluate on their use of technology in the classroom. In the context of technology-enhanced inquiry, preservice teachers in a technology-enriched Master of teaching program have demonstrated their ability to develop TPACK to make intentional choices about what, how and when to use technology to enhance inquiry. In this study, it was found that the preservice teachers used technology for the following reasons: to present a hook, to facilitate data collection, communication and discussion of the results. Moreover, the types of technologies used to facilitate these purposes included digital media, probeware, simulations, projectors and spreadsheets (Maeng, Mulvey, Smetana, & Bell, 2013). As a result, regarding TPACK, a teacher can reflect on the potential of using certain technologies and its impact on inquiry instruction and learning.

2.6. Technology-enhanced inquiry

2.6.1. Technologies to aid scaffolding or enhancement of inquiry. Once the technological pedagogical content knowledge is further developed, teachers can make more use of technologies to aid science education and the inquiry process. There is a vast array of technologies available for science education to help with visualizations such as animations and models. Furthermore, there are technologies to aid with data analysis, and online scaffolding environments that support inquiry, knowledge building and knowledge communities (Slotta, 2015). The World Wide Web provides a huge number of resources that may allow for research and inquiry learning. Furthermore, there are numerous advantages of technology integration on inquiry; a few which are listed in table 3 (Scanlon, Anastopoulou, Kerawalla & Mulholland,
2011). Some of these advantages overlap with previous findings about the reasons for technology use in the science classroom found in preservice science teachers in an enriched technology program (Maeng et. al, 2013).

Table 3: Advantages of technology integration on inquiry (Scanlon et. al, 2011)

<table>
<thead>
<tr>
<th>Advantages of Technology-Enhanced Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Ability to work with large amounts of information</td>
</tr>
<tr>
<td>2) Supports communication by facilitating expression</td>
</tr>
<tr>
<td>3) Enables complex computations</td>
</tr>
<tr>
<td>4) Interact with information in different formats</td>
</tr>
<tr>
<td>5) Respond to individual users</td>
</tr>
</tbody>
</table>

There are ubiquitous ways to use technologies to enhance inquiry. However, the literature focuses on softwares or programs that facilitate inquiry using scripts. Scripts are embedded in online softwares or other technologies to serve as scaffolds in the inquiry process of students. Furthermore, many types of online software encourage collaborative inquiry by providing collaborative inquiry scripts to allow for students to work in groups. For instance, the Web-based Inquiry Science Environment open source platform (WISE) guides students through the inquiry cycle, promoting learning throughout the inquiry process. Analogously, nQuire is an online software that guides the students through steps of inquiry. However, it also allows for data collection (e.g. making graphics, making videos) as well. One program was designed to support the hypothesis generation step in the inquiry process; it is called the hypothesis scratchpad. This program gives a template that learners can fill with variables and subsequently ensures that the hypotheses entered are testable. Other uses of technology in the literature included: whiteboards to construct knowledge claims and Flyer (a mobile-peer-to-peer messaging) to support
arguementative discussions during field trips. These two technologies help students with communication, analysis & interpretation within the inquiry cycle.

When looking at multiple levels of scaffolding in an information problem solving in web-based collaborative inquiry, Raes, De Wever and Vanderhoven (2012) found that teacher scaffolds were important for knowledge acquisition. Furthermore, students with low prior knowledge performed better with teacher enhanced, or a combination of teacher-enhanced and technology-enhanced scaffolds. This gives us a clue that there may be a specific synergy between technology and teacher scaffolds that could help students with knowledge acquisition.

All together, these findings suggest that there are a lot of technologies dedicated to enhancing the whole inquiry process or specific aspects of the inquiry cycle.

2.6.2 Examples and outcomes of technology enhanced inquiry. Although there are ubiquitous technologies to enhance inquiry, it is difficult to understand how these technologies are used in a practical science classroom. Here, I summarize examples of technology-enhanced inquiry and specific outcomes.

One of the outcomes of technology-enhanced inquiry units (including WISE technology within the Knowledge Community and Inquiry (KCI) model) compared to traditional inquiry instruction is that in technology-enhanced inquiry units have been found to increase students’ knowledge integration. However, there were differences in impact across science courses. Earth Science, Chemistry and Physics inquiry units seemed to have a greater impact than Physical Science, life sciences and Biology. Furthermore, variations were seen within science courses with different teachers. This demonstrates that science inquiry units’ impact differs depending on the subject, enactment of it by teacher and the cohort group (Lee, Linn, Varma & Liu, 2010). As
a result, differential enactment of technology enhanced inquiry instruction is inevitable and it is important to keep this in mind while reading this section.

Jones, Scanlon and Clough (2013) recruited students to participate in a sustainability inquiry through an after-school geography club, where they got to choose their inquiries, collect data from their home and report their findings with the club the following week. This process was supported by the nQuire, the online software, which helped them through their own personal inquiries and collect data from their homes to share it with the club. They found that if a learner has a choice in what inquiries they can conduct, it lead to increased motivation and engagement. Furthermore, it provided personal relevance for students in informal (no direct reliance on teacher) and semi-formal learning settings (Jones, Scanlon & Clough, 2013). On the other hand, these findings have been supported by another study that did not allow students to choose their inquiry question. In this study, students conducted inquiries supported by nQuire related to their health (e.g. “Do I eat enough nutrients to be healthy”). The topic was chosen specifically to be relevant to student’s daily lives. However, in this case there was no change in the student’s attitude towards science. (Anastopolou, Sharples, Ainsworth, Crook, O’Malley, & Wright, 2012). Further research should consider how allowing students to pick their inquiry topics impacts attitudes toward science.

Other examples of technology-enhanced inquiry learning environments had impacts on conceptual understanding of scientific phenomena, knowledge acquisition or metacognitive awareness of students. For instance, Sun, Looi and Xie (2014) co-created collaborative science inquiry lessons (CSI) with teachers using the CSI, web-based learning platform. This combined model-based inquiry and computer supported collaborative learning (CSCL) to get grade 7 students to learn about the types of diffusion and osmosis. The CSI web-based platform enabled
students to understand the objectives, discuss the inquiry questions, watch videos and simulations, create models of diffusion and conduct virtual experiments. Overall, conceptual learning increased in all students as demonstrated by increased test scores (Sun, Looi & Xie, 2014). Analogously, Raes, Schellens and De Wever (2011) implemented Web-based Inquiry science environment (WISE) in a science classroom with a whole task approach including embedded instruction to support information problem solving (IPS). Altogether, 347 students participated in this inquiry activity on the topic of climate change. However, this study had a slightly more specific finding because they focused on domain-specific knowledge and metacognitive awareness. It enhanced domain specific knowledge and metacognitive awareness in students. Metacognitive awareness is essential to web-based learning since it can allow students to be aware of their strengths and weaknesses, can give them insight on what strategies to use for problem solving as well as regulatory aspects of learning including the sub processes of planning, information management, comprehension monitoring, and evaluation (Raes et. al, 2011; Schraw & Dennison, 1994). With regards to metacognitive awareness, it has been suggested, “students are often ignorant of their needs for assistance or approach a task inefficiently, especially in light of multiple, recursive activities involved in inquiry learning” (Manlove, Lazonder & Jong, 2006, p.96).

Furthermore, a follow up study by Raes, Schellens and De Wever (2014) implementing WISE project with the knowledge integration approach to specifically look at the impact on three types of students: girls, low-achieving students and general track students. The topics remained global warming and climate change. Significantly higher learning gains were found in low-achieving students who began with lower prior knowledge. Furthermore, the same was true for general track students. However, these differences were not significant in girls, it was only true if
girls were low-achieving students and general track students as well. All students benefited equally in terms of their inquiry skills. (Raes, Schellens & De Wever, 2014). Lui & Slotta (2014) also used the KCI pedagogical model to get students to participate in an immersive simulation inquiry activity. As a result, it improved conceptions about evolution and biodiversity in pre- and post-test scores. Secondly, from pre- to post-test students’ explanations were also more focused on the process of evolution rather than on the surface knowledge (Lui & Slotta, 2014).

The use of technology can also be extended into field trip settings, as found by Laru, Järvelä and Clariana (2012). They used a mobile-peer-to-peer messaging tool called Flyer to support argumentative discussions while co-constructing knowledge during a field trip in a park. The results illustrated increased knowledge gains from pre-test to post-test suggesting that software-supported argumentation scaffolds are helpful in a field trip setting. However, they found that top performing dyads engaged in more argumentative discussions when co-constructing knowledge claims in comparison to low performing dyads. Furthermore, most of the active argumentation construction occurred in small groups through the mobile messaging tool. However, co-construction of knowledge claims as a whole class, via mobile messaging tool was not effective once it involved the whole class as illustrated by decreased interaction and lack of counter argumentation (Laru et. al, 2012). This could have implications on how to conduct inquiries using mobile-peer-to-peer messaging tool, demonstrating that small group argumentative discussion may be better than class wide interactions. However, the use of interactive whiteboards to co-construct a knowledge base for a classroom has been effectively done by Lui and Slotta (2014). Students had to collect and record field observations using tablets about one specific species from projectors that simulated a rainforest environment. The first iteration of the experiment was more open-ended and enabled students to make superficial
evolutionary connections, with very few exchanges with peers. They concluded that more curricular context and scaffolding was necessary and re-designed the activity for iteration 2. For instance, to provide additional scaffolding for students, researchers added a description of all ancestors for each specific species. In this way, students had more information to base their decisions on and for creation of knowledge claims. Therefore, it makes sense that students had a more in depth knowledge of evolutionary content. Overall, this demonstrates that the curricular connections and structure of scaffolds has a huge impact on the success of collaborative inquiry activities.

2.6.3 Pedagogical model for technology-enhanced inquiry. Setting up a technology-enhanced inquiry environment is a complex task, as it involves setting up a complex system of interactions. Not many researchers have been able to come up with a pedagogical model that takes into account all these levels of interaction for successful technology-enhanced inquiry in the class. One theoretical pedagogical model is presented in Figure 1 as suggested by Kim, Hannafin and Bryan (2007). They demonstrate the ideal model in which all levels align to support technology-enhanced inquiry learning in a classroom.

The outermost level, named the macrocontext includes all the National Standards for Science and educational reforms. Within this macrocontext, the teacher communities construct knowledge, such that more experienced teachers can share their knowledge with new teachers, building authentic teaching experience through online communities. Furthermore, teachers who know how to use inquiry tools can share their knowledge with other teachers because support is needed to establish a technology-enhanced inquiry (Kim et. al, 2007).
The microcontext represents the technology-supported inquiry class, which consists of 3 interwoven relationships: student-tool interaction, teacher-student interaction and teacher-tool interaction.

Firstly, student-tool interaction usually involves embedded scaffolding. For this to be successful researchers have suggested that 4 essential features be present including 1. Conceptual scaffolds that aid students’ understanding of theories 2. Metacognitive scaffolds that help with self-regulation of learning 3. Procedural scaffolds that assist with sharing tasks and planning steps 4. Strategic scaffolds that help with problem solving.

Secondly, teacher-student interaction is more complex as there is still much debate about the balance between teacher and technology scaffolds. Teacher can scaffold students by 1) providing question prompts that challenge students’ thinking and motivate the students to do inquiry and 2) by monitoring students’ learning processes.

Finally, as for the teacher-tool interaction; you can customize inquiry tools to best suit the needs of your classroom. However, the problem with this is that it can compromise the inquiry process it was designed for. Activities designed by researchers may have different learning goals than perceived by the teacher.

Altogether, the implementation of this model is often not realized in a real life science classroom due to various issues starting at the macrocontext level. The standards and reforms for science education do not always align with teaching practice and can often be competing forces. Secondly, the support through teacher communities is often non-existent as teachers simply search for inquiry activities online rather than relying on experienced teachers. Finally, at the microcontext level there is still much debate about how to design an inquiry lesson with technological support (Kim et. al, 2007).
2.7 Conclusion

Inquiry-based learning is highly supported by educational reforms, and is emphasized in the Ontario curriculum. Inquiry-based learning in the classroom results from active, student-centered pedagogy that enables students to gain experience doing science. Student outcomes of inquiry-based learning have various benefits including changing perceptions of the nature of science, increased knowledge gains and scientific inquiry skills. However, there remain many challenges for teachers in scaffolding this type of learning. Teachers are influenced by various perceptions of themselves and their students. In the light of these challenges, I suggest that technology can enhance inquiry in the science classroom. However, I acknowledge that incorporating technology in the classroom is a significant endeavour that has many challenges that come with it. It is for this reason that teachers need to have thoughtful considerations of how to use technology in the classroom. This can be facilitated with the use of the technological pedagogical content framework (TPACK). With the various science technologies available,
technology can be used to scaffold the inquiry process. There are various outcomes of technology-enhanced inquiry including increased knowledge gains, increased knowledge integration, increased motivation and engagement and increased metacognitive awareness.

As a result, technology-enhanced inquiry is a worthy pedagogy of pursuing as a science educator. Technology-enhanced inquiry seems to be enacted differently, depending on a teacher’s pedagogical beliefs (student-centered or teacher-centered). Furthermore, although there is a pedagogical model for technology-enhanced inquiry there is still a lot of debate in how to create technology-enhanced inquiry lessons or an environment that is conducive of it. Therefore, I aim to elucidate how technology-enhanced inquiry is enacted in the science classroom, by specifically looking at technology use as well as how technology enhances inquiry.

In chapter 3, I will describe the research methodologies used for this study and discuss the reasoning behind them. Firstly, I will address my research approach and procedure as well as instruments used for data collection. Secondly, I will discuss the sampling criteria and procedure used for recruiting and interviewing participants. This section will also include biographies for each participant. Finally, the chapter will conclude with methods for data analysis, ethical review procedure and methodological limitations and strengths of the study.
Chapter 3: Research Methodology

3.0 Introduction

In order to investigate how Ontario Secondary School teachers use technology in the science classroom to enhance inquiry, I reviewed the literature, recruited experienced educators for interviews and analyzed the interview transcripts for themes. In this chapter, I outline the qualitative research methodology used to answer the overall and subsidiary research questions:

How do teachers use technology to enhance inquiry and what are the outcomes?

• What kinds of technology and teacher scaffolds are used to support technology-enhanced inquiry?
• What challenges do teachers encounter in implementing technology-enhanced inquiry in the science classroom?
• What are the benefits of technology integration on inquiry?

I begin with the research approach with reasoning for my methodological choices followed by the methods for data collection. The next section is dedicated to participants, specifically the sampling criteria, the sampling procedure and the participant biographies. Finally, this chapter ends with a discussion of the data analysis, ethical review procedures as well as the strengths and limitations of my study.

3.1 Research Approach and Procedures

The research question for this study emerged from a gap in the literature about the enactment of technology-enhanced inquiry in science classrooms. In chapter 2, the literature review illustrated the lack of knowledge of teacher practices related to technology and inquiry in
real science classroom contexts. After completing the literature review, I created my interview protocol, which includes questions about teacher perspectives, practices, and experiences using technology-enhanced inquiry.

The purpose of this research is to discover the uses of technology to enhance inquiry in the secondary science classrooms. Keeping the purpose in mind, it is evident that the enactment of specific pedagogical practices is not readily measured quantitatively. Qualitative research is useful when the information for the topic of study is hard to measure quantitatively (Hoepfl, 1997; Strauss & Corbin, 1990). Hence, conducting a qualitative study was a suitable fit for my study.

Another benefit of qualitative studies is that it allows researchers to gain findings that may be helpful to study a phenomenon about which little is known (Hoepfl, 1997; Strauss & Corbin, 1990). There is very little known about how to enact inquiry-based teaching and learning with technology effectively. This displays another reason for using a qualitative research method for my study.

### 3.2 Instruments of Data collection

To address the research question in a way that allows for interpretation of pedagogical beliefs and practices of a teacher, I conducted my study through 45 minute semi-structured interviews. This approach is particularly effective to have an in-depth understanding of how teachers enact technology-enhanced inquiry in science classrooms including relevant lesson plans, resources and feelings about this topic. Considering the level of complexity of technology-enhanced inquiry, as a researcher I discovered the presence of various influences that impacts a
teacher’s enactment of this type of inquiry. Gill, Stewart, Treasure & Chadwick (2008) stated that “the flexibility of this approach, particularly compared to structured interviews, also allows for the discovery or elaboration of information that is important to participants but may not have previously been thought of as pertinent by the research team” (p. 291).

The semi-structured interview allowed me to design specific questions tailored to my research question, but also left room for follow-up questions in response to each individual’s experience. The interviews were recorded using my phone and transcribed using software for further analysis.

3.3 Participants

This section outlines a rationale for the sampling criteria established for the participants of this study as well as the method of recruitment. I will also provide details on each participant.

3.3.1 Sampling criteria. I developed the following sampling criteria to recruit my participants for this study:

- A minimum of 3 years teaching experience
- Experience teaching science courses from grade 9-12
- Use of technology in science courses to enhance inquiry-based learning

Firstly, a minimum of 3 years teaching experience was an essential criterion because inquiry-based learning is a challenging endeavor in a science classroom. Therefore, experience with the science curriculum and courses are required before being able to design successful inquiry-based learning activities. However, the younger teachers may have an advantage in knowing about current technologies that could be used in the classroom. As a result, there is a
tradeoff between knowledge of technology and implementing inquiry-based learning. Experience teaching science courses from grade 9-12 is essential for teachers to have knowledge of the curriculum. Furthermore, it would allow teachers to have possible insights on the outcome of inquiry-based learning with different age groups. The use of technology to enhance inquiry-based learning in secondary science classrooms is the most important criterion because it provide guidance to myself and other future educators on how to enact this pedagogy.

3.3.2 Sampling procedures. Considering the specificity of the sampling criteria iterated in the previous section, purposeful sampling was the chosen method for the sampling procedures. According to Ritchie, Lewis, Nicholls and Ormston (2013), this type of sampling occurs when “members of a sample are chosen with a 'purpose' to represent a location or type in relation to a key criterion” (pg.79). This ensures that the teachers will be able to answer the research questions outlined in Appendix B about the use of technology to enhance inquiry-based learning. Furthermore, it allows that “within each of the key criteria, some diversity is included so that the impact of the characteristic concerned can be explored” (Ritchie, Lewis, Nicholls & Ormston, 2013, p. 79).

To recruit teachers, I sent postings to teacher associations detailing the purpose of my study including the necessary participant criteria. In order to give teachers the choice of participating in my study, I provided them with my contact information to ensure that participation is completely voluntary. By providing adequate information to participants, they could consent voluntarily. This ensured that the dignity and rights of the participants were respected (Flick, 2009).
Additionally, considering that I interact with a broad network of teaching professionals, I also used convenience sampling in two ways to help me find participants. “Convenience sampling … lacks any clear sampling strategy: the researcher chooses the sample according to ease of access” (Ritchie, Lewis, Nicholls & Ormston, 2013, p. 81). The first approach was to e-mail Associate Teachers and professors with whom I have directly worked to ask for their recommendations for suitable participants. The second approach was to obtain the assistance of family members who worked in e-learning and who had connections with teachers who possessed high levels of technological experience. The e-mails I sent out in both these cases described the details of my research, the sampling criteria, and the interview process. It was specifically outlined that participation in this research was completely voluntary and withdrawal was possible at any point.

3.3.3 Participant biographies. My first interviewee Joanne is a science teacher who has four years of teaching experience, including 1 year of international teaching in England. She has experience teaching grade 7, 8, 9 and 10 general science courses here as well as in England. She also has taught grade 11 university chemistry here in Canada. Joanne has a bachelor and master’s degree in chemistry. Furthermore, she values inquiry-based learning in the science classroom to prepare students for further studies in science and to have a good understanding of the nature of science. Joanne also thinks technology is particularly engaging for students. She was introduced to me through one of my family members and I was assured that she was a passionate science educator interested in inquiry learning. From receiving my e-mail, she confirmed that she was suitable for the study and was interviewed soon afterwards.

Rachel has been teaching for five years. Prior to her teaching experience, she had been working in the engineering industry for over ten years. While her time working as an expert in
her field, she trained co-op and summer students for the industry. She repeatedly found that students struggled when learning to use new technologies. As a result, when an opportunity to teach science arose, she decided to pursue teaching so that she could address technological challenges in the classroom. This career move demonstrates Rachel’s passion in teaching her students about using new technologies. Rachel has taught grade 9 and 10 academic science, grade 11 and grade 12 university physics. She has completed a science degree in physics and a biological engineering degree. She is currently in the process of completing a master’s degree in teaching mathematics. With this unique background with a passion for technology, Rachel made a very suitable candidate for this study.

Eric is a secondary school science teacher that has been teaching for 12 years. He has experience teaching grade 7, 8, 9 and 10 academic science classes. Furthermore, he has experience teaching grade 11 university physics, grade 11 university chemistry and grade 12 university biology. His educational background includes a bachelor degree in biology and a graduate degree in neuroscience. About 10 years ago, Eric was asked to try using Moodle as a learning management system in his science classrooms to test it out. Eric used Moodle to enable him to set up his classroom as a real inquiry space. From all this information, Eric was a suitable fit for my study. I got into contact with Eric through one of my professors from OISE as he was deemed to be a technology savvy teacher that may be suitable for the study.

3.4 Data Analysis

After I conducted each interview, I transcribed the audio recordings on the computer using the InqScribe software. Inqscribe enabled me to slow down the audio tracks so that I could type out verbatim transcripts of the interviews.
The transcripts were read from beginning to end twice before starting the coding process. When coding, I read through the transcripts and picked out words or phrases that characterized each answer. I also made use of analytic memos to reflect while coding, to help me have a deep understanding of the transcript. Once I did this process with all my transcripts, I started making comparisons using the constant comparative method. Using this method, I took the codes from my three interviews and looked to see similarities and differences. As a result, I came up with categories. From these categories, I looked at how these categories could help answer my research questions and subsequently came up with three overarching themes.

3.5 Ethical Review Procedure

The consent letter (Appendix A) was sent out to all potential participants. It outlined the research aims, the interview process and ethical implications. The ability of participants to withdraw from this study at any stage was emphasized.

Confidentiality is of high importance in qualitative studies, as these studies often involve a disclosure of personal information (Flick, 2009). In order to avoid identification of the participants, I assigned a pseudonym to all participants. Furthermore, any information about the participants was securely stored on a computer. This includes audio-recorded materials and transcripts. This material will be destroyed after 5 years.

After transcribing the interviews, I sent them to all three participants for review to ensure accuracy and to provide them with the opportunities to identify any edits that they deemed necessary. It was determined that there are no known risks for participants in this study. Despite
this situation, participants were informed in the consent letter and during the interview that they had the right to refrain from answering any questions and/or withdraw at any point of the study.

3.6 Methodological Limitations and Strengths

Given the ethical parameters for conducting this research, only teachers were interviewed. This limitation does not allow for understanding the dynamic relationship present between teacher and students. In order to understand the effectiveness of technology-enhanced inquiry, the student’s perspective would bridge possible gaps between teacher and student perceptions. Another limitation is the small sample size of three teachers, which is not representative of teachers overall in Ontario.

On the other hand, this qualitative research did allow me to actively collaborate with teacher participants explaining their experience and stories. This provided me with the opportunities to ask questions to clarify or understand their point of view, which presented a significant strength of qualitative research (Creswell, 2007). Furthermore, this methodology will allow for bridging the gap between the theory and practice of inquiry-based learning in the classroom. These three teachers provided insight for other science teachers on how to establish successful technology-enhanced inquiry learning environments.

3.7 Conclusion

Considering that the nature of my research is focused on pedagogical practices, a qualitative research method is suitable. The semi-structured interviews allowed me to tailor the interview questions to my main research goal and discover relevant information that I did not
speculate. The sampling criteria allowed me to find teachers who were relevant to my topic of study and who would have insight on my main research goal. I used a combination of purposeful and convenient sampling to find my participants, keeping in mind that participation remains voluntary. Ethical considerations were carefully considered to make sure that participants were informed about the research process; including statements of confidentiality and the right to withdraw from the study at any point (see consent under Appendix A). Although this research included a small number of teachers, it provided me with the chance of understanding the experience of my participants with technology-enhanced inquiry-based learning.

In the next chapter I will discuss my research findings. My research findings will expand on the three themes that emerged from by data analysis. They are: 1) practices related to technology-enhanced Inquiry; 2) challenges of technology-enhanced inquiry; and 3) benefits of technology.
Chapter 4: Research Findings

4.0 Introduction

In this chapter, I present my qualitative research findings on how three teachers enact technology-enhanced inquiry in the secondary science classrooms. I hope these findings will help new teachers learn how to integrate technology in the science classroom in a meaningful way to enhance inquiry. I obtained this data by recruiting three teachers who actively use technology to enhance inquiry-based learning. The participants will be referred to with the following pseudonyms to ensure confidentiality: Joanne, Rachel and Eric. The teachers were recruited through personal contacts, ensuring that they fit the sampling criteria outlined in my consent letter (refer to Appendix A). This was followed by three 45-minute semi-structured interviews that were transcribed. The transcripts were coded into categories and subsequently into themes.

My three themes respond to my primary research question: How do teachers use technology in the classroom and how does this enhance inquiry? The first theme addresses teacher practices related to technology-enhanced inquiry. My findings aim to answer my sub-question: what kinds of technology and teacher scaffolds are used to support technology-enhanced inquiry? This theme is broken down into three sub-themes including how educators introduce technology in the classroom, specific examples of technology-enhanced inquiry and scaffolding technology-enhanced inquiry.

The second theme looks at the challenges of technology-enhanced inquiry, which answers the sub-question: what challenges do teachers encounter in implementing technology-enhanced inquiry? This theme is broken down into the following three sub-themes: challenges of implementing technology, balancing the practical inquiry skills and technology skills as well as challenging the failure narrative in science.
Finally, my third theme will address the sub-question: what are the benefits of technology integration within the inquiry process? This theme is broken down into two sub-themes including the benefits of specific technologies and metacognitive skills gained from technology. Finally, the findings are analyzed to get a sense of how educators use technology in the science classroom and how it enhances the inquiry process.

4.1 Practices related to technology-enhanced inquiry

This theme explores my primary research question, which is: how do teachers use technology in the science classroom and how does it enhance inquiry? I was interested in learning how teachers conceptualized technology-enhanced inquiry and have a better understanding of the roles of technology in the science classroom. From my participants, I discovered the unique interactions between teacher pedagogy, technology-use and the students’ inquiry process. My sub-themes begin with the introduction of technology in a classroom. For my next sub-theme, I will present examples of technology-enhanced inquiry in different science contexts. Finally, I will explore teacher and technology scaffolds that can help guide students through the inquiry process.

4.1.1 Introducing technology use in the classroom. Although students are often referred to as “digital natives”, capable of using and learning about new technologies rapidly (Prensky, 2001), it is still important to ensure students are comfortable with the technology a teacher integrates in the science classroom. As outlined in the literature, students have varying prior knowledge with regards to using technology. Students who are accustomed to traditional classroom settings may have trouble adapting to doing technology-based tasks. As a result, it was recommended that technology training be conducted before doing technology-enhanced inquiry
All participants in this study reported adopting this recommendation for introducing new technologies in the science classroom. Prior to using these technologies in class for problem solving, inquiry or other applications, they described how they dedicate class time to learning how to use the technologies. For instance, in Rachel’s physics class, various graphing softwares are used throughout the year, such as Logger Pro. Therefore, to ensure that students know how to use this software before doing inquiry labs or activities, Rachel scaffolds this at the beginning of the year. Rachel explains:

So when I start the semester off with physics, I spend about three days working with graphing equipment and graphing software that we use throughout the semester for almost all the rest of the labs and I give them some basic data to graph.

As a result, when Rachel’s students get to the inquiry lab or activity they will not have trouble using the technology. This is helpful because students can focus on learning the content and conduct data analysis rather than learning how to use the technology during the inquiry lab or activity. By doing this, the teachers are focusing on some of the basic skills such as graphing to ensure they can interpret their data and communicate scientifically once they get to the inquiry lab or activity. In addition, Rachel provides the students with a list of basic things they will have to do during the whole semester such as being able to “graph 3 different things on the same axes”. Rachel emphasized giving students time to practice specific technological skill sets that students will need for all inquiries for the whole course, which requires much advanced planning.

These findings emphasize the importance of introducing technology early on in the school year, in a low-stakes environment, to ensure that all students feel comfortable using the technology before using it in an inquiry task. This set up refers to the technological pedagogical
knowledge in the TPACK framework, since the teachers demonstrated that teaching and learning change when different technologies are used (Mishra & Koehler, 2006).

Technology integration is essential for technology-enhanced inquiry; however, it is not evident what this type of inquiry looks like in different science classrooms.

### 4.1.2 Examples of technology-enhanced inquiry.

The interpretation of technology-enhanced inquiry in biology, chemistry and physics classes differs quite a bit amongst educators and subject areas. The understanding and role of technology and inquiry differs with all participants. This section will provide example technology-enhanced inquiry labs or activities as defined by the three research participants.

Firstly, Joanne interpreted technology-enhanced inquiry as inquiry supported by computer simulations or virtual laboratories. She introduced an interactive, virtual lab that she could do online for students to “establish a mathematical correlation between mass and volume in the determination of density”. In this activity designed for grade 8 or grade 9 students, their task is to find the density of a virtual object by using the fluid displacement visualized in a graduated cylinder and a virtual scale to measure the mass. This lab represents a closed-ended, virtual inquiry lab. This lab is comparable to Sun, Looi and Xie (2014) diffusion inquiry lab using computer supported collaborative learning (CSCL). In this case, Joanne emphasized that this virtual lab is used because there is a lack of equipment in the school.

Rachel shared a different technology-enhanced inquiry that involves students working in groups to build a mouse trap car that could travel the furthest possible distance. The students are given a set of criteria at the beginning of the project, including: “you have to have at least three wheels, the only energy source you can have is the mouse trap, you can’t have any manufactured
parts”. Students are then given time to research in class using their phones, computers. Rachel describes what the students are doing during class time, they are:

- watching videos,
- reading articles,
- finding best practices from different aspects to manipulate what their design is going to be and some of them even go as far as sitting down into a program like AutoCAD or a similar design program and they will actually draw out blueprints for it.

Rachel’s interpretation of technology-enhanced inquiry was an example of project-based task. It includes a hands-on portion in combination with technology use. This choice of activity may have to do with Rachel’s educational background in biological engineering and her previous job in industry. The role of technology in this inquiry was for research and to use design programs to help them draw blueprints of their car.

Finally, Eric’s main example of technology-enhanced inquiry involved the use of specific technologies to help with the measurement of data. For instance, one of the first design labs for the grade 12 biology courses is the perturbation of the cell membrane of beetroots using different agents of their choice (e.g. alcohol of different chain lengths) and measuring this with a spectrophotometer. This represents a more open-ended inquiry lab. The spectrophotometer measures the “colour emission from a beetroot based on how they perturb the cell membranes”. Therefore, in this case, the interpretation of technology-enhanced inquiry involved the use of technical instruments used in the laboratory to help in quantitative analysis for data collection.

As we can see from these examples, technology-enhanced inquiry is enacted in various ways depending on the subject and technological tools available. Furthermore, there are differences based on the type of inquiry task assigned, some participants had more open-ended inquiries, while others had closed-ended inquiries. These findings are consistent with the
literature because inquiry-based learning has often been a difficulty to define. According to Bell et al. (2010) the 9 steps of inquiry include: orienting and asking questions, hypothesis generation, planning, investigation, analysis & interpretation, model, conclusion & evaluation, communication and prediction. As a result, if the three examples from our participants are compared using these 9 steps of inquiry, all of them have differing numbers of these steps present. In Joanne’s density inquiry she is missing the planning and model steps of inquiry since the virtual lab is pre-planned out for the students and they do not have to actually carry out the experiment in real life. In Rachel’s mouse trap car example, the hypothesis generation, and prediction steps are not explicit because they are already defined in the task of creating a model of a car. While, students may have some predictions about what materials would be best to use based on their research, it is not explicitly evident in the process. Finally, Eric had all nine steps of inquiry for his beetroot membrane disruption lab.

As a result, this demonstrates that technology-enhanced inquiry activities can be done across all science classrooms (biology, chemistry and physics), they have varying amounts of inquiry steps and skills incorporated as well as different roles for technology. Knowing examples of technology-enhanced inquiry activities is encouraging. However, to aid students in the process, scaffolding students through the inquiry process is essential.

4.1.3 Scaffolding technology-enhanced inquiry. All participants mentioned that scientific inquiry is a challenging process for students, especially if they are not accustomed to it. Therefore, teachers need to understand how much scaffolding is required to support students through this process. Eric sets up his grade 12 biology courses such that he begins with structured inquiry, with more constraints, and moves towards open-ended inquiry by the end of the course. This method agrees with the growing body of evidence that suggests that good
scaffolding needs fading of support to eventually let the individual start taking ownership over their learning (Collins, 1996).

In Eric’s class, scientific inquiries enable students to study a question that interests them. The students work in groups, using a variety of different technologies made available to them. As a result, all of these inquiries are defined as design labs and require scaffolding. For Eric, any design lab begins with a design conversation assessment with each group. Eric describes the process:

I literally have a sheet that I give them well before and they know what questions I am going to ask them. I will ask something like okay, so what’s your guiding question, what’s your hypothesis, what’s your control variable, why are you doing it this way?

Having this design conversation helps students understand what they are doing and fills in gaps in their knowledge. Eric’s inquiry projects normally last a few weeks, however by providing students with a sheet to guide design conversations he deconstructs the complex task of inquiry by guiding them with essential questions. Hsu, Lai and Hsu (2015) highlighted deconstructing complex tasks as a key strategy in effective inquiry lessons. Eric also facilitates group-to-group interactions during inquiry by encouraging groups to share strategies when encountering challenges.

Rachel reported a similar strategy to Eric with regards to scaffolding inquiry activities including the use of questioning to scaffold students and the encouragement of group-to-group interactions. However, Rachel had a unique strategy that involved purposeful grouping:

You have diverse classes now, so you try to pair people or group people up so you have some people who are very strong with technology and some people who are very strong
with hands on in the same groups and where one strength might be lacking, the other one can pick it up and they learn from each other.

This represents a cooperative learning strategy, which gives every group member a role, and each individual is able to contribute successfully to the group. The interdisciplinary nature of this technology-enhanced inquiry enables a diverse group of students to be engaged in doing science.

Neither Rachel nor Eric used technological scaffolds to aid students through the inquiry process. The scaffolding was designed by them, so that the technology could be used in a specific way. This suggests that technology needs to be used in such a way, to align or directly support teacher scaffolding. However, Joanne addressed the use of technology scaffolds in conjunction with teacher scaffolds. Joanne described engaging students in a virtual lab as follows: “You have your procedure on paper, and you give instructions at the very beginning. Now most programs will have tips, it will say, pay attention to the change in volume”. In Joanne's example, students could use the technological scaffolds to help them with the investigation (tools to collect data) and with analysis and interpretation steps in the inquiry process. The virtual lab is different from the other two inquiries, since it lacks a hands-on component. Therefore, it seems that the degree of hands-on work within a technology-enhanced inquiry can influence what type of scaffolds are used. With regards to the literature, many technology-enhanced inquiries involve the use of technological scaffolds. However, this often requires partnerships between science education researchers and schools. Science education researchers often provide pre-planned inquiry units with appropriate technology scaffolds and teacher instructions.

In summary, participants asked prompting questions, deconstructed the inquiry into specific steps and encouraged group-to-group interactions to support their students in
technology-enhanced inquiry. However, with higher technological demands, technology scaffolds also play a role in scaffolding students in technology-enhanced inquiry.

4.2 Challenges of Technology-Enhanced Inquiry

Although participants expressed a willingness to engage their class with technology-enhanced inquiry, they reported many challenges that need to be considered. This theme relates specifically to my sub-question: What challenges do teachers encounter when implementing technology-enhanced inquiry in the science classroom? First I discuss the challenges of implementing technology in the science classroom, in the participant’s school context. Then, I explore the challenge of balancing the technological skills and practical inquiry skills in a technology-enhanced inquiry activity. Finally, the third sub-theme looks at challenging the failure narrative in science with technology-enhanced inquiry.

4.2.1 Challenges of implementing technology for inquiry. Teaching science as inquiry presents many challenges and incorporating technology adds an extra degree of complexity that must be accounted for when doing technology-enhanced inquiry. Rachel and Joanne both agreed that technology could malfunction in many different ways and identified Internet failures and a lack of functioning computers as specific challenges. These examples were included under information technology infrastructure problems, as one of the most significant problems to integrate technology in the classroom for Canadian educators (Learning Partnership, 2015).

However, lack of access to technology as well as a lack of functional equipment was a significant problem according to Joanne. Some of the computers were outdated and ran obsolete operating systems. This made running many of the applications very unreliable. Joanne attributed these problems to the school board’s lack of funding in this department. Furthermore, Joanne
acknowledged that some of the students at her school had lower socioeconomic status, making access to technology at home not possible and putting them at a disadvantage. If using technology in the classroom, you have to ensure all students have equitable access either at home or at school.

Without regards to funding and IT infrastructure problems, Rachel and Joanne both agreed that using technology in the classroom could increase student engagement because they are always tied to their phones, but sometimes it can be a distraction. Rachel wonders about “how we can keep them on task, not texting, not facebooking, not playing games”. Rachel mentioned feeling that she had to constantly ensure that students were on task. Although it is often thought that student engagement can be raised with technology, it also depends on the inquiry task assigned. Jones, Scanlon and Clough (2013) found that personal relevance was important for engaging students in inquiry, and advocated giving students a choice over their inquiries. In support of this, Eric, who builds in a lot of choice in his design inquiry labs, reported never facing any challenges with student engagement. For him, the most significant challenge was timing and challenging the school culture. Eric stated that if technology-enhanced inquiry is not part of the school culture, getting students and teachers on board could be a challenge.

The challenges faced in technology-enhanced inquiry depend on the school board funding, the socioeconomic status of students and the school culture. However, there are common challenges to enacting technology-enhanced inquiry including time management, student engagement (varies) and IT infrastructure problems. Although implementing technology in the classroom can have challenges, these findings suggest that a teacher must also be aware of
the purpose of technology and evaluate if it truly enhances or supports the inquiry process, rather than take away from it.

4.2.2 Balancing the practical inquiry skills and technology skills. All participants agreed that technology could effectively enhance inquiry most of the time. However, they argued that there is a limit. When talking about technology-use, Joanne stated “so whenever you are relying on technology all the time, it takes away some of the human thinking process”. This statement demonstrates that if students rely too much on technology, it can be detrimental to the inquiry process, because the inquiry process requires that students constantly reflect. In the same way, using technology to simply find the “answer” to a science investigation does not mean you are doing authentic inquiry. This conception of trying to find the right answer in science, has been previously found in students with less inquiry-based activities, and illustrates the challenge of technology integration (Szott, 2014; Sandoval & Morrison, 2003).

Another example included students looking at interactive virtual cells on the computer. Joanne mentioned that having access to this facilitates learning. However, with regards to real-world cells under the microscope, it did not illustrate reality. Students may have trouble identifying what a cell really looks like under the microscope, which is a hands-on skill. Joanne expressed a belief in giving students the opportunity “to develop the skill of being able to use a burette or a pipette and kids need to practice to do it well. They will often get frustrated with a titration because they overshot, they don’t know how to control the flow of a particular chemical”. Although Joanne mentioned that students often perform better with virtual labs, hands-on skill development is important for overall knowledge of the nature of science and inquiry. This is supported by the literature, that states that students who participated in scientific inquiry developed a new understanding about the nature of science, more specifically that
scientific knowledge is built through many experimental trials, with the possibility of gaining uninteresting results (Walker & Molnar, 2013). Analogously, Rachel emphasized the fact that the hands-on portion is often more impactful on a student’s inquiry-based learning. Rachel agreed that inquiry-based learning should not only involve using technology to come up with an answer. If students simply rely on the technology, it is another way of avoiding failure because they are afraid of trying and coming up with the wrong answer.

In conclusion, these findings suggest that any technology-enhanced inquiry task should be implemented while carefully considering what the use of technology is contributing to the task. If the technology is replacing a hands-on skill or replaces a student’s problem solving skills, teachers may want to reconsider the role of technology in technology-enhanced inquiries.

4.2.3 Challenging the failure narrative in science. All participants mentioned that students are often afraid of using new technologies or participating in open-ended inquiry. Making mistakes is not seen as part of the learning process and can prevent the success of students. Rachel reported that she often exemplifies this idea by saying “the Wright brothers; their first plane did not go in the sky; how many things were created accidently. So, we have all these scientific breakthroughs but that is not what they were trying to do when they found it.” Rachel tries to emphasize this by encouraging her students to learn from their mistakes and try again when something fails. With regards to her mouse trap car project, it means students need to go back to the drawing board if their prototypes are not working the first time around. This encourages her students to problem solve, by figuring out what about the construction or materials is inhibiting their progress. Eric emphasized that he does not give out marks to students for “good data”. Instead, he simply gives marks for honest data with a reasonable explanation demonstrating critical thinking, for how things went wrong. In this way, the pressure to find the
“right” answer and doing everything perfectly is no longer there. This provides an authentic environment to make mistakes and learn from them. However, in Joanne’s case, using computer simulations “will guarantee that you can go back or do it again, without having to do the experiment from the very beginning”. In this case, it is evident that the technology is creating the perfect environment for students to be able to redo experiments very easily and find the “right” answer. Therefore, depending on how the technology is used, it could give students the wrong impression about participating in inquiry. If technology is used to help students find the “right” answer, it takes away from the inquiry process. The scaffolds will inhibit the student's’ ability to engage deeply with inquiry, but rather will be used to discover the “right” answer. Therefore, the reliance on technology to help students find the answer may alleviate their fear of failure. However, this does not help students be successful in scientific inquiry.

As aforementioned, some students may not be comfortable with the use of technology in the classroom. However, with an appropriate introduction to technology, this problem can be minimized. Furthermore, the successful mastering of a new technology can give students confidence needed to engage in the inquiry process. Technology often does not work and students need to troubleshoot the problem and find a solution. Rachel noticed that students found it difficult to face these challenges. It is for this reason that she uses technology as much as possible in her classroom that way students can face these challenges as opportunities to learn. As a result, we can see a parallel between the fear of failure in the inquiry process and the use of technology.

In conclusion, technology-enhanced inquiry tasks were found to help students confront their fear of failure. Teachers often provided the encouragement for students not to give up on their inquiry tasks and helping them by scaffolding. However, technology use itself can be
paralleled to open-ended inquiry because in both cases it requires troubleshooting when failure occurs.

4.3 Benefits of Technology

Educational reforms have lead to the integration of technology in the Ontario curriculum, since it is an important part of our society, particularly in application to science. Participants used technologies for a variety of purposes in the science classroom, including enhancing the inquiry process. Here I address how these technologies could be used to enhance skills required for the inquiry process. In this theme, I address my sub-question: What are the benefits of technology integration on inquiry? In my first sub-theme, I discuss the benefits of specific technologies in the science classroom and look at what inquiry steps it may support. My second sub-theme looks at how technologies can help students gain metacognitive skills required for inquiry.

4.3.1 Benefits of specific technologies. The participants expressed an awareness of the wide range of technologies specifically designed to benefit science education. However, it is important to know that there are pedagogical implications with the use of each technology. As we saw in the technology-enhanced inquiry examples, technology is used in different ways to enhance inquiry. Furthermore, oftentimes technology is used as a tool in the classroom for purposes other than inquiry. There are technologies to aid students with visualizations through animations or simulations and to help students with data analysis by enabling them to organize large data sets and communicate their findings appropriately (e.g. graphing software).

Furthermore, there are online, collaborative scaffolding platforms and software that can support knowledge building and inquiry (Slotta, 2015).
The participants noted using a plethora of technologies in their classroom including: interactive online simulations such as Gizmos, learning management systems such as Google classroom and Moodle, Google docs (for collaborative assignments), a game-based learning platform called Kahoot, Logger Pro (graphing software) and various technological tools used in quantitative data analysis. The benefits observed by the participants by using these technologies included increased student engagement (e.g. Gizmos, Kahoot), enhanced visualization of concepts (e.g. simulations), enabled manipulation and representation of data (e.g. graphing software), increased communication and collaboration outside of school (e.g. Google classroom, Moodle, Google docs), and allowing students to communicate information in many different formats (e.g. YouTube videos, rap songs, websites). According to these findings, technology mostly supported the investigation (i.e. collection & organization of data) and communication (i.e. reporting results) steps in inquiry.

Specific benefits of technologies related to enhancing inquiry were inferred from participants’ answers. Joanne mentioned that doing technology-enhanced inquiry in the form of a virtual lab was very beneficial because the technology scaffolds student learning by providing hints during the simulation. The hints serve as a prompt (e.g. for analysis and interpretation), to help students reflect on the inquiry process and self-regulate their learning. Therefore, the technology in a virtual lab helps in large class settings because it saves time. Unlike real, hands-on labs, Joanne reported not having to answer all student questions before students could move on to the next segment of the lab. On the other hand, Eric stated that he would never use simulations for lab experiments he could conduct in the classroom. However, he did mention that the use of simulations in the classroom for processes that are not readily observable in the real world, such as evolution, is very helpful. In the TPACK framework (Mishra & Koehler, 2006),
this reflection fits in the technological content knowledge since he talks about the use of technology appropriate for the content.

Finally, Eric uses Moodle, a learning management system, to achieve a flipped classroom model. Consequently, he is able to do more hands-on, design inquiry labs in the classroom. In Eric's flipped classroom, students watch online lectures posted on Moodle to learn the content themselves and bring any questions they may have to the classroom. They take quizzes after learning the content and when they succeed they can move to the next lesson. According to Eric, this builds accountability for the student to make sure they are on track, and it enhances their ability to self-regulate their learning. When participating in inquiry in Eric's classroom, students build a database of articles to read, collectively as a class to support their inquiry and build on each other’s knowledge. Furthermore, they must participate in anonymous peer feedback of their lab reports through Moodle. Peer feedback can serve as a reflective assessment of the inquiry process. This self-awareness in the inquiry process can be helpful for student success.

In conclusion, teachers use technology to support learning in a variety of ways by enhancing or facilitating student engagement, visualization, manipulation & representation of data as well as communication & collaboration. For inquiry, technology seems to support the steps of investigation and communication for the most part. Moreover, there are benefits of using specific technologies depending on the inquiry topic and size of the classroom; one of the benefits includes metacognitive skills.

4.3.2 Metacognition skills gained with technology. Both Rachel and Eric stressed the importance of the process rather than the product, with regards to technology-enhanced inquiry. Rachel shared her belief that self-awareness of the process of learning constitutes an important part of being successful in the 21st century. This self-awareness of your own learning is referred
to as metacognitive skills. As described in the literature, it includes knowledge about how we learn, knowledge of strategies or procedures and when or why to apply these strategies (Schraw et. al, 2006). In Joanne’s virtual density lab, students get prompts to scaffold the inquiry process. These prompts give students strategies on how to think through the inquiry problem.

In Rachel’s build a mouse trap car example, she explained “when you are going forth and experiment in that you need to keep going back and re-evaluating, you need to look back at your process, you need to reflect, so we built, it's been built into this”. With regards to technology, this process is facilitated with access to technologies to enable students to keep a digital record of their progress, integrate new knowledge and research to help make new hypotheses on how to improve their mouse trap car. This constant re-evaluation and reflection on the process of inquiry in design inquiry or project-based tasks is what the teachers stated they want their students to take away from the course.

Eric also expressed this belief, as he provides the opportunity for reflective assessment during his design labs, as well as peer assessments. However, he facilitates this process by using technology. Moodle automatically assigns each student three people to give feedback on their lab reports, Eric explained “so that allows me to create an electronic workshop environment where I can sort of say, you know, here are the people, here is your first draft, here is the feedback you got from these people, here is your second draft, how much of it did you incorporate”. This method of peer evaluation once again, adds accountability for students to complete their work. From this electronic workshop, students can learn to critically evaluate the lab reports of others and receive feedback to help them learn how to improve. This has the potential to help students become aware of the learning process during inquiry. As a result, it can strengthen the inquiry process and students’ ability to make and communicate scientific arguments. The technology
enables the teacher and the student to see the progress of their lab report over time. Secondly, Moodle permits anonymity, an important feature because students can often be afraid of being critical of their friends’ assignments. The use of Moodle can help to build a learning community to reflect on a student’s learning and other’s learning to build more knowledge.

Overall, technology can aid students to gain metacognitive and critical thinking skills helpful for the inquiry process. The use of online softwares, the World Wide Web, digital media and learning management systems (i.e. Moodle) have been used to enhance these skills and facilitate the inquiry process.

4.4 Conclusion

This chapter has explored findings relating to how technology is used in the science classroom and how this enhances inquiry. It has been found that technology-enhanced inquiry activities can vary a lot and can include: virtual labs, project-based tasks and design inquiry labs. All of these activities have different uses for technology. In addition, technology is mainly used to support the investigation (e.g. collection and organization of data) and communication (e.g. presentation of results) steps of inquiry according to Bell et al. (2009).

Various strategies and scaffolds were used to enact technology-enhanced inquiry including: introducing technology at the beginning of the course, holding design conversation assessments, deconstructing complex tasks into smaller steps, asking prompting questions, encouraging group-to-group interactions and using cooperative learning strategies.

Differential enactment of technology-enhanced inquiries depends on the challenges faced due to school board funding and school culture. All teachers had to address the failure narrative in the science classroom, which is common to any inquiry task. However, teachers expressed
feeling privileged to address this narrative, to ensure students become confident and ready to face challenges ahead of them.

The usage of technological tools such as online softwares, the World Wide Web, digital media and learning management systems was found to potentially help students gain metacognitive skills throughout the inquiry process.

The role of technology in enhancing inquiry should help students be successful in inquiry. In this research, I have found some evidence for this. In chapter 5, I will discuss the implications of this research including recommendations for school boards and teachers in enacting technology-enhanced inquiry. I will also recommend areas for future research.
Chapter 5: Conclusion

5.0 Introduction

The main purpose of this research was to learn about how technology is used in secondary science classrooms to support or enhance inquiry and the outcomes of this. The themes that emerged from the qualitative analysis included practices related to technology-enhanced inquiry, challenges of technology-enhanced inquiry and benefits of technology.

In this chapter, I address the key findings from each theme and their significance. Subsequently, the implications of these findings for the educational community as a whole, as well as for my professional practice and identity are discussed. Based on these implications, I have recommendations for educational stakeholders which is followed by areas for further research and concluding comments.

5.1 Overview of Key Findings and their Significance

Teacher practices related to technology-enhanced inquiry varied among participants. It was found that participants had different interpretations for the role of technology. Furthermore, each inquiry presented had varying degrees of inquiry steps. However, there were similarities in certain teacher practices including the dedication of class time for the introduction of new technologies, as well as teacher-enhanced scaffolds for inquiry. Teacher-enhanced scaffolds consisted of prompting students with questions to guide them and assessing them throughout the inquiry. This was confirmed as an appropriate teacher scaffold within the pedagogical model for technology-enhanced inquiry (Kim et. al, 2007). As a result, teacher scaffolds seemed to be the focus for technology-enhanced inquiry. Technology scaffolds were only mentioned for the closed-ended, virtual laboratory on density.
The second theme addressed the challenges of technology-enhanced inquiry. The major challenges associated with implementing technology were due to infrastructural, funding, school culture, time management, and technology as a distraction. However, the findings also illustrated that overusing technology could limit students’ opportunities to practice inquiry skills. As a result, there is a delicate balance between using technology to enhance or support inquiry, and using technology to find the “right answer”, to avoid failure. As a result, participants outlined that the enactment of technology-enhanced inquiry is an opportunity to address the failure narrative in students. Participants enable this by providing opportunities to make mistakes, while focusing on the process of inquiry rather than the outcomes.

Finally, the third theme addressed the benefits of technology with regards to the inquiry process. These findings illustrated that technology can play a beneficial role in the context of classroom inquiry. Technologies (e.g. online softwares, Logger Pro and spectrophotometers) used in the classroom mainly supported the investigation (e.g. collecting, recording and organizing data) and communication (e.g. reporting results) steps of the inquiry process, as previously found in a study about preservice teacher practices in an enriched technology program (Maeng, Mulvey, Smetana, & Bell, 2013). Specifically, technology was shown to help students gain metacognitive skills while giving them the opportunity to overcome the failure narrative.

These findings have implications for the educational community, which will be examined in the following section.

5.2 Implications

This research has wide ranging implications for the educational community as a whole, but it is particularly relevant for preservice and novice teachers, as well as teachers who lack technological knowledge or experience. I will start by outlining implications from all my key
findings in each theme, for the following educational stakeholders: educational researchers, teachers, school communities, school boards, and the Ontario science curriculum.

5.2.1 The educational community. In this section I will outline the specific implications of my research for each of the following stakeholders: educational researchers, teachers, school communities, school boards, Ontario science curriculum and students.

Firstly, these findings have implications for educational researchers, as it reveals a gap in the literature around technology-enhanced inquiry. The teacher scaffolds presented in my findings align with the theoretical pedagogical model of technology-enhanced inquiry (Kim et. al, 2007). What was largely absent, however, were the technological scaffolds. In the literature, technology scaffolds usually refer to specific softwares that have embedded scripts that scaffold the inquiry process. However, the gap is evident with respects to making the research relevant to teachers who use a variety of technologies to enhance inquiry, without the provision of specific softwares and direct guidance from educational researchers.

Secondly, the findings have implications for teachers. The benefits of technology on the inquiry process are multifold, as supported by my findings. These findings provide a new perspective as to why technology should be used in the science classroom. Teachers should be using technologies to enhance inquiry since they facilitate certain steps of inquiry and help students develop metacognitive skills. In addition, my findings provide a variety of teacher scaffolding and strategies to enact technology-enhanced inquiry. It has implications for teacher practices in the context of real science classrooms across all disciplines. However, my findings also point to a larger need for teachers to face their own failure narrative. In other words, teachers should be willing to face a variety of challenges with respect to technology-enhanced inquiry. For instance, teachers will need to learn how to face technological failures and develop
a deep understanding of the role of technology in their inquiry as well as time management. From my research findings, it is evident that doing technology-enhanced inquiry takes a lot of time. Furthermore, the participants emphasized that if technology does not play a specifically designed role, to enhance inquiry, it can take away from scientific investigation skills. As a result, it implies teachers need to carefully think about the role of technology. These problems may be exacerbated by an unsupportive school community. I will expand on these points in the recommendations.

My findings also present implications for school communities in terms of how they support technology-enhanced inquiry. Every school has a school culture defined by the values of the school; from the administration, to the teachers and students. Challenges of enacting technology-enhanced inquiry can arise in certain school cultures that are defined by traditional teacher-centered approaches to teaching. Therefore, teachers hoping to enact technology-enhanced inquiry in this type of school may lack support and it may put tremendous pressure on the teacher to have it succeed.

Due to the challenges and complexity of enacting technology-enhanced inquiry as well as the constant changing landscape of technologies, there are implications for school boards. Participants mentioned that school boards need to consider how professional development is offered to support teachers with these challenges and changes. Furthermore, the findings reveal that depending on school board funding, there is differential access to technologies. This implies that school boards need to consider equity of access, to ensure that technology-enhanced inquiry can be done across all its schools.

Other implications involve changes to the Ontario secondary science curriculum to circumvent the many challenges, including time management so that teachers can do more
technology-enhanced inquiry. Although the present curriculum has improved with the science reforms, which focuses more on science, technology, society, and the environment (STSE) as well as inquiry, teachers still consider it content heavy. This puts limits on their ability to engage in technology-enhanced inquiry, which requires time. In addition, the curriculum does not address the failure narrative in the science classroom, a major challenge and opportunity with technology-enhanced inquiry.

Finally, my findings suggest that technology-use can help students develop metacognitive skills. These skills are invaluable for students to self-regulate their learning and learn to deal with failure. This further supports implications for all educational stakeholders including school administrators, school communities, school boards, and educational researchers to buy into technology-enhanced inquiry.

5.2.2 My professional identity and practice. This research has had a significant impact in my understanding of the role of technology in the classroom. Although I have been afraid of using new technologies in the classroom, my participants made me realize that using technology simply involves being prepared. In other words, if the teacher is comfortable and prepared for technology to malfunction, technology use is doable. However, after carefully evaluating current practices of technology use, I believe that technologies can serve as much more than simple means of data collection, enhanced visualizations or facilitating representation of data. The specific role of technologies and its benefits with regards to inquiry are often overlooked. For instance, in analyzing the technology use of my participants, it was evident that technology played a role in the planning of investigations, organizing data, evaluating data and re-evaluating claims. For instance, the use of Google Docs to work on an inquiry task can help with the planning stages of inquiry. Moreover, the use of Moodle to set up an electronic workshop for
peer editing of lab reports allowed students to evaluate the claims they made. Overall, various technologies can facilitate interactions between students and enable them to build or critique knowledge claims, and to strengthen their ability to think critically.

However, I also realized that the role of technology needs to be carefully considered by looking at the purpose of the inquiry. If the inquiry aims to help students learn hands-on, practical skills, using too much technology could interfere with this goal. Therefore, when looking at the TPACK framework to see how technology integration helps the pedagogical and content knowledge, a clear purpose for the inquiry needs to be developed. I hope to develop my TPACK framework and consider the purpose of my inquiry before doing technology-enhanced inquiry in my classroom.

In terms of teacher practices, I realize that introducing technology in the classroom could be a challenge for many reasons including infrastructural or funding issues. However, with my understanding of how technology-enhanced inquiry can help students overcome the failure narrative, I realize that it is invaluable. I hope to bring more attention to implementing this type of pedagogy into schools. In addition, I gained insight about leading students in inquiry, another pedagogy with which I am not yet comfortable. The specific strategies outlined in my findings will guide my planning of technology-enhanced inquiry.

5.3 Recommendations

Although technology-enhanced inquiry enactment is complex in nature and involves many challenges, it does help students develop metacognitive skills and face the failure narrative in science. For these reasons, I provide recommendations to circumvent challenges and increase the benefits of technology-enhanced inquiry. There are recommendations for the educational
community, as a whole, in how to help teachers enact technology-enhanced inquiry. I will focus on recommendations for teachers, school communities, school boards and the Ontario science curriculum.

Firstly, teacher practices related to technology-enhanced inquiry have been documented in this research to serve as guidelines for teachers who hope to try this type of inquiry. Here, I list some of the specific practices and strategies recommended by current science educators broken down into technology-use in the classroom, teacher scaffolding and teacher perceptions. In order to use technology in the classroom, teachers need to be comfortable using the technology and be prepared for possible malfunctions. This means having alternative plans if technology fails. Furthermore, to introduce new technologies in the classroom participants recommended dedicating class time to exploring all features of this technology. Finally, appropriate technology-use requires an understanding of the TPACK framework and the purpose of an inquiry. In other words, technology use must enhance pedagogy and content, while not impeding the purpose of the inquiry. Secondly, teacher scaffolding during technology-enhanced inquiry includes prompting students with questions to guide them through the inquiry process while constantly assessing their progress, as supported by the literature. When engaging students in open-ended inquiries, it is recommended that teachers participate in design conversations that can help students reflect on the design of their own inquiries. With regards to groupings for technology-enhanced inquiry, the use of diverse groupings of students with various abilities in technology and practical, hands-on skills can help students work collaboratively. Encouraging group-to-group interactions is recommended to help students problem-solve during inquiry. Thirdly, to enact technology-enhanced inquiry, teachers need to help students focus and reflect on the process of inquiry, rather than the outcome. This stance is required to help students
overcome the failure narrative. Therefore, teachers need to adapt these perceptions with regards to the inquiry process. Furthermore, the use of technologies to support the reflection (i.e. anonymous peer editing) process is recommended. In this way, it can help students self-regulate their learning and develop metacognitive skills.

To support teacher practices related to technology-enhanced inquiry, there are recommendations for school communities. There are recommendations for the creation of an environment of teacher collaboration. An environment of teacher collaboration should include the acceptance and support of trying new things, such as technology-enhanced inquiry. This can be fostered by having departmental science meetings that encourage collaboration, sharing of resources and experiences from the classroom.

Teacher practices are also informed through professional development, provided by the school board. It is recommended that professional development be offered at the beginning of the year, including online access to videos and step-by-step instructions for how to use certain softwares or technologies in the classroom. In this way, teachers can have constant support in using new technologies or softwares. Furthermore, other recommendations include more funding of useful technological equipment and teacher training. Useful technological equipment refers to technologies that can aid the inquiry process. For instance, the technology should be able to run software that could enhance the inquiry process.

With regards to challenges of time management and the failure narrative, there are recommendations for changes to the Ontario science curriculum. Recommendations include, rewriting the curriculum to emphasize skill development, less focus on content and creating flexibility in the curriculum to build in choice for students. For instance, instead of having to do a lab for every unit, students could pick one lab which they would explore deeply throughout a
course. Finally, inquiry skills in the curriculum, should be reframed to focus on targeting the failure narrative.

The benefits of technology are multifold, when it comes to doing inquiry. Recommendations for how teachers can achieve these benefits are encompassed in the strategies above. However, the benefits of technology need to be discussed with all educational stakeholder, so that everyone is convinced of its importance for students.

5.4 Areas for Further Research

Although the literature suggested a pedagogical model for technology-enhanced inquiry, it only seems to encompass a narrow range of technologies that contain embedded scaffolds. This research looked at the current practices of teachers in the field, without access to these specific technologies or educational researchers. As a result, there does not seem to be much research looking to build a practical, pedagogical model that bridges the research driven technology-enhanced inquiry and practical technology-enhanced inquiry. Further research could extend these findings to build this type of model, in which teachers could learn to adapt the model for various types of technologies. In addition, this research only looked at the interactions between teachers and technology, further research should include field observations that include teacher-student and student-technology interactions.

Finally, the quantitative outcomes of technology-enhanced inquiry were not measured in this research specifically. Student benefits were inferred through the pedagogical choices of technology use inside and outside the classroom. Further research should quantitatively measure how the use of different technologies can help students reflect on the inquiry process and develop metacognitive skills.
5.5 Concluding Comments

Overall, this research provides discussion on how technology-enhanced inquiry is performed in the science classroom. Teachers seem to rely heavily on teacher scaffolds to conduct inquiries, with hesitance in using technology scaffolds. Furthermore, challenges of technology-enhanced inquiry are various in nature including technological implementation, funding and time management. However, with careful analysis of the roles of technology in inquiry, it has been found that technology can enhance the investigation and communication steps of inquiry. Moreover, technology can address the failure narrative in the classroom and enable the development of metacognitive skills.

These research findings have implications for teacher practices, in terms of how to enact technology-enhanced inquiry. Consequently, there needs to be a school culture conducive to this type of inquiry. Moreover, to achieve this school boards need to provide access to professional development and have funding for technologies. Moreover, there are implications for the curriculum, in terms of framing it to circumvent the challenges that teachers may face in doing this type of inquiry.

Based on these implications there are a few key recommendations in place. Notably, most recommendations are regarding teacher practices. Firstly, strategies in technology-use includes dedication of classroom time to introduce new technologies. Secondly, teacher scaffolds for technology-use includes prompting students, holding design conversations and having diverse groupings. Thirdly, teachers are recommended to perceive inquiry, as a process and not an outcome. With regards to the school board, it is recommended that they provide funding for useful technologies, access to quality professional development online. Finally, the curriculum
should be rewritten to focus on skill development rather than content, with emphasis on the failure narrative.

In conclusion, this research has expanded the possibilities of technology-use in science classes to enhance inquiry. I hope that it encourages new ideas in teachers, to keep trying to engage students in inquiry and help them develop metacognitive, technological and critical thinking skills in this ever-changing world.
References


Appendices

Appendix A: Letter of Consent for Interviews

Date:
Dear ______________________________,

My Name is Natalie Urbanc and I am a student in the Master of Teaching program at the Ontario Institute for Studies in Education at the University of Toronto (OISE/UT). A component of this degree program involves conducting a small-scale qualitative research study. My research will focus on the enactment of technology-enhanced inquiry learning in the science classroom. I am interested in interviewing teachers who have a minimum of 3 years of teaching experience, experience teaching science courses at various levels (Grade 9-12) and who use technology to support inquiry-based learning in a science classroom. I think that your knowledge and experience will provide insights into this topic.

Your participation in this research will involve one 45-60-minute interview, which will be transcribed and audio-recorded. I would be grateful if you would allow me to interview you at a place and time convenient for you, outside of school time. The contents of this interview will be used for my research project, which will include a final paper, as well as informal presentations to my classmates. I may also present my research findings via conference presentations and/or through publication. You will be assigned a pseudonym to maintain your anonymity and I will not use your name or any other content that might identify you in my written work, oral presentations, or publications. This information will remain confidential. Any information that identifies your school or students will also be excluded. The interview data will be stored on my password-protected computer and the only person who will have access to the research data will be my course instructor Dr. Arlo Kempf. You are free to change your mind about your participation at any time, and to withdraw even after you have consented to participate. You may also choose to decline to answer any specific question during the interview. I will destroy the audio recording after the paper has been presented and/or published, which may take up to a maximum of five years after the data has been collected. There are no known risks to participation, and I will share a copy of the transcript with you shortly after the interview to ensure accuracy.

Please sign this consent form, if you agree to be interviewed. The second copy is for your records. I am very grateful for your participation.

Sincerely,

Natalie Urbanc
Appendix A: Letter of Consent for Interviews

Name:
Phone Number:
Email:

Course Instructor’s Name: Dr. Arlo Kempf
Contact Info: arlo.kempf@utoronto.ca

Consent Form

I acknowledge that the topic of this interview has been explained to me and that any questions that I have asked have been answered to my satisfaction. I understand that I can withdraw from this research study at any time without penalty.
I have read the letter provided to me by Natalie Urbanc and agree to participate in an interview for the purposes described. I agree to have the interview audio-recorded.

Signature: ______________________________________

Name: (printed) ______________________________________

Date: ______________________________________
Appendix B: Interview Protocol

Introductory Script: Thank you for agreeing to participate in this research study and for making time to be interviewed today. This research study aims to learn about how a small sample of teachers use technology to support inquiry-based learning in the science classroom for improving pedagogical practices of science teachers. This interview will last approximately 45-60 minutes, and I will ask you a series of questions focused on inquiry-based learning and technology use in the science classroom. I want to remind you that you may refrain from answering any question, and you have the right to withdraw your participation from the study at any time. As I explained in the consent letter, this interview will be audio recorded. Do you have any questions before we begin?

Background Information
1. How many years have you been teaching?
2. Over the course of these years, what science subjects have you taught (including grade level)?
3. What is your educational background?
4. How did you get interested in technology-supported inquiry learning?

Teacher Perspectives/Beliefs
1. How would you define inquiry-based learning?
2. Do you think that this type of learning is valuable? Why?
3. Is inquiry-based learning practical for all courses and grade levels? If not, which classes is it most beneficial for? Can you provide any examples?
4. Do you think technology-enhanced learning environments are beneficial to students? Are there any drawbacks?
5. Do you believe that inquiry-based learning can be supported effectively with technology?
6. Do you think that technology-enhanced inquiry learning allows students to gain 21st century skills?

Teacher Practices
1. What kind of technology-enhanced inquiry activities have you done with your students? Describe it and what were the specific outcomes?
2. How do you assess the students understanding of inquiry-based learning activities or labs? What assessments are taken? Are there any check-in points?
3. What kinds of scaffolds are present to aid students throughout the activity (Include technology and teacher scaffolds)?
4. If possible, could you share some of the learning goals associated with any technology-enhanced inquiry activities you have done.
5. Where did you learn to use the technology and how do you demonstrate it to students?
6. From assessments and evaluations, do students perform well in these activities?
Supports and Challenges
1. What resources do you use to support you in enacting technology-enhanced inquiry or to help you design lessons? (Name online software, websites, teacher communities)
2. What challenges do you face when enacting technology-enhanced inquiry in your classroom?
3. How could the educational system support teachers to do more technology-enhanced inquiry learning in science classrooms?

Next Steps
1. What advice would you give to beginning teachers to implement technology-enhanced inquiry in their science classroom?