Fostering Student Inquisitiveness in Secondary Science Classrooms

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Abstract

Students' interest, achievement, and motivation in science declines as they reach secondary school. This in turn leads to fewer students pursuing further education and subsequently, careers, in science, technology, engineering, and mathematics (STEM) fields. Given the importance of STEM in a thriving society, it is of value to address how to increase students' interest, achievement and motivation in science. Increasing student inquisitiveness in science class is one way to do so. To explore how teachers encourage student inquisitiveness in their science classes, I conducted classroom observations and semi-structured interviews with three secondary science teachers at an independent school. Findings indicate that the participants were affected by barriers such as: following a mandated curriculum, preparing students for the next level of education, and preparing students for standardized exams. Yet, teachers used a variety of strategies to encourage student inquisitiveness including: making the learning interesting, modeling question asking, encouraging students to ask questions, and giving students autonomy. Findings from this study provide insights to teachers, not only of science, looking to for ways to encourage their students to be inquisitive, even when facing barriers that may limit their teaching practice.

Keywords: STEM, student inquisitiveness, teaching practice

Résumé

L'intérêt, les résultats et la motivation des élèves pour les sciences diminuent à mesure qu'ils atteignent l'école secondaire. Il en résulte une diminution du nombre d'étudiants qui poursuivent leurs études et, par la suite, leur carrière dans les domaines des sciences, de la technologie, de l'ingénierie et des mathématiques (STIM). Étant donné l'importance des STIM dans une société prospère, il est utile de se pencher sur la manière d'accroître l'intérêt, les résultats et la motivation des étudiants dans le domaine des sciences. L'un des moyens d'y parvenir est d'accroître la curiosité des élèves dans les cours de sciences. Afin d'étudier comment les enseignants encouragent la curiosité des élèves dans leurs cours de sciences, j'ai effectué des observations en classe et des entretiens semi-dirigé avec trois professeurs de sciences du secondaire dans une école privée. Les résultats indiquent que les participants étaient confrontés à des obstacles tels que: suivre un programme d'études obligatoire, préparer les élèves au niveau d'enseignement suivant et préparer les élèves à des examens standardisés. Pourtant, les enseignants ont utilisé diverses stratégies pour encourager la curiosité des élèves, notamment: rendre l'apprentissage intéressant, modeler la façon de poser des questions, encourager les élèves à poser des questions et donner de l'autonomie aux élèves. Les conclusions de cette étude fournissent des indications aux enseignants dans tous les domaines educatifs, qui cherchent des moyens d'encourager leurs élèves à être curieux, même lorsqu'ils sont confrontés à des obstacles qui peuvent limiter leur pratique de l'enseignement.

Mots-clés: STIM, curiosité des étudiants, pratique de l'enseignement

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Chapter 1: Introduction

Students' interest and achievement in, as well as their attitudes towards, science begins to decline in middle and secondary school (George, 2006; Hampden-Thompson & Bennett, 2011; Hassan, 2008; Jocz et al., 2014; Kim, 2016). For example, George (2006) did a study that examined a sample of 444 students' attitudes towards science and attitudes towards the utility of science throughout the middle and secondary school years and found that attitudes towards science are positively correlated with students' attitudes about the utility of science. The data show that while students in Grade 7 have higher attitudes towards science, by Grade 11, these attitudes have decreased which is correlated with a decrease in students' views of the utility of science.

While these trends are concerning for students' academic success, they have larger implications on society. The number of people opting out of science, technology, engineering and mathematics (STEM) education, is increasing (Hampden-Thompson & Bennett, 2011; Hassan, 2008; Jocz et al., 2014). Canada, Australia, the United States, and Europe have identified this decrease in people prepared to participate in STEM careers a national concern as only skilled workers, educated in these areas, can pursue these fields (Hampden-Thompson & Bennett, 2011). According to the U.S. Department of Commerce, "STEM occupations are growing at 17% while other occupations are growing at 9.8%" (Engineering for Kids, 2016, para.1). Additionally, STEM workers are crucial to helping societies prepare for the future. Their innovation "leads to new products and processes that sustain economies" (Engineering for Kids, 2016, para.2). This decrease in people qualified for STEM careers poses an economic threat to countries such as Canada and the United States (Anderson, 2011). Therefore, it is crucial to address how to increase student interest and achievement in science, as it is necessary to have a population equipped to participate in the STEM workforce.

Researcher's Background

"You can teach a student a lesson for a day; but if you can teach him to learn by creating curiosity he will continue the learning process as long as he lives."—Clay Bedford

I have always had a passion for learning science. Growing up in California, and in a family where being outdoors was central to our livelihood, I was always curious about the things I saw outside. I was curious about the tides, why sometimes the beach was so flooded that we could not walk on it, while at other times, it seemed as if we could walk into the middle of the ocean. I was curious about the landforms, especially the sea cliffs, present along the Northern California coastline and why that solid rock was supposed to keep us "safer" if a large earthquake hit. I wanted to know why it hailed, even if the temperature outside was above freezing. The list could go on. It was this curiosity and excitement about nature that made me excited for my science classes, especially in middle school and high school. My teachers in middle school continued to fuel this curiosity and excitement for science. What I did not understand though, was why upon reaching Grades 11 and 12, many of my friends chose not to take any science classes, while I chose to take two science classes instead of the required one, each year. My friends expressed the feelings that science was "too hard," that it was "too much memorization" and that the thought of taking AP[1] Physics or Chemistry was scary. My passion, however, was still strong, as I formed a meaningful connection with my AP Chemistry teacher who worked hard to bring her love of the ocean into our chemistry lessons and with my

[1] Advanced Placement (AP) courses are college level courses offered in United States secondary schools for college credits.

advanced environmental science teacher who made sure to bring us outside to interact with nature whenever possible. This excitement and passion for science turned into a strong desire to teach science upon graduating from Boston College.

I was lucky to get my first teaching job, where I taught Grade 6 science, at a small private school serving Grades 6-12 in Washington, D.C. In my first year, I was tasked with redesigning the Grade 6 science curriculum. As a first-year teacher, with only student teaching experiences to support this curriculum design, I was intimidated and overwhelmed, but began an extensive research process to figure out what students should be learning in the 6th grade. It was through this research and reflections on my own science education, that I decided the curriculum should be as hands-on and relatable as possible. This research is what led me to come to know about teaching science through inquiry. I continuously saw mention of the words “inquiry,” “teaching through inquiry,” and “inquiry-based instruction.” While it was praised, I could not find any concrete examples to help me incorporate this pedagogy into my own curriculum. As it was my first year of teaching, I decided that the idea of inquiry would be something that I would wait to approach in my second year, when I had more solid grounding.

Fast forward to my second year of teaching, I remembered that I wanted to improve my curriculum and had also learned about my school’s mission to use more “creative teaching” in our end of summer faculty meetings. That is when I realized that my mission to use more creative teaching could be through inquiry. Again, I began my research process, trying to figure out how other teachers were using inquiry, but I had trouble finding specific instances of teachers incorporating inquiry in their curricula. When I approached my Department Chair for help, she simply told me that it sounded like a good idea, but that her expertise was in Grades 11 and 12 and that she did not have the resources to help me. Throughout the entire year I researched and attempted to change my curriculum, but ended up frustrated as I felt I did not have the time, resources, nor appropriate information to incorporate inquiry into my curriculum. This frustration and desire to know more about implementing inquiry-based instruction is what led me to McGill University and the focus of this thesis. I am determined to learn more about this important pedagogy so that I can incorporate it into my teaching when I graduate.

Inquiry-Based Instruction

Inquiry-based instruction is a form of authentic learning that allows students to develop into critical thinkers, ready to apply their knowledge to a problem in order to arrive at an answer or a solution (Barron & Darling-Hammond, 2008). Inquiry-based instruction is a student-centered teaching method, born out of constructivist learning theory, that puts students' ideas, questions, and observations at the forefront of the learning process (Fitzgerald et al., 2017; Minner et al., 2009; Ontario Ministry of Education, 2013; Tuan et al., 2005). Throughout the process of inquiry-based instruction, students are engaged, collaborate with one another, and develop a final product to demonstrate their thinking and learning process (Barron & Darling-Hammond, 2008). Inquiry-based instruction includes the following attributes:

> Learners are engaged by scientifically oriented questions; learners give priority to evidence which allows them to develop and evaluate explanations that address scientifically oriented questions; learners formulate explanations from evidence to address scientifically oriented questions; learners evaluate their explanations in light of other explanations, particularly those reflecting scientific understanding; [and] learners communicate and justify their proposed explanations. (NRC, 2012, p. 249)

Research indicates that hallmarks of inquiry-based instruction, including hands-on activities, interactions between teacher and students, and applications of science, as well as group work and making connections to everyday life, are beneficial to students (Aktamis et al., 2016; Fitzgerald et al., 2017; Hampden-Thompson & Bennett, 2013; Jocz et al., 2014; Minner et al., 2009; Tuan et al., 2005). Therefore, inquiry-based instruction is central to learning science and increasing student interest in science as students become engaged in the work of science.

Purpose of the Study

As a relatively new science teacher, I am passionate about learning more about inquiry-based instruction in order to eventually implement it into my own classroom. I am determined to learn methods that spark curiosity, questions, engagement, and excitement in students. I want to be part of the solution that goes against the trend of students losing interest, engagement and motivation in science (George, 2006; Hampden-Thompson & Bennett, 2011; Hassan, 2008; Jocz et al., 2014; Kim, 2016) and I am determined to create a classroom where my students are fully *involved* in their learning. I am eager to learn the teaching skills necessary to set up a classroom where students ask and answer their own questions. In doing so, I hope to foster curiosity and increased learning in my students. Ultimately, I want to learn more about inquiry-based instruction in order to engage my future students in science, to prevent them from believing that science is simply rote memorization of facts, and to relate science to every student's life and help them realize that, they are indeed, interacting with it every single day of their lives.

In this study, I focus on three science teachers who use inquiry-based instruction to varying degrees. I also consider the factors that influence the ways in which they teach their classes. While inquiry-based instruction encompasses different aspects and teacher moves, my study focuses on one specific component of the teacher's role in inquiry-based instruction: encouraging student inquisitiveness. My research sheds light on the specific moves teachers make to encourage inquisitiveness in their classrooms while also considering how internal and external factors may be influencing what it is that they are doing and saying in the classroom. Student inquisitiveness is one of the most important parts of learning and of scientific inquiry, as it is a key process towards meaningful and active learning. As such, it should be the focus point of inquiry-based instruction (Chin & Osborne, 2008). Therefore, the purpose of this study is to determine how teachers are encouraging their students to be inquisitive in the classroom. It is important to keep students interested, curious and engaged in science while helping them to develop their ability to ask questions that lead to scientific investigations. Students asking questions in science class is a large component of developing their scientific literacy; therefore, teachers must be giving their students ample guidance and opportunities to ask these scientific questions (Hofstein et al., 2005).

Research Questions

In this study, I will explore how teachers support their students in being more inquisitive in science class, as a way to lead them towards using inquiry-based instruction. Specifically, I focus on three secondary school science teachers to ask the following research questions:

1. What factors influence how these teachers teach and in what ways?
2. What teaching strategies do these teachers use to encourage student inquisitiveness and why do they use these strategies?

Plan of the Thesis

This thesis contains five chapters: Introduction, Literature Review, Methodology, Findings, and Discussion. Chapter 1 (Introduction) provides rationale for the research on student inquisitiveness. Chapter 2 (Literature Review) provides background information on factors that can influence how teachers teach, the benefits and challenges of student inquisitiveness, and strategies that can be implemented by teachers in the classroom to encourage student inquisitiveness. Chapter 3 (Methodology) provides information about the research context, participants, data collection and data analysis. Chapter 4 (Findings) presents themes that were found in the data gathered from classroom observations and participant interviews. Finally, Chapter 5 (Discussion) answers the research questions by summarizing the findings and making connections to existing literature and suggesting areas for future research.

Chapter 2: Literature Review

In this chapter, I present existing literature regarding: factors that impact the ways in which teachers teach, student inquisitiveness, the benefits and challenges of encouraging students to be inquisitive, and strategies that can be used to increase student inquisitiveness. While this study is focused on science teachers and their actions in their classrooms, this chapter is more generally about the components listed above. Regardless of the subject matter being taught, these components may impact teachers' practice. It is important to understand how different factors influence teachers' teaching practice while also examining different ways in which teachers can encourage their students to be inquisitive.

Factors Influencing Teaching Style

From the day they enter their teacher preparation programs, science teachers are fed information about science and science teaching that ultimately impacts the ways in which they teach science. Through their time in school and as a practicing teacher, teachers develop differing views and beliefs on scientific theories, scientific processes and progressions and changes of scientific knowledge (Brickhouse, 1990). Ultimately, teachers' beliefs about education, as well as the factors listed above, influence the ways teachers perceive of science education and how they teach the content (Brickhouse, 1990; Roehrig & Luft, 2004). The ways in which teachers (science or otherwise) teach are not only defined by their pedagogical preferences, but also by different factors that exist in their school communities. As a result of school structure and administrative mandates, teachers need to take into account the mandated curriculum, preparing students for the next level of education, and standardized exams when teaching their respective courses (Engel & Randall, 2009; Hamachek, 1999).

Curriculum. One factor which influences the material teachers cover, as well as the ways in which they teach, is the curriculum that they are mandated to follow by their school or province. Most teachers in North America are given a curriculum, with certain goals that they need to meet by the end of the year. Studies show that teachers can feel limited in the classroom because of the curriculum they are expected to follow. For example, Osborn et al. (2000) found that teachers felt that a standardized curriculum took away from their abilities to meet the specific needs of their students, as well as the opportunity to be creative with the curriculum, as they had to focus on covering a wide variety of topics in a short amount of time. Furthermore, Hurley (2004) found that Canadian teachers felt that their role encompassed implementing curriculum and government mandated policies, rather than inspiring their students and creating change in their classrooms. Additionally, Schweisfurth (2006) found that when teachers felt able to expand on the mandated curriculum, they were reminded that they cannot stray too far away from the curriculum, as the teachers needed to ensure they meet the required goals. Indeed, when teachers focused on topics that were deeper and related to bigger societal issues, they felt they did so because of their own consciences rather than as a result of a government mandate (Schweisfurth, 2006).

Preparation for the next level of education. In addition to meeting the requirements laid out by the curriculum, teachers are also aware that they should be adequately preparing their students for the next level of education, particularly secondary school teachers whose students are moving into the university level. As a result, teachers may feel limited in what they can do in the classroom, out of fear that what they are doing is not preparing their students for the next step in their educational journey. Schwartz et al. (2008) found that teachers questioned whether they should focus on depth or breadth in science in order to prepare their students for university.

Those who focused on breadth believed that their students would be better served having encountered a wide variety of topics at a more surface level, while those who focused on depth of a topic believed that there were certain topics that students should know at a deeper level, while disregarding others at a surface level (Schwartz et al., 2008). Sadler and Tai (2001) found that students' grades were higher in university when secondary school physics teachers taught their students in a rigorous way, but also when they spent time covering the material in depth. Furthermore, they found that it was helpful to students when teachers took the time to approach problems in a variety of ways, therefore providing more opportunities for students to understand the problems (Sadler & Tai, 2001). Therefore, depending on their beliefs, as well as the requirements set by their mandated curriculum, teachers' teaching style may be impacted by whether or not they believe they should cover a wide range of topics in less depth, or if they should focus on deep understanding of certain topics before moving on to something new.

Preparation for standardized exams. Standardized exams are a third factor that can influence how teachers teach their classes. There are many forms of standardized exams including: state or provincial tests (administered to students in a particular state or province), national or international exams (administered to students across a country, or countries), and university entrance exams. In Canada, provinces decide when students will be administered a provincial exam and in which subjects. For example, Québec administers provincial assessments and uniform ministry examinations in Grades 6, 9, 10 and 11 (Volante & Jaafar, 2008). Students at public schools in the United States take state examinations, the National Assessment of Educational Progress (NAEP) and the Program for International Student Assessment (PISA) (Turner, 2014). In Finland, students take one standardized exam at the end of secondary school and in Japan, students do not take a standardized exam at the end of secondary school, however, most students are required to take an entrance exam for university (Turner, 2014).

Teachers may feel the weight of these standardized exams, and as a result, they may influence the pedagogy that they use in the classroom (Schwartz et al., 2008). Standardized exams can impact whether a student can move on to the next level of education, influence how a school is "rated" by the government, be used to assess teachers, and determine which universities a student is accepted into. As a result, teachers may adapt their teaching practice to teach their students in ways that will enable them to perform well on these exams.

Furthermore, standardized exams have been found to limit reform efforts, specifically in science education (Anderson, 2011). In the United States, although the call for inquiry-based instruction and overall reform is high, these efforts get "sidelined by efforts to improve standardized [exam] scores" (Anderson, 2011, p. 117). Similarly, Boyd (2010) found that state examinations caused teachers to teach their students at the lowest level, relying heavily on curriculum materials provided. The literature also shows that school leaders feared that teachers focusing efforts on adopting pedagogies outlined in reform efforts would not contribute to increased standardized exam scores (Anderson, 2011). Teachers felt more concerned about teaching to the exam, and some even expressed that they strayed from teaching in the ways that they thought were best, as they were held accountable to their students' scores on these state mandated exams (Anderson, 2011). Therefore, it is important to investigate how teachers' teaching contexts influence the ways in which they are teaching in the classroom, and to determine if the stress of higher education and standardized exams, are influencing teachers' teaching practice.

The ways in which teachers teach greatly impact how students learn. It is important to consider why teachers are teaching in the ways they are, and how their pedagogy influences student learning. When considering teachers' use of inquiry-based instruction, it is important to focus on an essential component of this pedagogy: student inquisitiveness. Therefore, in order to encourage the use of inquiry-based instruction in the classroom, it is necessary to understand how teachers can foster student inquisitiveness in their classrooms.

Student Inquisitiveness

A key feature of inquiry-based instruction is that the teacher is creating an environment where students are inquisitive and are constantly seeking to know more. An inquisitive person is one who wants to engage in good questioning (Watson, 2015). "Asking questions about the nature of the material world, and being able to answer them, is a key feature of science" (Chin & Osborne, 2008, p. 5). Asking questions can be defined as "one of the thinking processing skills which is structurally embedded in the thinking operation of critical thinking, creative thinking, and problem solving" (Cuccio-Schirripa & Steiner, 2000, p. 210). Inquisitive students not only ask questions, but they demonstrate engagement in their learning, curiosity about what it is that they are learning, and a desire to know more. Consider a child who encounters a new toy for the first time. The child will try to figure out how the toy works by playing with it, experimenting with its different functions, moving it in different directions, and examining every corner of it. The child does so, all in the effort to answer the question: How does this toy work? Similarly, to figure out why something is the way it is, inquisitive students will experiment, problem solve, and engage with the topic at hand.

While inquisitive students can ask questions internally to themselves, as a child might do when playing with a new toy, they can also ask questions externally to their peers and their teachers. While both internal and external questions are characteristics of an inquisitive students, this thesis focuses on the questions that students ask out loud to their peers or teachers. Students may ask questions to their peers and their teachers as a result of cognitive disequilibrium (Graesser et al., 2005). Cognitive disequilibrium occurs when "individuals are confronted with obstacles to goals, anomalous events, contradictions, discrepancies, salient contrasts, expectation violations, obvious gaps in knowledge, and decisions that require discrimination among attractive alternatives" (Graesser et al., 2005, p. 1236). Equilibrium is restored when students come to an answer or understanding of their question (Huang et al., 2017). Students may also ask questions for other reasons including: they may be unfamiliar with a word or a concept; there may be a gap between what they know and what they would like to know; or they may simply be curious and want to learn more (Chin & Osborne, 2008).

Question asking includes the processes of students restating previously asked questions and generating new questions (Huang et al., 2017). Research shows that as students get older, they ask fewer questions as they fear not knowing an answer or a specific fact (Chin & Osborne, 2008; Hofstein & Lunetta, 2003). Additionally, students tend to ask factual questions that can be answered with one simple response, instead of requiring explanation and further questioning (Chin & Osborne, 2008; Hofstein & Lunetta, 2003; Tseng et al., 2015). In a typical classroom setting, students are always learning how to answer their teacher's questions; however, they rarely learn how to ask their own, productive questions (Huang et al., 2017). Furthermore, students are conditioned to follow step-by-step instructions but less often are they asked to think about how they would solve a problem and devise a solution to that problem (Huang et al., 2017).

It is important to encourage students to ask questions, as their engagement in asking questions provides evidence that they have been thinking, evaluating and reasoning with what they do and do not know (Chin & Osborne, 2008). Student questions also provide the teacher with information such as what students are thinking, how they are conceptualizing the information, what is confusing to them, and what they would still like to know more about (Chin, 2004). One way in which teachers can encourage students' inquisitiveness, is by providing opportunities for students to be curious in class.

"Curiosity is the desire to know more" (Schutte & Malouff, 2019, p. 563). When students are curious about something, they will inherently become more inquisitive and ask questions in order to learn more about the phenomenon or topic at hand (Engel & Randall, 2009). For example, Engel and Randall (2009) found that those students who were more curious in a setting demonstrated this curiosity by exploring the different objects, asking questions and demonstrating a strong desire to know more about what they were experiencing or seeing. Therefore, student inquisitiveness and curiosity go hand in hand, because without one, the other does not exist. It is important to consider student inquisitiveness, as it benefits both students and teachers in a classroom.

Benefits of student inquisitiveness. Student inquisitiveness and more generally, students' questions are of benefit to the students themselves for a number of reasons. First, students' questions are valuable tools to help them to identify what they do not know or understand, while also allowing students to focus their curiosity and learning on a topic or on an area of interest. Student-generated questions also help to motivate students, increase their interest in a topic, promote discussion and debate and allow students to construct knowledge on their own (Chin, 2002; Chin & Osborne, 2008; Huang et al., 2017). For example, Chin and Kayalvizhi

(2007) found that about 75% of Grade 6 students preferred to study questions that they had posed, rather than those that the teacher or the textbook had posed to them. Finally, students' questions have the potential to transform a passive classroom into an active, engaged one; therefore, students need to learn the skills to ask good questions and should be encouraged to ask questions that will lead to productive inquiry-based learning in the classroom.

Students' questions also aid teachers in enhancing their teaching practice and meeting the needs of their students (Chin & Osborne, 2008; Huang et al., 2017). Students' questions help teachers to evaluate students' understanding and their ability or inability to understand a concept at a higher level (Chin & Osborne, 2008; Chin & Osborne, 2010; Huang et al., 2017). Students' questions signal to teachers what students still do not know or what requires further clarity or explanation (Bekkink et al., 2015; Biddulph et al., 1986). Thus, based on their students' questions, teachers are then able to alter their lessons in order to make sure their students remain engaged in their learning, while also creating opportunities for future inquiry-based lessons (Chin & Osborne, 2008). While there are many benefits to having students ask questions, there are many reasons why this does not occur.

Challenges to developing student inquisitiveness. Students may encounter different challenges when developing their own inquisitiveness in the classroom. Such challenges could be related to students' ages and previous experiences with asking questions in the classroom (Biddulph & Osborne, 1982). For example, Good et al. (1987) found that the number of student questions increased between kindergarten and Grade 7, then decreased until Grade 12. One reason why students may ask fewer questions when progressing from 7th to 12th grade is that as students get older, especially in secondary school, they do not like to call attention to themselves by asking questions (Good et al., 1987). Furthermore, as students get older, their inquisitiveness may decrease as they are more interested in knowing the facts, and less interested in coming to an understanding of something. As a result, these students may ask factual questions that are not the result of curiosity and do not require much explanation or further inquiry (Good et al., 1987). Another challenge to developing students' inquisitiveness is that students may not know how to ask questions (Chin & Osborne, 2008). For example, students' questions, in order to be beneficial to them from an inquiry standpoint, should be investigable. Developing students' ability to ask investigable questions is a skill that needs time to develop and can be enhanced with support from teachers (Herranen & Aksela, 2019).

While asking questions is a challenge for students, teachers may also choose not to encourage their students to ask questions for a variety of reasons. For example, Rop (2002) found that teachers found students' questions to be a nuisance, as the questions interrupted the flow of the lesson. Similarly, Brown et al. (2006) found that teachers viewed lessons that incorporated student questions as requiring a lot of effort and taking away from instructional time. Researchers have also found that teachers see their role as knowledge providers and thus believe that when students ask questions, the teacher's role is to provide an answer (Eshach et al., 2013). Consequently, teachers may refrain from encouraging their students to ask questions because they worry that they may be unable to answer the questions or they fear their science background will not be adequate to answer a question (Biddulph et al., 1983; Eshach et al., 2013; Symington & Osborne, 1985). Therefore, teachers who are not confident in their answers may fear student questions (Eshach et al., 2013). As a result, Eshach et al. (2013) found that some teachers would ignore their students' questions. Despite these challenges for teachers and students, in order to support students to increase their engagement and motivation in science, it is important to consider the teacher's role in developing student inquisitiveness in the classroom, as well as ways in which they can promote student inquisitiveness.

Teacher's Role in Developing Student Inquisitiveness

Teachers play an important role in supporting student inquisitiveness (Chin & Osborne, 2008). This is particularly important in science classrooms as here, it is of the utmost importance to engage in inquiry as this encourages students to act, think and learn like scientists (Chin & Osborne, 2008). Research shows that when teachers take the time to guide their students in the process of generating questions, students are able to walk away with a deeper understanding of their own learning process, therefore moving their focus from solely concentrating on learning outcomes and more on the process of learning (Tseng et al., 2015). It is thus important that science teachers find different ways to encourage their students to ask questions in class, in order to work towards promoting an inquisitive and scientific classroom.

Teacher strategies to develop student inquisitiveness. Teachers can use many different strategies in order to encourage inquisitiveness in the classroom. These include: giving students time before and during activities to ask questions; making the learning interesting; giving students question words; modeling question asking; explicitly encouraging students to ask questions; refraining from judging students; asking students to record their questions; using a question board; encouraging students to elaborate on what they think; and encouraging student autonomy. Not only are these strategies useful for encouraging inquisitiveness in the classroom, but they can also allow students to begin to act as scientists in the classroom, as they prompt investigation, exploration and questioning. The following sections will describe teacher strategies to encourage student inquisitiveness in more detail.

Giving students time before and during activities to ask questions. One way in which teachers can encourage student inquisitiveness is by giving students time, including wait time and structured time, before and during activities to ask questions. While teaching, teachers can use wait time, that is three to five seconds or more of silent time, for students to think before asking or answering a question (Chin, 2002, 2004; Chin & Osborne, 2010; Maskill & Pedrosa de Jesus, 1997; Tanner, 2017). In doing so, teachers give students the opportunity to be curious about a new topic before getting into the details and structured content. Giving students wait time allows them to fully process and formulate what it is that they would like to know, as well as time to structure their questions (Gilliam et al., 2018; Ingram & Elliott, 2015; Wasik & Hindman, 2018). When provided with ample time to think, students produce more responses, and questions, as compared to when teachers immediately interject during conversations (Wasik & Hindman, 2018).

Teachers can also give their students structured time during a lesson to ask questions and include this structured time in their lesson plans (Chin, 2002, 2004). In order to do so, teachers can present the students with a problem and ask what questions they have about the problem before attempting to solve it (Chin, 2004). Teachers can also give their students designated question time throughout a lesson, in order to show students that asking questions during a lesson is encouraged and is the norm. In their study, Chin and Brown (2002) found that when given explicit time to ask questions, students, even those who did not typically ask questions, asked questions because they were provided with the opportunity to do so. The questions that students generate during this time can be used at the end of the lesson, as well, to act as a guide for students to grasp what they learned in the lesson, and what questions remain at the end of class (Chin, 2002).

Making the learning interesting. Another strategy that teachers can use to encourage student inquisitiveness, is to find ways to make the learning interesting for students (Biddulph et al., 1986; Chin, 2002; Krajcik & Sutherland, 2010). In order to make the learning interesting, teachers can: give students interesting representation forms to explore science content (Biddulph et al., 1986), give students interesting contexts to explore science content (Hampden-Thompson & Bennett, 2013), and give students inquiry-based activities (Hofstein et al., 2005).

Using interesting representation forms is one way that teachers can make learning interesting for their students to explore science content. Interesting representation forms can include (but are not limited to) charts, graphs, images, videos or lab activities. These representation forms force students to think more about a phenomenon, while also sparking their attention and interest (Biddulph et al., 1986; Chin, 2002). These representation forms can be interesting to students when they display unexpected outcomes or challenge the students' thinking, therefore generating more questions from students (Biddulph et al., 1986). Furthermore, by giving interesting representation forms to explore science content, the students can be more motivated and engaged to ask questions (Krajcik & Sutherland, 2010). These representation forms are interesting because the information is not presented to students using only text or spoken words. Instead, these representation forms allow students to interact with the content in various ways.

Another way in which teachers can make the learning interesting for students is by giving students interesting contexts to explore science content. Teachers can do so by making science content more relatable to students, either by considering their lives, their interests, or what they already know (Hampden-Thompson & Bennett, 2013; Harmer & Cates, 2008; Jocz et al., 2014; Stroupe, 2014; Tan & Seah, 2011; van Zhee et al., 2000). When students are able to connect content or activities to real life and are able to consider solutions for these real-world problems, they may become more motivated to learn (Harmer & Cates, 2008; Jocz et al., 2014). Furthermore, by making these connections to their lives, students' curiosity and interest increases, therefore prompting them to ask more questions (Hampden-Thompson & Bennett, 2013; Jocz et al., 2014; Stroupe, 2014; Tan & Seah, 2011). Therefore, by relating class to the real world and to students' lives, teachers can help to increase their inquisitiveness as they become more interested in, and curious about, the topics being covered.

Finally, teachers can make the learning interesting for students by using inquiry-based activities, as students' questions are the starting point for these activities (Hofstein et al., 2005; Tan & Seah, 2011). For example, Hofstein et al. (2005) found that students in inquiry-based classrooms, who were required to ask questions by nature of the teaching approach, asked many more questions than students in traditional classroom settings. Furthermore, students in inquiry-based classrooms were more interested in studying questions that required further investigation, while the students in traditional classrooms were more interested in receiving an answer to a question that did not require more investigation. By giving students inquiry-based activities, teachers are making the learning interesting for students which can help to increase question asking in their classrooms. While teachers can use all three examples listed above individually, they can also combine the strategies to make the learning interesting for their students.

Giving students question words to help them begin questions. A strategy that can be used to guide students in asking more questions, as well as to help them in formulating questions, is giving students question words which they can use to begin their questions (Chin, 2002; Chin & Brown, 2002; Chin & Osborne, 2010; Rosenshine et al., 1996). These include: "what if," "why does," or "why are". Teachers should also take the time to teach their students how to phrase questions and what the differences are in questions that begin with the words: why, how, what if, when, and where (Chin, 2002; Chin & Brown, 2002; Huang et al., 2017; Rosenshine et al., 1996). By teaching students how to use these words, and when it is appropriate to do so, teachers give students additional tools for inquisitiveness which they can use in the future. Asking students to begin questions using these question words is helpful as it also encourages them to ask higher-level questions, rather than simply recall questions (Chin, 2002). Students can be encouraged to generate questions by comparing, contrasting, inferring cause and effect, determining strengths and weaknesses, and explaining ideas (Huang et al., 2017). A study done by King (1991) demonstrates the usefulness of question starters, as once students were given these supports, they quickly adopted them and used them to advance in their question asking, compared to those students who were not given any questioning strategies. Therefore, by giving students question stems or starters, teachers are providing them with the tools necessary to ask more questions.

Modeling question asking. Another way in which teachers can encourage inquisitiveness, is by modeling question asking themselves; in other words, by demonstrating to students what types of questions can be asked. It is important for teachers to model question asking, as students may be unsure of how to ask a question, and what questions look like in their respective classroom environments (Biddulph et al., 1986). A teacher could also model how a broad question can lead to subsequent, more focused questions and investigations to give the students a sense of what an investigable question looks like (Chin, 2002, 2004). Asking questions is a skill that teachers need to teach their students, before they can actively employ this skill, which is why it is important that teachers demonstrate to their students how they can ask questions (Chin, 2002). Additionally, by modeling question asking, teachers are not only giving their students examples of questions that can be asked, but they are also making it the norm that questions are asked in their classroom environment (Chin & Osborne, 2008).

Explicitly encouraging students to ask questions. Once students are equipped with the tools that they need to ask questions, teachers should encourage student inquisitiveness by explicitly asking them to ask any questions they may have (Chin, 2002; van Zhee et al., 2000). By asking students to ask questions, teachers signal that it is okay if students have questions, which can increase possibilities for inquisitiveness in the classroom (Chin, 2002). Chin and Brown (2002) found that students asked questions when explicitly asked to do so, and conversely refrained from asking questions when they were not prompted to do so. Additionally, Fowler (2012) found that when teachers put students in a "hot seat" and required them to ask a question, question-asking increased amongst all students. In these situations, students also developed a deeper understanding of the topics being covered. Furthermore, students commented that being required to ask questions provided them with additional question-asking practice, therefore helping them to develop their question-asking skills (Fowler, 2012).

Refraining from judging students' contributions. Another way in which teachers can encourage inquisitiveness is by refraining from judging students' contributions (Chin, 2002). Students will feel more comfortable asking questions when they know that they are not going to be reprimanded for asking a "bad" question. "Students' questions must always be received with sensitivity and enthusiasm" (Chin, 2002, p. 63). By accepting all students' questions, teachers are also creating a receptive classroom atmosphere, where question asking is the norm and where students are encouraged to ask questions (Chin, 2004; Stroupe, 2014). According to Chin (2004), the "key to a questioning climate is the attitude of the teacher towards questions" (p. 110). Furthermore, by refraining from judging students' questions or contributions, teachers create an atmosphere where all claims and questions are backed up by further questioning and reasoning by students (Rogat et al., 2014; Stroupe, 2014). Stroupe (2014) found that when teachers refrained from judging students' questions, students shared more ideas and asked more questions as compared to classrooms where students' ideas were evaluated as right or wrong, without further discussion. Therefore, by accepting all questions, teachers create an atmosphere where inquisitiveness and students' contributions are accepted and encouraged.

Asking students to record their own questions. Teachers can encourage their students to ask questions by asking them to record any questions they may have, either in a notebook, on a computer, or on another writing or recording tool (Chin, 2002; van Zhee et al., 2000). Writing down questions is especially useful as it gives all students the opportunity to ask questions, including those who are less vocal in class (Maskill & Pedrosa de Jesus, 1997). Additionally, by asking students to write down any questions they may have, teachers are providing students with more thinking time, instead of the pressure usually felt due to time limitations when asked to share their questions orally (Maskill & Pedrosa de Jesus, 1997).

Finally, by writing down their questions, students are participating in a form of note taking. Note taking is beneficial to students' learning and has been shown to increase cognition and achievement, and therefore learning, in classrooms (Titsworth & Kiewra, 2004). By asking students to write down questions, teachers are giving them the opportunity to remain inquisitive, they are giving students extra time to generate questions, and they are giving students opportunities for increased cognition and achievement.

Using a question board to record student questions. In addition to having students write down their own questions, teachers can encourage inquisitiveness by making a public record of students' questions, to be displayed throughout the class on something such as a whiteboard

(Chin, 2002; Krajcik & Sutherland, 2010; van Zhee et al., 2000). Creating a public record of student thinking is important as it displays to the teacher where students are at and what they would like to focus their attention on (Windschitl et al., 2012). By representing their thinking in a clear and public way, students' ideas and questions can become the drivers of class discussion.

Additionally, recording students' questions publicly allows students and teachers to revisit ideas and questions throughout the class, allowing the discussion to continue while also giving students the opportunity to revise or restate their questions or contributions (Stroupe, 2014). In this way, students' ideas and questions become resources for the entire class (Michaels et al., 2008). By publicly displaying students' questions, teachers give their students the opportunity to have a visual representation of different types of questions, as well as allowing students to see themselves as active participants in the classroom and to demonstrate that they value their students' ideas and that the questions are worthy of being shared with the whole class (Warren et al., 2001; Windschitl et al., 2012), hopefully encouraging students to ask more questions.

Encouraging students to elaborate on their thoughts. Once students are asking questions, teachers can encourage them to ask more questions by prompting students to elaborate on their thinking (Cano et al., 2014; Chin, 2002; Rogat et al., 2014; Windschitl et al., 2012). Doing so provides the opportunity for discourse in the classroom, giving students opportunities to reason through, question and strengthen their understanding of a topic or phenomenon (Windschitl et al., 2012). By pressing on student thinking and by asking students to elaborate on their ideas, teachers are working to direct and encourage further student thinking and questioning (Hlas & Hlas, 2012). For example, Cano et al. (2014) found that the more that students were required to explain their thinking and make sense of information given to them, they asked more questions and at a deeper level than those students who were not encouraged to elaborate on their thinking. This elaboration not only helps those students who are contributing, but it also helps the teacher to evaluate where students are at in a lesson (Franke et al.,1997). Additionally, when students provide explanations to questions or ideas, they are able to grasp the material at a deeper level, engage in further questioning to come to an understanding, and create a sense of learning for themselves (Nathan & Knuth, 2003; Webb & Palinscar, 1996). Research demonstrates that teachers need to press on students' thinking to support students in the process of elaborating on their thinking (Franke et al., 2009). Not only does elaborating on their thinking cause students to ask more questions, but it also provides opportunities for their peers to inquire on their reasoning and begin asking each other questions, therefore increasing possibilities for inquisitiveness in the classroom (Windschitl et al., 2012).

Encouraging student autonomy. In order to promote student inquisitiveness, it is important that teachers give students opportunities for autonomy in the classroom, that is, working independently from the teacher (Dunlop et al., 2013; Jocz et al., 2014; Schutte & Malouff, 2019). In order to enhance autonomy in the classroom, there are a variety of approaches that teachers can take.

Group work is one way in which teachers can encourage autonomy, and as a result, inquisitiveness, in the classroom (Marbach-Ad & Sokolove, 2000a; van Zhee et al., 2000; Windschitl et al., 2012; Woods-McConney et al., 2016). Working with peers allows students to problem solve together thereby modeling the process that scientists use to arrive at conclusions for their real-world problems (Woods-McConney et al., 2016). In these groups, students ask questions, challenge their peers' findings or contributions, and work to reach shared understandings (Galton et al., 2009; Laal & Ghodsi, 2012; Woods-McConney et al., 2016).

These groups are interactive and learner-centered, preventing students from becoming passive during class (Galton et al., 2009; Woods-McConney et al., 2016). By structuring class activities, projects, discussions and other learning opportunities around group work, teachers are creating an inquiry environment where students can question and debate with one another. This environment is central to creating a classroom where students are guiding their learning and asking many questions, instead of being told exactly what steps to take by teachers. Therefore, by asking students to work with their peers and by giving students autonomy in the classroom, teachers are increasing the potential for student engagement, interest, curiosity, and further inquiry, in the classroom (Jocz et al., 2014; Schutte & Malouff, 2019).

In addition to group work, teachers can encourage autonomy in other ways. For example, teachers can: give students a problem to solve on their own, give students choice in a topic to study or activity to do, encourage students to work on their own before stepping in to help them, or ask students to elaborate on their thinking (Chin, 2002; Dunlop et al., 2013; Rogat et al., 2014; Schutte & Malouff, 2019). When students have autonomy, their interest in a topic or activity increases and often this leads to students wanting to know more and asking questions (Jocz et al., 2014; Reeve & Jang, 2006; Schutte & Malouff, 2019; Stefanou et al., 2004). Giving students autonomy in the classroom prioritizes the students' thinking and allows students to develop answers to problems that they believe are important and relevant without a specific "prescription" from the teacher (Dunlop et al., 2013).

Summary. When considering how to encourage student inquisitiveness in class, it is important that teachers consider the strategies described above. Doing so gives students the opportunity to engage in the process of learning to ask questions, while also giving them more time to ask their own questions and discuss their findings with their peers. While the information described above can be applied to many different classroom contexts, it can have an important impact on science classrooms. Teachers should use these strategies to support student inquisitiveness and to encourage their students to act, think and learn like scientists (Chin & Osborne, 2008). The strategies described above can aid students in the process of acting and thinking like scientists as they encourage students to discuss, debate, problem solve, share their ideas, revise their ideas based on their own, and their peers' contributions, all while collaborating with one another in order to reach an answer or explanation. While the strategies described in this chapter can encourage student inquisitiveness, it is also important to consider the factors that impact teachers' teaching practice, such as the mandated curriculum, standardized tests and preparation for the next level of education, as they all influence what a teacher ultimately feels they can or cannot do in the science classroom.

Chapter 3: Methodology

My research study focuses on three science teachers in the same school and the ways in which they encourage inquisitiveness in their classes. This chapter introduces the context of the study and the three participants. It also describes the data collection and analysis methods used in this study, as well as ethical considerations.

My thesis is a qualitative study (Creswell, 2012) using a multiple case study approach (Merriam, 1998; Yin, 2018). This qualitative approach was chosen to explore the "central phenomenon" of three teachers' use of strategies to encourage inquisitiveness and inquiry in their science classrooms (Creswell, 2012, p. 129). A multiple case study is appropriate for this thesis as it "tries to illuminate a decision or a set of decisions" made by three teachers, "why [these decisions] were taken, how they were implemented, and with what result" (Schramm, 1971, p. 6). Additionally, the teachers in this study cannot be understood independent of their contexts (Merriam, 1998; Yin, 2018). The individual teachers and their actions in their classrooms are the focus of the case studies.

Research Context

This thesis focuses on three secondary science teachers from an independent school in Eastern Canada, The Ocean School. The Ocean School is relatively small Anglophone school in Québec that follows the mandated curriculum that exists in Québec, the Québec Education Program (QEP).

The Ocean School. Participants in this study are secondary science teachers at The Ocean School. The Ocean School is an independent school located in an urban center in Eastern Canada. Founded in 1930, it consists of two campuses encompassing Kindergarten through Grade 11, with approximately 450 students. The Ocean School is a coeducational, nondenominational school and is committed to a student-centered pedagogy, that fosters engagement, excitement, and collaboration between students and teachers. Furthermore, they are firm believers in "learning by doing." The Ocean School works hard to ensure that all students have creative outputs, giving their students ample opportunities to participate in the arts during the academic day, as well as through extra-curricular activities. The Ocean School provides many out of classroom learning experiences for its students, including field trips, outdoor education and travel to different countries.

Québec education system. Teachers at The Ocean School are following a mandated curriculum, more specifically, the QEP (Gouvernement du Québec, 2020). Furthermore, the Progression of Learning "complements each school subject by providing further information on the essential knowledge that students must acquire and be able to use each year" (Gouvernement du Québec, 2020, para. 3). The framework lays out which topics should be covered between Grades 7-11 and identifies the ways in which these competencies can be evaluated.

Furthermore, some of the participants in this study were preparing their students to take standardized exams. In Québec, the Ministry of Education chooses which courses will be administered these standardized exams, otherwise known as ministry exams, and students take them when they are eligible to do so (Gouvernement du Québec, 2020). Students in Québec take a ministry exam in Science and Technology at the end of Grade 10. The results that students earn on ministerial exams carry more weight than do the grades that they earn from their teacher in the course (Gouvernement du Québec, 2020). This is to "ensure that the value of the Secondary School Diploma (SSD) is recognized by institutions of higher learning (universities and Collège d'Enseignement Général et Professionnel (CEGEP), for example) and by employers" (Gouvernement du Québec, 2020, para. 1). As a result, the ministry "moderates" the students' grades in the courses where they are administered a ministry exam. In other words, performance on the exam and in the course should be comparable to avoid the ministry exam weighing more heavily and changing a student's final grade in the course (Gouvernement du Québec, 2020).

Finally, participants in this study were also preparing their students to continue onto a higher level of education. In Québec, CEGEP is an educational step between secondary-level education and university. Here, students focus on areas of study which they want to pursue in university, or where they prepare to enter the workforce (Fédération des cegeps, 2020). Thus, participants who teach Grade 11 courses were also preparing their students for CEGEP.

Participants

Participants selected for this study are three science teachers from The Ocean School. Lilian, Roger and Noah were selected based on connections I made with them having been a student teacher at The Ocean School five years ago. The participants were selected through purposeful sampling (Creswell, 2012; Merriam, 1998), as they teach science and were willing to participate in this study. All three teachers are aware of inquiry-based education.

Lilian has been teaching for 22 years, 17 of which have been at The Ocean School. She teaches Grade 10 Science and Technology and Grade 11 Chemistry. Roger has been working at The Ocean School for 11 years. He began his career at The Ocean School as a lab technician and officially began teaching his first course in 2011. He teaches Grade 7 Science, Grade 10 Science and Technology, Grade 10 Engineering, Grade 10 Math and Grade 11 Physics. Finally, Noah has been teaching for a total of 14 years, all of which have been at The Ocean School. He teaches Grade 7 and 8 Science, as well as Grade 11 Physics.

Data Collection

Data collection for this study took place in two ways: classroom observations and one-on-one, semi-structured interviews. Data were collected between September 2019 and November 2019 and observations and interviews were planned with participants based on their availability. As part of this qualitative case study, additional interviews were conducted after data collected earlier in the study had been transcribed and analyzed as a way to address emerging themes in the data (Creswell, 2012).

During the week of September 30th, 2019 to October 4th, 2019, I conducted my first classroom observations and initial interviews with the participants. The first one-on-one interview consisted of open-ended questions, as a way to become familiar with each participant's teaching experiences, their specific classroom contexts, preferred pedagogy, ideas about inquiry and student inquisitiveness, and experiences with inquiry in their own classrooms. Questions, such as the following, were asked in the first interview:

1. What is your preferred style of teaching? Why?
2. What mandates how/what you teach?
3. What does it mean for a student to be inquisitive?
4. How do you foster an inquisitive classroom?
5. To you, what does it mean to use inquiry-based instruction?

The open-ended questions, in addition to probes, allowed me to address thoughts or ideas brought up by the participants during the interviews (Creswell, 2012). These interviews took between 30-45 minutes and were audio-recorded.

Between September 30th, 2019 and October 30th, 2019, a total of 17 direct classroom observations took place (Yin, 2018). Noah and Lilian were each observed six times and Roger was observed five times. Each class and associated observation lasted a total of one hour and 15 minutes. While observing the classes, I acted as a nonparticipant observer as I did not involve myself in the activities occurring during class (Creswell, 2012). During each class, field notes were taken, either electronically or by hand, on a formal observation chart (Appendix A) created prior to the first observation.

The observation chart was developed using information gathered during the literature review process. This information made up the observation points that were used during classroom observations. More specifically, the observation points focus on strategies that teachers use in order to promote inquisitiveness in their classrooms. These observation points include: giving students time before and during an activity to write questions; giving students interesting material; giving students unstructured time to observe different stimuli; giving students question words; modeling good questions; refraining from judging students; asking students to record their questions; writing students' questions on a question board; explicitly encouraging students to ask questions; encouraging students to elaborate on what they think; and, encouraging students to work together in pairs or groups. Furthermore, the observation chart includes an "additional notes" section, to note any other teacher strategies not already included in the chart. The observation points used differ slightly from the strategies listed in the literature review, as the observation chart was created after an earlier review of the existing literature. The observation chart is more general to ensure that a variety of perspectives and strategies could be examined during classroom observations. The goal was for the observation points to guide me in my observations, without overly limiting what I was looking for.

The observation chart was used during each classroom observation. I recorded if and how teachers were using the points described in the chart. The field notes included direct quotes from teachers, as well as notes describing the instances that led to teachers using any of the strategies described in the chart (Creswell, 2012).

Final interviews were conducted on November 18th, 2019, after the initial data had been transcribed and analyzed. This final interview focused on themes that emerged from earlier classroom observation and interview data, as well as strategies listed on the chart that were not used in any classroom observations (Creswell, 2012). Questions, such as the following, were asked during the final interview:

1. What are your views on how science should be taught?
2. How does the curriculum given to you influence how science should be taught?
3. One strategy said to be useful in encouraging inquisitiveness is the use of a board specifically designated to record student questions. What do you think of this strategy?
4. Another strategy is to give students question words such as: how are, why does… etc to help them begin their questions. What do you think of this strategy?

Data Analysis

All interviews were transcribed verbatim and any handwritten observational charts were made electronic. Initial data analysis was done using the teaching strategies described in the observation chart. A codebook was created to list the themes, or codes, directly related to the strategies, and a short identifier for each code (Merriam, 1998). For example, the teaching strategy "giving students interesting material" was coded as "material" and the teaching strategy "encouraging students to elaborate" was coded as "elaboration." This is consistent with a *pattern matching technique* for data analysis, as the literature illuminated different strategies that would be important to look for during classroom observations and interviews and became pertinent to the data analysis process (Yin, 2018). Data analysis was also done from the ground up, as new codes emerged in the data analysis process. Initial codes were related solely to the teaching strategies described in the observation chart; however, through the coding and data analysis process, new themes, such as autonomy and relatability emerged numerous times in the observation and interview data. As a result, they became codes related to encouraging student inquisitiveness. These new codes were then added to the existing codebook, as they became important to consider when analyzing the remaining data. Once separated into different codes, data were analyzed within each code to look for subthemes emerging from the data. Data were further categorized into these subthemes and described accordingly (Merriam, 1998). After all data had been coded and analyzed, the different codes were organized into two overarching themes. These themes were: factors influencing teachers' teaching style and strategies to encourage student inquisitiveness. This coding process was completed using Google Docs and the commenting function to add in the code or codes that applied to the data being analyzed. All of the transcribed and coded data made up the case study database used for this study (Merriam, 1998). The data from interviews and classroom observations were triangulated as the teachers' views and opinions expressed in interviews were compared against the field notes taken of their actions during classroom observations. This triangulation of data ensures the trustworthiness and validity of the data (Flick, 2004).

Ethical Considerations

Well before beginning this study, ethical approval was obtained from McGill's Research Ethics Board. In an initial meeting, before beginning interviews or observations, prospective participants were informed of the ethical review and procedures and were provided a copy of the ethics proposal. Furthermore, I clarified any questions that the participants had about the study. Later, each participant signed a consent letter, knowing that they could terminate their participation at any time. Participants were told that their identity would be kept anonymous throughout the research process and that they would be referred to by a pseudonym. Participants were asked for permission to record, verbatim, what they were saying in their classrooms and during interviews, and to use what they said as potential quotes in the thesis. Additionally, all data collected were stored on a password protected computer.

Chapter 4: Findings

In this thesis, I examine how three secondary school science teachers encourage inquisitiveness in their classes. In examining the cases of Lilian, Roger and Noah, two themes emerged from the data analysis. These themes are: factors influencing teachers' teaching style and strategies to encourage student inquisitiveness.

The Case of Lilian

Lilian teaches Grade 10 Science and Technology and Grade 11 Chemistry. Lilian's Grade 10 Science and Technology classes consist of one section of enriched science and one regular stream science class. The regular stream Science and Technology class is required of all Grade 10 students, but students who wish to pursue science in CEGEP and future education take the enriched Science and Technology instead of simply the regular stream class. Both Grade 10 classes take the required ministry exam at the end of the year. Lilian's Grade 11 Chemistry class consists of students who would like to pursue science in their future studies and are taking multiple science classes in their final year of secondary school.

In regard to her teaching style, Lilian described herself as a teacher who uses a more traditional teaching style. She said, "I think I'm a very traditional teacher...I do a lot of talking but to make up for that, I try to be very enthusiastic." (Interview, 9.30.19) However, despite describing herself as a traditional science teacher, Lilian believes that science teaching should be student-centered. When asked how science should be taught, she replied: "Ideally, it would be a lot of student led, like what they're interested in more than this is the curriculum and a lot of the kids figuring out how to solve problems, which would be really great" (Interview, 11.18.19).

Lilian teaches in a way that demonstrates her flexibility and ability to adapt to anything at any moment. She explained this notion in regard to her own teaching:

> A lot of my teaching has to do with being able to roll with the punches. ‘Cause kids get discouraged and I think that's a big part of not doing well, so I try to be very positive. My mantra is “I'm training you. You are trying on your running shoes. Which ones are gonna be for the race, we don't know, we gotta find that strategy.” (Interview, 9.30.19)

Therefore, Lilian strives to meet the needs of each individual student and therefore works hard to adapt to students’ needs in order to meet them where they are in class. Lilian also likes to build relationships with students while she teaches. She said, “Another thing I try to do is really try to show the kids that I like them, and I think that's a big part about the way I teach also” (Interview, 9.30.19). Therefore, this aspect of connecting with students is a big part of her teaching style and something that she makes sure to do in her classes. Finally, Lilian likes to teach students skills that they can use in their lives. For example, when reflecting on the technology part of her Grade 10 Science and Technology curriculum, Lilian said:

> [M]y hope is that this part of the curriculum is being put forth in order to get kids to be more sustainable. This is my perception of it, my positive thinking about this part is that if “Oh, I know how something works, I will not simply throw it out, I may get a new part and fix it,” so if it's a screw then kids will know “Oh, I can just replace that screw.” (Interview, 9.30.19)

By teaching students these skills, Lilian hopes that they can be useful to students in the future. In summary, Lilian uses a more traditional style of teaching, but in doing so demonstrates flexibility, a care for each student and a desire to help them succeed.

Lilian believes that students are inquisitive when they ask questions, problem solve and try to figure things out on their own. She said: “[B]eing inquisitive would mean questioning, trying to figure out the answers themselves, no leading or as little as possible” (Interview, 9.30.19). Students exhibit inquisitiveness when they ask questions and try to problem solve, and Lilian believes that the teacher should support students in doing so. She elaborated:

> I try to get them to ask questions. Sort of like "How do you think this works?" You know, a lot of us are very good about asking questions but not leaving enough time for kids to kind of see what they think so you have to hold yourself back. (Interview, 9.30.19)

Furthermore, Lilian made connections between inquisitiveness and problem solving, saying that being inquisitive inherently involves solving problems and figuring things out. Therefore, Lilian believes that students are inquisitive when they ask questions and try to problem solve.

Factors influencing Lilian's teaching practice. As a Grade 10 Science and Technology and Grade 11 Chemistry teacher, Lilian feels that different factors influence her teaching practice. These factors include: the curriculum given to her, her awareness of preparing students for the next level of education, and her obligation to prepare students to take the Grade 10 ministry exam.

Meeting the goals of a mandated curriculum. Lilian reflected on how the science curriculum at The Ocean School influences how she teaches her classes, as well as the topics she was able to cover. More specifically, Lilian shared how the mandated curriculum in Québec, the Québec Education Program (QEP), influences her teaching practice saying, "You skim over a whole bunch of things and it kind of dictates the depth of what you're doing. Yeah, I think it influences me a lot for sure" (Interview, 11.18.19). Here, Lilian describes how the QEP not only influences what she has to teach, but also how she teaches because of the wide array of topics that she has to cover in a limited amount of time. Furthermore, Lilian believes that she would spend more time on different topics if she did not have to follow the QEP. Of this, she said, "There's topics that I'd love to spend more time on, and [I] could do that. I'd be focusing on stuff that’s more interesting to me. Like environmental things or global problems and science” (Interview, 11.18.19). Since she has to follow a strict curriculum, Lilian feels that she does not have time or space to focus on other science topics. Therefore, Lilian feels that if she was not so constricted to these curriculum guidelines, she could be teaching more about content that she loves.

Preparing students for the next level of education. In addition to the mandated curriculum influencing what she does in her classroom, Lilian also feels that the pressure of preparing her students for CEGEP and university impacts how she teaches. For example, when reflecting on teaching Grade 11 Chemistry, Lilian said:

> There's no ministry [exam] but they're going to CEGEP. So you kind of want them to be okay in CEGEP...So I always feel like I should do as much as I can, while keeping in the “do you get it” mode. (Interview, 9.30.19)

Additionally, she believes that going into depth on certain topics means that she would “not [be able to] cover everything” which puts her students at a disadvantage in CEGEP and university (Interview, 9.30.19). Since Lilian has to prepare her students to meet the demands of CEGEP and university, she believes that she has less time to devote to other activities or conversations and instead needs to ensure that she covers as much content as possible.

Furthermore, Lilian believes that students preparing for CEGEP and university adds a sense of competition and pressure on the marks that the students are receiving. When asked if she believes that CEGEP preparation takes away from the learning, Lilian responded, “Yeah…it’s all about the mark. Like, I want students to see what they did wrong, what they did right, learn from their mistakes. It bothers me that everyone is so pressured towards the marks” (Interview, 11.18.19). Since good marks are required to get into CEGEP and university, Lilian believes that her students become more concerned about marks and less concerned about the learning that is taking place. Lilian feels that the need to adequately prepare her students to meet the needs of CEGEP and university and also to receive the “required marks” to be accepted to a post-secondary program impacts how she teaches her classes.

Preparing students for standardized exams. In addition to the mandated curriculum, as well as the need to prepare students for the next level of education, Lilian feels that the Québec ministry exam greatly influences her teaching practice in her Grade 10 Science and Technology courses. Not only does the ministry exam influence what Lilian teaches, but it also impacts how she structures different activities in her Grade 10 class. For example, Lilian saves group work only for performing lab activities. She does this because students’ lab marks are not moderated by the ministry and are, instead, only moderated by her, the classroom teacher.

Since the ministry exam has a significant impact on the students’ final grade in their Grade 10 Science and Technology course, Lilian believes that it is important that students work in ways that reflect how they will write the exam. During her first interview, Lilian discussed the importance of teaching and evaluating her students in a way that demonstrates what they can do alone, and not in a group. She justified this thought by saying that the exam requires students to independently demonstrate that they have learned, without the help of a group or a partner. She specified that the ministry exam is not done with “your partner, not your group and that's why I'm very heavy on quizzes every week to keep them on track and then they have a unit test” (Interview, 9.30.19). Lilian feels that it is important to give students individual quizzes and exams, as they will eventually be writing the ministry exam on their own as well.

The ministry exam also impacts how Lilian teaches because of the weight the exam has on the students' final grade. Lilian explained the impact that the ministry exam has on her teaching practices. She said:

> So, I'm 50% [and the ministry is] 50%. It's the average, but if I give 90s and then they get a 60 on the exam, it will not be the average. It'll be closer to 60. So that's why I'm very conscientious about [the classwork] needs to be what you can do. (Interview, 9.30.19)

Therefore, the ministry exam has such a large influence on her students' marks that she feels she has to teach in ways that would reflect the exam. Because Lilian feels the weight of the ministry exam on both her and her students' shoulders, she does a lot to make sure she teaches in ways that she thinks will help students succeed and not skew their marks at the end of the year.

In conclusion, Lilian reflected on the fact that the ministry exam feels like a hindrance to her teaching because she feels the pressure of teaching in a way that will guarantee that her students succeed on this standardized exam. When asked if she thinks that the ministry exam puts a constraint on how she teaches, Lilian responded:

> I think the ministry exam definitely guides me because I know exactly how it is and what it's going to be. So I'm always trying to imagine, okay, what would the ministry ask about this so what do the kids need to know or what do they need to be able to do. So yeah, it's definitely a big constraint for sure. (Interview, 11.18.19)

Therefore, preparing her students for the ministry exam has a large impact on how Lilian teaches. Indeed, the ministry exam is just one of the factors that cause Lilian to feel pressure and restrict her teaching in certain ways.

Strategies to encourage student inquisitiveness. During her classes and in conversation during interviews, Lilian used and reflected on different strategies to encourage student inquisitiveness including: making the learning interesting, modeling question asking, encouraging students to elaborate on their thoughts, and giving students autonomy. In the sections that follow, I describe how she used these strategies, and, if applicable, how she reflected on these different strategies.

Making the learning interesting. Lilian made the learning interesting for her students by using different representation forms to present the science content in order to encourage her students to ask questions. These representation forms included: images, in-class demonstrations, and videos.

One way in which Lilian prompted questions from her students was by showing them different images that acted as discussion starters about different topics. One such discussion began when Lilian showed her Grade 11 Chemistry students an image of a metal container with symbols for fire, pressure, temperature and volume next to the container. After showing the image, Lilian asked her students to consider what would happen when the metal container was subject to fire, different temperatures, different pressures, and different volumes. Lilian also asked her students to think about how all of these factors are related. Students immediately became interested in the discussion and began to ask questions about what would make the metal container in the image explode, what would happen if the container froze, and what would happen if they brought the container down to the bottom of the ocean. The images seemed to be effective at getting Lilian's students to ask questions in addition to prompting interest and discussion.

In another instance, when Lilian's Grade 10 Science and Technology class was beginning to learn about the structure of the atom and static electricity, she began the lesson with a demonstration using a balloon and one student's hair. This demonstration prompted many questions, and a lot of discussion amongst her students about static electricity, different charges, and what was happening to the electrons when the balloon was rubbed against the student's head. This demonstration clearly showed something happening to the student's hair as the balloon was rubbed against it, and students immediately became interested and asked many questions.

Lilian occasionally showed videos to her students during her class to spark question asking. For example, when discussing the discovery of the atom, she showed a video on cathode rays that led to Thomson's model of the atom, a video of Rutherford's alpha ray experiment, and a video on the size of the atom. The three videos were related, as they all built on one another and described the evolution of the model of the atom. The videos allowed for class discussions during which students brought up themes explored in the videos. Students were interested in knowing how one discovery helped pave the way for the next discovery, ultimately leading us to understand the atom in the ways in which we do today. Furthermore, they were interested in how scientists were able to do such experiments, safely, such a long time ago. One aspect that really caught their attention and that prompted many questions was the fact that Rutherford had to hide behind a brick wall during his alpha ray experiment to keep himself safe. By showing her students videos during class, Lilian helped to create an atmosphere of interest, questions and discussion between the students and with the teacher.

Modeling question asking. Lilian modeled question asking in order to demonstrate the types of questions students could be asking and to encourage them to ask more questions. For example, during a lesson in her Grade 10 Science and Technology class about closed-circuit systems, Lilian asked her students a question that required them to consider a scenario that differed from the focus of the lesson. As Lilian projected an animation of a closed-circuit system, students were discussing what they believed the outcome would be. But, in order to get students to consider other scenarios, Lilian asked a question that modeled how they could do so. She said, “What if you looked at it from the point of view of an open circuit?” (Observation, 10.10.19). By asking this question, Lilian signaled to her students that it is okay, and that it is encouraged, to ask questions that relate to alternate scenarios.

Lilian also modeled question asking by demonstrating different questions students could be asking themselves to determine why they are completing something in a certain way. For example, while completing a lab on the Ideal Gas Law, Lilian’s Grade 11 Chemistry students wondered why they had to add a specified amount of water to the setup. Instead of answering their questions directly, Lilian modeled what types of questions the students could ask themselves in order to figure out the answer to their question. She said, “Well, what could happen if there’s too much water? And what could happen if there’s not enough?” (Observation, 10.25.19). Students used her question to reason through an explanation for their own questions. In asking such questions, Lilian modeled question asking that requires students to think more outside of the box and consider something new in order to arrive at answer.

Furthermore, Lilian modeled question asking by getting students to think about the bigger picture. By doing so, she allowed her students to think about science in general and how what they are learning in class can fit into a larger view of science. For example, when her Grade 10 students were discussing the evolution of the model of the atom, she asked questions such as: “Why is it important to look back on history when doing science?” (Observation, 10.24.19), “What do we know today about the atom that [Democritus] didn’t know?” (Observation, 10.24.19), and “Can you tell me why I care about talking about the atom before I mess with your hair in static electricity?” (Observation, 10.24.19). By asking these questions, Lilian demonstrated to her students the types of questions that may not be exactly related to the content and to moving further along in "completing" the content for the day, but instead, showed her students that they can ask questions that tie together their learning, or that ask them to make connections to the content being covered and the real world.

At times, Lilian modeled questions that students could ask simply out of curiosity. During an Ideal Gas Law lab, she wanted the students to be more curious about what would happen if they waited longer to put a flame to hydrogen gas. She said, "If we give the hydrogen more time to reach the top, will the pop will be bigger? Now let's wait a minute and a half and see what that does" (Observation, 10.25.19). Instead of following the lab instructions and waiting 30 seconds for the hydrogen gas to collect, Lilian demonstrated to her students that it is okay to ask questions out of curiosity and try something in a new way (assuming it is safe) in order to see if their curiosity would change the results. In doing so, Lilian modeled questions that could be asked as a result of genuine curiosity in the lab, hopefully encouraging them to ask these types of questions in the future. Lilian wants students to be asking questions, specifically questions related to "how does this work" (Interview, 9.30.19). So, by modeling question asking for her students, Lilian tried to encourage inquisitiveness in her classroom.

Encouraging students to elaborate on their thoughts. Another strategy which Lilian used to encourage her students to ask questions was by finding ways to have them elaborate on their thoughts, ideas or questions. When students would contribute an idea during class discussions, she responded to their contributions with statements such as: "How do you know that?" (Observation, 10.9.19) and "Is there another way you could have looked at this?" (Observation, 10.10.19). Instead of telling students why what they are saying does or does not make sense, and instead of giving them other ideas to use, Lilian asks them to do this thinking work for themselves. In doing so, she asks students to think about what they said and elaborate on their thoughts.

Lilian also used elaboration as a way to determine what her students were thinking during class activities in order to encourage her students to question their own thinking. When students were participating in a lab based on Avogadro's Law, Lilian circulated around the room to observe what they were doing. At times, Lilian would approach students and say things such as: "Why are you doing it this way?" and "How do you know when it's finished?" (Observation, 10.2.19). She did so to encourage students to think more about what they were doing, question their actions, and continue the lab having taken those comments into consideration. In another situation, a student had completed the lab activity and began to write up her lab report but had questions regarding possible sources of error. Lilian helped guide the student in her understanding of possible sources of error by asking her to elaborate on her thoughts. She said: "It's not a source of error because…what did we say about the magnesium?" (Observation, 10.2.19). Therefore, in asking this student to consider what happened with the magnesium in the lab, Lilian helped the student recapitulate the lab, ask questions about different steps in the lab, and come to an understanding of what the possible sources of error could be.

In another instance, Lilian's Grade 10 students were beginning a unit on the atomic model. One student contributed his thoughts on the different parts of the atom, particularly, in relation to the charges of protons, neutrons and electrons. Once this student completed his thoughts, Lilian responded by saying, "How come? How do you know that?" (Observation, 10.24.19). While the student was correct in his initial contributions, Lilian's question encouraged him to further back up his ideas with evidence and give an additional explanation. She described the importance of students who "can explain [a phenomenon and explain] how [they] would solve [a problem]" (Interview, 9.30.19). Therefore, by asking her students to elaborate on their thoughts, Lilian not only challenged them to question their own thinking and encourage them to be inquisitive, but also got insight into their thinking.

Giving students autonomy. Another way in which Lilian encouraged inquisitiveness in her classes was by encouraging students to be autonomous and work as much as possible without her help. For example, in Lilian's Chemistry class, students were encouraged to be autonomous while completing the lab of the day which focused on the Ideal Gas Law. Lilian received many questions as students were trying to figure how they would execute the lab. While she gave the students a general idea of how the lab worked, she did not give them an exact, step-by-step procedure. Instead, the students were in charge of figuring out exactly what they should do which allowed them to ask questions. For example, when a student asked a question about the procedure for the lab, Lilian responded "Are you looking at the procedure? It's not step by step, so you guys are going to have to organize it better" (Observation 10.25.19). During these activities, she never gave students the answer, but she did point to places that could help them out. For example, Lilian said, "You should have a paper that tells you what you're measuring" (Observation 10.25.19). Instead of telling the students *what* they were measuring in the lab, she instead hinted at where they could find this information, encouraging them to remain autonomous in their work. Therefore, by encouraging autonomy Lilian also created an environment where questions were asked.

Summary of the case of Lilian. Lilian is a teacher who strived to make learning fun for students, while also taking into consideration the different requirements that she needs to meet, including teaching a mandated curriculum, preparing students for CEGEP and university and preparing students to take a ministry exam. Nevertheless, Lilian found ways to use different strategies to encourage inquisitiveness in her classroom, specifically: making the learning interesting, modeling question asking, encouraging students to elaborate on their thoughts, and giving students autonomy. While she felt the impacts of certain constraints, she found instances where she could make the learning as student-centered as possible, while still meeting the requirements placed upon her.

The Case of Roger

Roger teaches many courses including: Grade 7 Science and Technology, Grade 10 Enriched Science and Technology, Grade 10 Engineering, Grade 10 Regular Math and Grade 11 Physics. For the purpose of this thesis, classroom observations only focused on his Grade 10 Engineering class in order to add an elective course to the data collection. Grade 10 students in the enriched science stream take two science courses: the required Science and Technology and an elective course, instead of an Arts course which other students can opt to take. There are two elective courses offered to the enriched students: the Engineering course (which Roger teaches) and a Marine Biology course.

During classroom observations, the Grade 10 Engineering students were working on a forklift project. After learning about different mechanisms to enable the forklift to move, students were tasked with creating a model forklift that could lift a few pounds in a controlled manner. The students learned how to use different tools in the workshop, including drills, saws and metal cutters, and, once they were trained in how to use these tools safely, they were free to use any of these tools.

Roger is a strong proponent of finding ways to use hands-on activities in his teaching, as he believes that doing so allows students to be fully engaged in the learning process.

Furthermore, he believes that hands-on activities make teaching more enjoyable for the teacher. Roger reflected on this idea:

> I'm just thinking about my projects in engineering and those are the ones that I obviously appreciate the most just because it's less of me talking in front… so getting them to do something around the room and hands-on activities, and it's one thing to see a model working, but trying to ask specific questions that you won't have the answers right away to and for them to see yes, you use a model and this is how it works, but I think that with inquiry learning where you can analyze situations... I think that if all of it could be that way it just makes teaching a lot more enjoyable for sure. (Interview, 9.30.19)

Roger added that he tries to stay away from lecturing as much as possible, as he feels that this style of teaching is not beneficial for students. Roger said, "I don't really like to lecture at the front 'cause I feel like you only have a limited time span where they're actually going to continue listening to you" (Interview, 9.30.19). As indicated by his words, Roger believes that hands-on activities get his students involved and in doing so, he does not risk losing their attention. Roger did reflect that sometimes lecturing is necessary, but said, "I try to limit the amount of time I would need to present something and get them to do more hands-on activities" (Interview, 11.18.19). Roger also reflected on the fact that he likes projects and problems that have more than one right answer saying:

> Sometimes it's them that's going to come up with the right answer collaboratively and there might be more than one answer and that's something that I really enjoy doing, especially in the project that we're doing now, is, I like projects where there's more than one answer. If there's only one right answer, I don't think it's a very good project. (Interview, 9.30.19)

When projects have more than one right answer, the students are able to come up with different answers on their own, which Roger enjoys, especially when considering the multiple solutions that students have come up with in his Engineering class that he had not yet thought of.

Roger believes that it is important to make science curriculum relatable because this way students can acquire skills to use in the real world, creating further engagement with the material. When describing how he designs his Engineering course Roger said:

> For the Engineering course, that was an option course that I designed so it was all concepts that I looked into that I thought that high school students can grasp and be useful and be connected to what engineers do. It's also very much connected to a science course but in a practical sense. So, it helps them with what they're learning in theory in science, really put it in a practical setting but they also get to design it, to build it. So, it gives it a different twist, a different approach for those that like hands-on learning. (Interview, 9.30.19)

Therefore, with this hands-on learning, students were able to gain engineering skills and apply them in a practical sense.

Roger believes that inquisitive students are curious, that they care to know more about a phenomenon, and that they are always asking questions. He said:

> They have to be asking a lot of questions when they are inquisitive and they have to be curious and it has to be their interest. So if they're going to be inquisitive they're going to, um, it could just be anything that they want to know what the answer is at that point cause they're inquisitive. They care to know. (Interview, 9.30.19)

Therefore, for students to be inquisitive, not only are they asking questions, but they are doing so because they are curious and they care to know the answer. He added that hopefully whatever is going on in class is “interesting enough for them to want to know it, ask questions and try to figure it out what's going on depending on the situation” (Interview, 9.30.19).

Roger believes that in order to foster inquisitiveness in a classroom it is important to remain free of evaluation after a student says something or asks a question. He said:

> If you want it to be inquisitive then you definitely can't always answer someone's response by going “that's a good point” before another student wants to maybe, you know if you keep saying “that's right, you're on the right track,” then it's not really them discovering it ‘cause you already said that the answer is on the right track. (Interview, 9.30.19)

According to Roger, if a teacher wants students to remain inquisitive, they should refrain from expressing to their students if they are on the right track. Roger believes that doing so may allow students to come up with their own answers, ones that he has not thought of himself. He adds:

> [The students] often want your opinion because they're like okay, faster to the point, like they want the answer, but you have to know that you don't have all the answers so, sometimes it's them that's going to come up with the right answer collaboratively and there might be more than one answer and that's something that I really enjoy doing. (Interview, 9.30.19)

Indeed, Roger believes that student inquisitiveness not only gets students involved in their learning but can also allow them to discover new answers to problems. In order to maintain an inquisitive environment, Roger emphasizes that the teacher should give students opportunities to contribute their own thoughts and questions, without evaluation or response from the teacher.

Finally, Roger reflected on the necessity of a supportive environment to encourage inquisitiveness in his class. He shared that his students recognize that it is okay to ask questions and to support their classmates in being inquisitive. When asked how to foster an inquisitive classroom he said:

> It has to be made clear at the beginning that if one person is asking a question it's likely that someone else is thinking the same question in their head and, it's not nice to judge them because if you start judging one person then everybody feels like everyone is going to be judging each other, so it has to be an environment where they know that they're not being judged and they can ask questions and it being collaborative and everyone has a right to add to the conversation. (Roger, Interview, 9.30.19)

Not only should the teacher refrain from evaluating students' contributions, but students Roger believes that students should also give each other the space to contribute and ask questions. According to Roger, an inquisitive environment is achieved when all students feel that they have the right to participate without judgement.

Factors influencing Roger's teaching practice. Roger teaches a wide range of courses including junior-level general science courses, elective courses, and courses with a ministry exam. In his interviews, he reflected on how different factors including the mandated curriculum, the need to prepare his students for the next level of education, and the pressure to prepare his students for the Grade 10 ministry exam, influences his teaching practice.

Meeting the goals of a mandated curriculum. Roger feels that the QEP and the Progression of Learning influence his teaching, especially in his Grade 10 Science and Technology class, as these curriculum documents outline the vast content needed to be covered in a limited amount of time. Roger explained that the strict series of topics he needs to cover, in addition to limited time, impacts his teaching practice. He said, "So, when you look at time, and you want to do certain things, you have to meet the Progression of Learning targets…[The ministry] choose[s] the concepts and the topics" (Interview, 11.18.19). As he says, Roger does not choose the material that he would like to cover nor does he decide how much material is covered in a school year. As a result, Roger feels that the mandated targets set by the QEP and the Progression of Learning, coupled with a lack of time to meet these targets, impacts what he can do in his upper level courses.

While the Progression of Learning affects his teaching, Roger believes that the Progression of Learning also provides more flexibility in classes that do not have a ministry exam. For example, Roger said:

> [T]here is a Progression of Learning for every grade, but again... since Grade 7 does not have a [ministry] exam at the end of the year you have a lot of flexibility in how you want to approach that course…The thing with our Progression of Learning, in Grade 7 and 8, each school can choose what concepts they want to put in Grade 7 and 8. So, the way that we divide it up, it works and we meet those targets, but it's just easier to do so, we have that flexibility. (Interview, 9.30.19)

Therefore, in the younger grades, and especially in his Grade 7 course, Roger does not feel as limited by the Progression of Learning because he believes that he has more flexibility and less content to cover.

Preparing students for the next level of education. In addition to feeling restricted by the mandated curriculum, Roger believes that the need to prepare his students for the next level of education, specifically CEGEP and university, also has an impact on his teaching practice. While reflecting on his Grade 11 Physics course and its requirements Roger said, "I definitely have to respect the Progression of Learning in that course so that they're ready for CEGEP" (Interview, 11.18.19). Therefore, in addition to feeling confined by the QEP and the Progression of

Learning, Roger also felt pressure to prepare his students for CEGEP. In order to adequately prepare his students for CEGEP, Roger believes that he needs to closely follow the QEP and the Progression of Learning. He added, “I have to make sure that they have the tools that they need to go to the next level” (Interview, 11.18.19). Therefore, Roger implied that by swaying from the mandated Progression of Learning, he would not be adequately preparing his students for the next level of education, so this awareness influences his teaching practice.

Preparing students for standardized exams. Roger described the impact that the ministry exam has on his teaching. Specifically, Roger shared that the curriculum is clearly specified for courses that have a ministry exam. He said, “So in my Grade 10 enriched science course it has a ministry exam at the end of the year and the government dictates what topics we have to teach for each course” (Interview, 9.30.19). While the curriculum ensures that Roger covers the required content to prepare his students for the exam, he shares that he can still decide how he wants to teach the content. He continued: “[The curriculum] forces me to make sure that I have those concepts all done but then I get to be creative with how I want to implement that afterwards” (Interview, 9.30.19). Although he had to keep the ministry topics in mind when teaching, Roger felt that he could be a bit creative in how he taught those topics, so long as they were covered by the end of the year.

Strategies to encourage student inquisitiveness. In his Grade 10 Engineering class, Roger used many different strategies to encourage student inquisitiveness. These strategies included: making the learning interesting, modeling question asking, encouraging students to ask questions, refraining from judging students’ contributions, encouraging students to elaborate on their thoughts, and giving students autonomy in the classroom.

Making the learning interesting. One way in which Roger promoted an inquisitive environment was by making the learning interesting for his students. He made the learning interesting by giving his students different representation forms to explore science content. He did so by giving his students objects to manipulate and explore. As students built their forklift models, he encouraged them to use the different tools and materials in the classroom. These objects included: different chains, pieces of wood, different screws, nuts and bolts, and other wood working tools. Here, Roger required his students to manipulate these objects on their own, instead of demonstrating for them, thereby giving them chances to explore. As students explored, they learned how these different objects work, and how they may or may not help them progress in their projects. Since students were invested in their projects and were determined to get them to function properly, the exploration of the different tools in the workshop was an important aspect of the forklift project and prompted much engagement from the students.

Even in cases where he gave them a suggestion, Roger would still ask his students to explore the materials first on their own instead of telling them what to do. In some instances when students were trying to figure out the best solution to their problem, he would ask students to model what it is they want to happen and he asked if the materials they have are possible to use for what they want to do. Other times, when students were having difficulties finding the best materials for their job, Roger said, “So let’s look around the shop and find something that might work better!” (Observation, 10.1.19). As students searched for the useful materials in the workshop, they asked questions to Roger and other classmates, ensuring that their investigations would lead them to the most appropriate materials for their projects. Therefore, by allowing students to freely manipulate and explore different materials, Roger provided them with the space and multiple opportunities to ask their own questions as a result of their exploration.

Modeling question asking. Roger modeled question asking in order to provide guidance to his students and to model which questions they should be asking in order to help them move further along in their projects. As students worked on their projects, he would circulate the classroom and take time to stop by every table and discuss what the students were doing and why they were making those choices. When students were struggling, Roger would model which types of questions could help them work through their problems. For example, he asked questions such as, "If this is what you want [your forklift] to do, where would [the pulley] go?" (Observation, 10.1.19), "Does it matter if you do [put the screw] a little bit to the side?" (Observation, 10.24.19), and "So what happens if there is no hole [in the side structure]?" (Observation, 10.29.19). These questions demonstrate to students that they should be asking themselves questions that allow them to imagine alternate scenarios, experiment with different tools, and try to work backwards in order to arrive at a solution. The questions asked by Roger were ones that students could have asked themselves in order to make progress in their projects.

In his interview, Roger reflected on the idea of modeling these types of questions. He said, "If they're not asking themselves questions like 'Why are you getting that and why do you think so,' then I'll be asking them questions like that" (Interview, 11.18.19). Indeed, Roger modeled the types of questions that require explanation that he wanted the students to be asking themselves.

Explicitly encouraging students to ask questions. Another way in which Roger ensured that his students were asking questions was by explicitly encouraging them to do so. Roger went as far as to make one assignment focus solely on the questions that students were asking their peers during their presentations. During the forklift project, Roger devoted a few class periods to student presentations. Each group presented their model for their forklift to the class, and the other students were required to ask the presenting group questions about their projects in order to help them address any problems and move along in their design. Students were evaluated on the questions they asked rather than their presentations. Roger explained why he gave projects where students were marked on their question asking. He said:

> I started putting in the presentations where they're helping each other out and it's not the presenters that are getting evaluated it's the ones in the audience so that they're paying attention on how to help them out or give them suggestions or just ask questions if they don't understand. If they don't understand something, then probably the presenters don't understand exactly what's going on. That opens the door for others to help out. (Interview, 9.30.19)

Therefore, by evaluating students on their questions, Roger gave them the push they might need to think of questions to be asking their peers. In addition, throughout the presentation process Roger would say things such as: “Ask questions if you don’t understand something” (Observation, 10.1.19), “Any other questions based on that system?” (Observation, 10.1.19), and “Anything else? Questions about how this is going to work, where you might see issues?” (Observation, 10.10.19). By asking these questions, Roger provided additional opportunities for students to ask their own questions, therefore increasing student inquisitiveness in the class. As Roger required students in the audience to ask questions to the presenters, he created ample opportunities for all students to engage in question asking. As a result, each presentation ended with the majority of the students surrounding the presenters, interacting with their models and asking additional questions sometimes for up to 45 minutes.

Refraining from judging students’ contributions. Roger was very supportive when his students asked questions and always accepted all questions, therefore encouraging them to continue asking questions. For example, when his students were asking their peers questions during their project presentations, Roger would respond by saying, “Very good questions” (Observation, 10.1.19), “That’s a good question. How would you do it?” (Observation, 10.1.19), and “Yes, that is the question!” (Observation, 10.10.19). In responding to students in these ways Roger does not shut down his students’ questions and instead demonstrates that they are supported in asking their questions.

Roger was also supportive of students who contributed their ideas to a discussion, project or activity. For example, after his students described their project idea to him, he replied, “That’s what I was thinking and you guys came up with it on your own” (Observation, 10.1.19). Or, “That’s great. You want it in the center” (Observation, 10.29.19). In another instance, a student was struggling to find the best way to get his mechanical system to work efficiently. The student had an idea that was different from something that Roger had suggested he consider. Instead of judging this student and completely dismissing his idea, Roger responded with “I leave it to you. Maybe you can prove me wrong” (Observation, 10.24.19).

Roger reflected on the fact that he wants his students to feel safe and comfortable to participate in his class. He said that he wants his students to know that “everyone has a right to add to the conversation” (Interview, 9.30.19) and this includes asking questions. Roger demonstrates that he values his students’ ideas by not putting anything down. As he said to a student one day, “Sure, anything is possible” (Observation, 10.10.19). Roger believes that an inquisitive classroom not only has to be free of judgement, but also has to be a place where students feel that they have the space to collaborate and be inquisitive together.

Encouraging students to elaborate on their thoughts. Roger encouraged students to elaborate on their ideas as a way to help them solve problems on their own. For example, when the Grade 10 Engineering students were struggling to figure out how their mechanisms would work, Roger said things such as: "How does it work? What's going to turn first?" (Observation, 10.1.19), "So how can we attach that piece to the fork?...Okay…using what?" (Observation, 10.29.19), "What could you do to use the same idea and still make it work?" (Observation, 10.24.19), and "What's the problem? Why would it never work?" (Observation, 10.1.19). As students answered these questions, they took the time to explain to Roger what they were thinking, which then resulted in them asking more questions in order to find the best solution to their problem. Instead of immediately jumping to give students answers, Roger asked them questions to get them to think and elaborate on their thoughts. Consequently, the students asked more questions as a result of thinking through their problems, explaining possible solutions, comparing and contrasting these ideas, to eventually arrive at the most feasible idea.

Roger also used elaboration as a strategy to better understand his students' thoughts. As his students were working on their projects, Roger would ask questions such as: "What do you mean? I want to understand what you're thinking" (Observation, 10.10.19), and "Why did you make that choice?" (Observation, 10.29.19). As students responded to his questions, they began asking themselves even more questions in order to reach a more complete and solid understanding of what it was they were working on. Roger wants his students to be able to explain things for themselves. He wants his students to answer the question "What does this [result] mean" by themselves (Interview, 11.18.19). By asking questions, Roger pressed on students' thinking resulting in students asking even more questions.

Giving students autonomy. Roger encouraged student autonomy in almost every class observed by having students work through every aspect of this project on their own. For example, during his classes, Roger encouraged students to figure out solutions to any issues they encountered. He asked students to explain their ideas by saying things like, “Can you show me what that would look like?” or “That’s a good question. How would you do it?” (Observation 10.1.19). Instead of telling students how he would solve their problem, Roger asked them to figure it out themselves. As students would use the materials to demonstrate what they meant, or as they tried to explain their questions, they would ask even more questions because they were working through these problems on their own. Furthermore, Roger believes that giving students autonomy can instill a sense of pride in them when they figure something out. Of this he said:

> There is something about having a sense of pride that you were able to figure it out on your own. If you get [the answer] from the teacher, it’s a bit detached. It’s not like you discovered anything on your own. (Interview, 9.30.19)

Instead of giving students the answers, Roger encouraged students to work out their problems or find solutions on their own, as a way to encourage autonomy in the learning process.

Summary of the case of Roger. While Roger teaches many courses, classroom observations were only conducted in the Grade 10 Engineering course. This was a course where Roger felt a lot of freedom and flexibility in what he could do. Nonetheless, Roger still felt that his teaching practice was influenced by multiple factors. These factors include: the curriculum given to him, the need to prepare his students for CEGEP, and the need to prepare his students to take the ministry exam. Although affected by these factors, Roger believes that he can still find ways to make learning activities-based and hands-on, methods which he feels allow students to learn best. Furthermore, Roger used many different strategies to encourage inquisitiveness in the Engineering course including: making the learning interesting, modeling question asking, encouraging students to ask questions, refraining from judging students’ contributions, encouraging students to elaborate on their thoughts, and giving students autonomy.

The Case of Noah

Noah teaches Grade 7 Science and Technology, Grade 8 Science and Technology and Grade 11 Physics. Grade 7 and 8 students are required to take Science and Technology as part of their education program. Content covered in the Grade 7 course is added to and built upon in Grade 8. The Grade 11 Physics class consists of students who want to pursue science in CEGEP, and are therefore taking multiple science classes in their final year of secondary school.

Noah is a strong believer that all teaching should include some hands-on activities. Noah describes a typical class to consist of him going over notes then "reinforce[ing] that with some lab or simulation or some kind of activity" (Interview, 9.30.19). Noah also believes that some topics lend themselves more to hands-on activities than others. Of this, he said:

> For some things, the topic lends itself more to doing more practical hands-on experiments. But I think you can at least do some kind of experimentation with everything. I mean even for Grade 7 space science, we do this moon lab where a student is sitting in a chair and they're spinning around and they have a meter stick with ball for the moon on it and then you can see it going through the different phases of the moon. So I think there's always opportunities for experimentation, or if not that, at least simulating an experiment. (Interview, 11.18.19)

Even when it is more difficult to do a hands-on learning activity, Noah feels that it is important to do some sort of simulation or activity for every topic to reinforce the learning.

Furthermore, Noah believes that science should not be taught through memorization. He explained this by saying, "I think [science teaching and class] should try to model what is actually done in the real world by scientists. Real scientists aren't sitting around just memorizing the periodic table or something" (Interview, 11.18.19). Noah continued by explaining what he believes to be commonly occurring in Québec science classes. He said:

> I think the way that science is sometimes taught is in a very rote manner where it's just memorization. I think that's the wrong way to do it. Especially teaching Grade 7, there are a lot of kids who come in and that's what they think science is. It's just like memorize a bunch of stuff about animals of Québec or whatever. (Interview, 11.18.19)

Instead of teaching through memorization, Noah is a firm believer that teachers should teach science in a way that models what scientists in the real world are doing in their day-to-day jobs.

Furthermore, rather than learning via memorization, Noah believes that students should engage in science via activities and experiment. He said, "I think really doing things, doing experiments on things, doing simulations when you can't do an experiment. Taking a participatory part of it I think is a big thing. So the student participation and engagement in science" (Interview, 11.18.19). Noah believes that students' participation in science is necessary for their engagement in science and that the way to achieve this engagement and participation is through hands-on activities and simulations.

Finally, Noah expressed that it is important to set the norm that students can be wrong and make mistakes. He justified this by discussing the classroom norms that he created for his classroom. These norms are posted on the wall for every student to see. Noah said:

> The last class norm that I have is to be wrong sometimes. I expect [students] to be wrong sometimes. I expect [students] to make mistakes but learn from those mistakes. I expect [students] to say "I don't know" rather than just making something up. There are times when "I don't know" is the right answer. There are times when there isn't just one right

> answer. When there could be multiple correct answers, or multiple answers that are all bad and [students] have to choose the least bad of them. (Interview, 9.30.19)

Noah includes making mistakes in his classroom norms because he believes that when students make mistakes, they are able to learn more and gain a better understanding for the future.

Noah believes that students are inquisitive when they ask a lot of questions. He said, "[Inquisitiveness is] getting them to ask those questions and to be invested and motivated in those questions" (Interview, 9.30.19). Furthermore, Noah believes that having students ask questions is intricately tied in with inquiry-based instruction. He said:

> I always really encourage [question asking] which really ties with the whole inquiry-based learning. So I know sometimes I feel that I get a little too easily distracted when a student asks a good question that's sort of tangential to what we're talking about in class. But if it's like a good question then I kind of want to go down that path 'cause I think that's what science is all about. (Interview, 11.18.19)

Noah states that questions are tied to inquiry-based learning, and that they are the basis of what science is about, which is why he believes it is important to encourage questioning in his class.

Noah also believes that inquisitive students are active in the learning process. When asked what it means for students to be inquisitive, he said:

> I think that it means that students should be engaged in the learning process in more than just a target for knowledge to stick to. Like it shouldn't just be me spewing out information and them just receiving it. They should be not passive like that. (Interview, 9.30.19)

He added, "They should be an active partner in the learning so that they are asking questions, trying to figure things out on their own, or in a group work kind of setting" (Interview, 9.30.19).

According to Noah, students are inquisitive when they are fully engaged in the learning process, not just listening to the teacher tell them information to remember.

Noah's ideal classroom would involve students asking questions and figuring things out. He said:

> I think that being able to have that opportunity to ask questions and then to try to figure out answers other than just googling it, like let's try to do an experiment and figure that out. I guess my golden rule is two parts if I have to sum it up. Being able to ask questions and being able to do something to try to find the answer. (Interview, 11.18.19)

Noah believes that it is important that students work to figure answers out on their own and problem solve by doing experiments. By doing so, students will remain inquisitive in science class.

Factors influencing Noah's teaching practice. Noah reflected on different factors that influence his teaching practice. These factors include: the mandated curriculum given to him at The Ocean School, the necessity to prepare his students for the next level of education, and the focus on preparing students for standardized exams.

Meeting the goals of a mandated curriculum. Noah believes that the curriculum mandated by the Québec government sets targets for him to meet in his courses, however, Noah feels less pressured by the curriculum for his Grade 7 and 8 Science and Technology classes. In these classes, Noah feels more freedom because his students will continue to build upon these concepts as they move through their secondary school career. He elaborated:

> [Grade 7 and 8 science teachers] don't have to follow a certain textbook, or be teaching this lesson on that day, so a lot of it is just generated by ourselves, just to make sure that

> we meet those final goals [set by the curriculum]…How you go into those concepts is up to each teacher because we're not beholden to a specific textbook. (Interview, 9.30.19)

As the curriculum is less specific in the younger grades regarding how the material should be covered and when, Noah feels more freedom and flexibility in his teaching practice for the Grades 7 and 8 courses.

Noah believes that the mandated curriculum makes it more difficult to implement inquiry-based learning in his courses. He feels that the student-centered aspect of inquiry-based instruction proves challenging for teachers to meet curricular goals. He said, "So I think like full 100% inquiry, with the students actually driving the curriculum, might be a little hard to do in the classroom because we have a curriculum we gotta be aiming towards" (Interview, 9.30.19). Therefore, as inquiry-based learning has the potential to take away from teaching the mandated curriculum, Noah feels that he has to limit the amount of inquiry that he can incorporate into his lessons. Noah believes that the curriculum has an impact on how much inquiry he can incorporate into his classroom because he believes that inquiry can take away from teaching the mandated curriculum.

Preparing students for the next level of education. In addition to teaching Grades 7 and 8 Science and Technology, Noah also teaches one section of Grade 11 Physics, and he reflected on feeling the pressure to prepare his students to succeed in CEGEP and university. He believes that preparing his students for CEGEP and university takes time away from his ability to go in-depth on topics of his choice or stifles his ability to do other activities. For example, Noah said:

> Of course for something like Grade 11 Physics, there's the added stipulation that we have to make sure that we're preparing them for CEGEP and university programs, so whereas in Grade 7 and 8 I have a bit more flexibility, I can spend more time on space and less

> time on something else, but in Grade 11 I've got to make sure that they've got all the basics that they need for their future science courses. (Interview, 9.30.19)

Noah feels limited in what he can do in his Grade 11 Physics course, as he is responsible for preparing his students for future science courses in CEGEP and university.

Preparing students for standardized exams. During this study, Noah did not teach a science course that prepared students to take a ministry exam, but he reflected on the one year that he taught Grade 10 Science and Technology and the pressures that this exam caused him to feel. He Noah said:

> I think [the QEP is] a bit more strict in Grade 10 because that's the only science course where there's a ministry exam and then like, you have to be using the exact terminology that the ministry uses. Even if you understand the concepts, if you don't use the exact same words and some of the words are counterintuitive there, then that could penalize [a student] in the final exam which counts for a lot of [their] grade. (Interview, 9.30.19)

Not only does Noah feel that the ministry exam impacts the content covered in Grade 10, but he also notes how this high-stake exam can influence the words that teachers use in their teaching practice, in order to set their students up for success on this exam.

Noah also believes that the ministry exam gives teachers less time for "quality learning" and impacts how teachers teach because of the quantity of material that they have to fit in (Interview, 11.18.19). Specifically, Noah feels that the standardized exams take away from the teacher's ability to teach in more meaningful ways, especially through pedagogies like inquiry-based instruction. Of this, Noah said:

> I do feel that [the ministry] exam at the end does sort of take away from a teacher's ability to do more in depth inquiry-based learning because by necessity you're sort of teaching to

> the test. You can have some inquiry-based stuff that targets that, but a lot of those standardized exams I think are going to be fairly multiple choice, memorize the answer kind of situations. I'm not a huge fan of standardized testing, but it's a necessity in some courses. (Interview, 11.18.19)

The ministry exam highly impacts what Noah feels Grade 10 teachers can do in the classroom because of the amount of content to be covered, as well as the limited amount of time that teachers have to cover the content. As a result, he feels that these exams limit his ability to implement teaching techniques that would produce quality learning, such as inquiry-based instruction.

Strategies to encourage student inquisitiveness. Noah used many strategies to encourage student inquisitiveness in his classroom. These include: making the learning interesting, modeling question asking, encouraging students to ask questions, refraining from judging students' contributions, encouraging students to elaborate on their thoughts, and giving students autonomy.

Making the learning interesting. Noah made the learning interesting for his students in different ways which engaged students and prompted question asking in his courses. He did so by making connections to the real world and by giving students different representation forms to explore the science content.

Noah's Grade 8 classes on renewable and non-renewable energy resources were full of rich discussions and questions from students, as Noah made many connections to the real world. These topics created a lot of discussion in the class and between students as students were able to relate to the content. Questions arose when Noah brought up greenhouse gases, the difference between fog and smog, when he asked students to determine the pros and cons of renewable and nonrenewable energy resources, and when he brought up the creation of fossil fuels. Yet, even more questions arose when Noah began discussing real-world problems with his students. Discussions involved topics such as: heavy metals, mining and the damage that it is doing to Alaska and Antarctica, the pros and cons of nuclear reactors, how wind turbines and hydro dams work, how solar panels are used, and what technologies could exist in the future. Noah increased discussion and inquisitiveness in his classroom by bringing up "big issues, global issues" that seemed to grab students' attention (Observation, 10.2.19).

Noah did his best to make his classes relatable to his students' lives in order to encourage inquisitiveness. He believes that students find it more interesting when science interacts with society and influences their lives, which in turn, causes them to ask more questions. For example, Noah explained:

> When science intersects with society there are a lot of things that are not straight forward answers. So that's why I think it's a good reason to discuss those things and debate those things and look at all of the different sides of it. (Interview, 9.30.19)

Therefore, because the interactions of science with society can have so many different sides to the story, it becomes an interesting discussion and debate for the students and causes them to ask many questions. This point was evidenced in a few classes, for example, content related to renewable and non-renewable energy sources in his Grade 8 classes, and content related to space science in his Grade 7 classes. Students seemed to know about these topics not just from science class, but from the media, news sources, and daily conversations which fostered more interest in the topics.

Noah believes that when topics are related to students' lives, students become more interested and ask more questions. He said:

> [Student inquisitiveness] is totally based on student interest…That engagement is I think one of the key things for inquiry. It has to be something that engages them so that's why I try to pick things that influence their real lives. (Interview, 9.30.19)

In order to further elaborate on this point, Noah described a debate project that he assigns to his students, based on artificial sweeteners. For the purpose of this project, students were each given one artificial sweetener that they needed to research in order to learn more about the pros and cons of their sweetener. At the end of the research, students engaged in a debate where they tried to decide which artificial sweetener was the best and the one that should continue to be used. Noah believes that this activity was easily relatable to students' lives, as these artificial sweeteners were ones that his students see in many of the candies and foods that they eat. As these were topics that students could relate to, they asked many questions to enhance their understanding of the concepts. Therefore, by choosing content and assigning projects that students can relate to their own lives, Noah believes that students will be more engaged and ask more questions.

In addition to grabbing students' interest through real-world contexts that were relatable to students' lives, Noah made the learning interesting by bringing up more abstract topics, such as space science, which also generated discussion and questioning. While space science is still a real-world topic, it is one that is much less tangible for students, making it appear much more abstract and foreign, yet equally fascinating. For example, one abstract topic that Noah had the students explore was about how people experience time in different ways on different planets. Noah explained that people travelling in space would have thought that five years had passed, whereas people on Earth would have thought that ten years had passed. This resulted in many questions and elaboration on both the students' and Noah's part. Students were very interested in knowing why time is experienced differently on different planets and began asking questions about what would happen if they traveled to another planet and left their family and friends on Earth. This was an abstract discussion as students had never experienced the phenomenon being discussed and had no connections to anyone who had, or to any similar experience. This led to another discussion about the length of years on Earth compared to other planets. This topic brought up many questions about leap years and how they factor into measuring Earth years and then a general discussion about how years are calculated on different planets when compared to on Earth. Noah started discussions using abstract content that prompted much interest and curiosity in his students, resulting in many questions from his students.

In addition to making the content relatable to students' lives and introducing abstract topics, Noah used different representation forms through which students could explore science content. One such representation form was videos. Noah used videos to spark interest and questions with his students. For example, in his physics class, he showed a Mythbusters video that included kinematics concepts that had been discussed in previous classes. This video showed a car going off of an elevated jump and flying through the air, which prompted questions about what would happen if the car were lighter, going faster, or if the jump was not elevated as much. As another example, in Noah's Grade 7 class, he showed a video of a meteor hitting a town in Russia, which prompted many questions about what students saw in the video and about meteors striking the Earth. Students wanted to know what their experience would be like if a meteor struck the Earth near them and they were curious to know why meteors can even strike Earth in the first place. During another lesson in his Grade 7 class, Noah showed a video on the Earth's moon which led to a discussion and many questions about the tides, gravity, and if the moon could ever become a planet. Additional examples of Noah's use of video occurred in his Grade 8 class when he showed videos about the history of fossil fuels, the different types of hydro dams and solar power. Students were asking questions about how scientists made the move to renewable energy such as hydro and solar power and wanted to know more about how they work to generate energy.

Noah's use of videos aligns well with why he likes to show his students videos. He believes that videos have the potential to grab students' interest and promote question-asking. Noah said:

> I started doing this thing where, at the beginning of class, I usually start off with a video, for a few reasons. Usually the video is connected to what we're learning in class, just to get them more interested in it because sometimes seeing a flashy video will get them more curious about something or get them more interested in something, as opposed to just seeing it on a handout or notes… And if it is related to the topic, hopefully it gets them interested in that topic and gets them asking questions, inquiring about that topic (Interview, 9.30.19)

Noah's beliefs aligned with his actions in class, as he shows videos to encourage question-asking and discussion, and his decision to show videos seemed to have the intended effect on the students, as they allowed for students to ask many questions.

Another representation form that Noah used to make the learning interesting was interactive websites. These websites were used to spark curiosity and questioning in his students. For example, in his Grade 7 class, Noah asked students to explore a Solar System Scope website[2] to help them determine the length of a year on different planets. This online model of the Solar System allows students to manipulate different planets with their track pads, interact with

[2] https://www.solarsystemscope.com/

planets' rotational periods compared to other planets, and access information such as the planet's structure, composition and temperature by clicking on different hyperlinks. The visuals on this website and the students' exploration led to questions and discussions about different planets as well as the sun. This interactive nature of the website allowed the students to be active in the learning process, therefore providing more opportunities for questions and discussions. Noah's use of interactive websites allowed his students to interact with the science content in ways that engaged them and allowed them to ask questions.

Modeling question asking. By modeling question asking, Noah encouraged inquisitiveness amongst his students as he demonstrated which types of questions they could be asking. Of this, Noah said, "I encourage questions but I guess I only lead by example, like giving them questions that we are going to be addressing and they see different ways of asking questions" (Interview, 11.18.19). Therefore, in leading by example, Noah implicitly modeled question asking for his students, encouraging them to ask questions in different ways.

Noah also asked questions that allowed students to think about the bigger picture of what they were learning. In a class about fossil fuels, Noah posed the question, "Why do you think so much of the world uses fossil fuels?" (Observation, 10.2.19). By asking such a question, Noah gave his students the opportunity to connect their class learning to a bigger picture about the world and why so many people and nations use fossil fuels. As a result, students began asking more questions about fossil fuels and how they could convince more people to invest in renewable energy. Noah modeled questions that relate to the bigger picture, to encourage his students to do so as well, and to demonstrate what types of questions his students can ask.

Explicitly encouraging students to ask questions. Noah encouraged students to ask questions, especially in times when he felt that students might have questions to ask. For example, in these moments, he would say, “Oh did [you] have a question?” (Observation, 10.2.19). Furthermore, Noah offered words of encouragement to motivate students to continue asking questions, so as not to shut down their question asking. For example, in one class Noah said, “A lot of you are asking questions about this which is good!” (Observation, 10.7.19). By using these phrases, Noah demonstrated to his students that they should continue asking questions because their questions are contributing to the class in positive ways.

Refraining from judging students’ contributions. Noah was very supportive of his students who asked questions, which in turn, prompted more question asking. When students asked questions, Noah responded with statements such as, “Yeah that’s a good question…I don’t actually know that” (Observation, 10.2.19) and “That’s a very good question” (Observation, 10.7.19). In one instance, a student asked a question about the history of fossil fuels. As Noah did not know the answer to the question on the spot, he followed up on the student’s question in the next class. Noah answered his student’s question by explaining that he found a video to help him answer the question. He said, “Someone asked a question last time about the history of fossil fuels so I found a video that talks a bit about the history” (Observation, 10.7.19). By responding to his students’ questions in these ways, Noah demonstrated to students that any question is accepted and will not be judged in the hopes that this would open up the floor for them to ask more questions. Furthermore, even when he did not know the answer to a question, Noah did not shut the question asking down, but instead, indicated that research needed to be done to figure out the answer, or came to the following class having figured out how he could help answer the students’ questions.

Encouraging students to elaborate on their thoughts. Noah found different ways to encourage students to elaborate on their thoughts in order to encourage further questioning and learning. He elaborated on this thought:

> Instant gratification of knowing you have the right answer isn't going to lead to as much learning compared to if you have to think about why you have the right answer, what's the reason that answer is right…[the students] justify it to themselves. (Interview, 11.18.19)

By asking students to justify their thoughts, he feels that he avoids the possibility of he, the teacher, "shut[ing] down [the] inquiry" (Interview, 9.30.19). Noah gave an example of a scenario in his Grade 8 science class to further illustrate this point. He said:

> One student had an example of a person as a simple machine and then others were like well no a person isn't a machine. So, I asked them all "Why would you say that, how would you justify it?" And they would say well people have different parts that have different functions and they use energy. So, it was an interesting way to get to the end goal of having a definition of what a machine is. By having ideas up there, some that could be right and some that could be wrong and going through those and discussing them as a class and trying to get to a final consensus about what it is. (Interview, 11.18.19)

During this discussion about humans as simple machines, Noah pressed his students to explain their thoughts in order to help all students grapple with the points being made, and ultimately come to a consensus understanding about the comparison being made. In order to encourage student inquisitiveness, Noah asked his students to elaborate on their thoughts, which allowed them to further question and justify their thoughts and ideas.

Giving students autonomy. Noah gave students different opportunities to be autonomous in his classes, as a way to encourage student inquisitiveness. One way in which he did so was by asking students to solve problems on their own, without his help. For example, Noah gave his Grade 8 students a list of facts about renewable energy sources then had them determine the pros and cons of those energy sources. He said, "I haven't told you which ones are pros and which ones are cons. It's up to you to figure that out" (Observation 10.2.19). Instead of telling students the answers, Noah gave them the task of figuring them out.

Another way that Noah encouraged autonomy was by giving students individual research projects. For example, Noah planned a debate project where the students were assigned a country on which they would be an expert. The project asked students to research their assigned country's energy production and usage, in order to prepare them to hold a United Nations (U.N.) type conference at the end. When introducing this project Noah said:

> We are going to hold a U.N. type debate where you will be presenting about how your countries use energy, and you will be given a challenge and your countries will debate and try to figure out a way to solve the challenge as a global community. (Observation 10.9.19)

While preparing for the debate, students had many questions about their countries' uses of energy. When students tried to ask Noah for help, he encouraged them to be autonomous, which provided further opportunities for student inquisitiveness. Therefore, students acted autonomously in trying to solve the problems that emerged in class and during their research, which encouraged inquisitiveness.

Furthermore, Noah fostered autonomy by encouraging his students to work together in pairs or groups when they were struggling. For example, while completing the pro and con activity, one student had a question. Noah responded to the student by saying: "Well that's why I want you guys to discuss [in your groups]" (Observation 10.2.19). As a result, students worked together, without Noah's help, asking questions to help them determine the best solution to the problem they were given.

Noah was conscious about explicitly asking his students to collaborate. Noah encouraged this collaboration because he thought that his students would "understand [a concept] more, if they worked towards [an understanding] together instead of just hearing [an answer from the teacher]" (Interview, 9.30.19). As students collaborated on the pro and con activity they asked each other questions and problem solved before turning to Noah to get the answer. By encouraging students to collaborate with each other, Noah gave the students autonomy and put the work of figuring things out and asking questions on the students themselves.

Noah believes that giving students autonomy increases opportunities for inquisitiveness. When asked why he thought group work encouraged opportunities for student inquisitiveness, Noah said:

> I might be like "Okay, you think that, any other ideas, now which of those ideas are correct?" And I get them to discuss it, again getting them to think about it more before I confirm which one is the right answer. Because, if I do that, then that kind of shuts down any inquiry. (Interview, 9.30.19)

Therefore, Noah believes that collaboration is a necessary component of student inquisitiveness, as it gets students to think, discuss and come to conclusions on their own, without the thoughts or opinions of the teacher influencing their thought processes and questions.

Summary of the case of Noah. Noah is a strong believer in making learning as relatable and hands-on for students and tries his best to do so in every class. In his Grade 7 and 8 Science and Technology classes, Noah feels that he has the flexibility to do what he wants, while finding ways to meet the requirements of the Progression of Learning. As a result, classroom observations demonstrate how Noah used different strategies to encourage inquisitiveness in his class. These strategies included: making the learning interesting, modeling question asking, refraining from judging students' contributions, encouraging students to elaborate on their thoughts, and giving students autonomy. Finally, Noah worked hard to grab his students' interest and attention by including interesting discussions and assignments in his curriculum. He believes that these are the best ways in which to encourage students to be inquisitive.

Chapter 5: Discussion

This research study focuses on the ways in which science teachers can encourage student inquisitiveness in their courses, while also taking into account the factors that influence their teaching practice. Ultimately, by performing this study, I hope to gain insight on how to encourage student inquisitiveness in my own science class as a steppingstone towards inquiry-based instruction. In this chapter, I describe how the findings from the cases of Lilian, Roger and Noah, as well as how information gathered in the literature review, answer the research questions posed in Chapter 1.

Discussion of Each Research Question

Question 1: What factors influence how these teachers teach and in what ways?

There are different factors that exist that influence how teachers teach. While these factors may differ in different school contexts, there were three main factors that influence teachers at The Ocean School. These factors include: meeting the goals of mandated curriculum, preparing students for the next level of education and preparing students to take standardized exams.

Meeting the goals of the mandated curriculum. As teachers at a secondary school in Québec, all three participants in this study had to meet the goals prescribed to them by the mandated provincial curriculum. The goals they had to meet, and the flexibility they felt within this curriculum, varied between teachers.

All three teachers participating in this study felt that the Québec Educational Program (QEP) and the Progression of Learning influenced their teaching practices, as these documents dictate the content that needs to be covered in a school year. The participants agreed that the curriculum they were required to follow in a school year can be very prescriptive. They all agreed that they must adhere to a specific curriculum, which took away opportunities for them to go into depth on topics that they find interesting, important, or ones that they care about. While all three teachers in this study agreed that the mandated curriculum can be quite restrictive, some specified that they felt less pressure from the curriculum in the younger grades.

The participants who taught younger students, Grades 7 and 8, felt that they had more flexibility in teaching towards the mandated curriculum. Specifically, although Roger and Noah taught all grade levels, they felt less constricted by the mandated curriculum in Grades 7 and 8 as there are fewer topics to cover. Furthermore, the progressive nature of the topics covered in these grades, meaning they will be revisited in future grades, allowed the teachers to feel more freedom to focus on what they deemed as important for their students to learn. Because the mandated QEP and Progression of Learning do not prescribe as much content to be covered in Grades 7 and 8, teachers felt more freedom to vary their teaching practice, as well as to cover more content that they choose.

When teachers are required to adhere to a specific curriculum, they feel the impacts of this curriculum on their teaching practice. The extent to which the teachers in this study felt the impacts differed depending on the grades they teach. These sentiments are consistent with Hurley (2004), Osborn et al. (2000) and Schweisfurth (2006). Specifically, teaching towards a mandated curriculum results in teachers feeling unable to teach towards their interests or passions (Hurley, 2004), as well as preventing them from implementing new pedagogies (Osborn et al., 2000) because of the pressure they feel to help their students succeed in reaching the goals set by the curriculum (Schweisfurth, 2006). Findings from this study suggest that teachers who teach younger students feel that they have more flexibility with the mandated curriculum, while those who teach older students feel that with increased content to cover, and little time, they need to follow the guidelines in order to help their students succeed. It would be interesting to consider how teachers find ways to make connections to content about which they are passionate, while still managing to meet the goals of the mandated curriculum.

Preparing students for the next level of education. In addition to meeting requirements set by the mandated curriculum, the teachers participating in this study were also aware of their job to prepare students for the next level of education. All three teachers agreed that the pressure to prepare their students for CEGEP and university impacted their teaching practice. They felt this pressure as an obligation to prepare students for future science courses. More specifically, they felt that in order to adequately prepare their students, they should cover as much content as possible, while also being aware that it was essential that their students understand the material being covered. Furthermore, the pressures associated with preparing students for the next level of education, impacted *how* the teachers participating in this study delivered the content they were required to teach. For example, while Noah would have like to vary his teaching methods in his Physics class, he felt that he was unable to do so, and expressed that the stress of preparing students for the next level of education suppressed his ability, or willingness, to give a variety of activities in class.

Many teachers are required to prepare their students for the next level of education. As a result, these teachers may feel limited in what they can do in their classrooms because they feel pressured to do what is deemed best to prepare students for the next step. For many teachers, what is best is to strictly follow the curriculum given to them, even if covering a wide range of topics goes against their beliefs. Similar to findings by Schwartz et al. (2008), the teachers in this study attempted to balance depth and breadth, along with understanding. While some teachers believed it was better to focus on breadth, others believed that depth was more important when preparing students for university and future science courses (Schwartz et al., 2008). For example, Lilian grappled with covering as much content as possible while also making sure to consider if her students understood what was going on. Therefore, it is important to consider how teachers' awareness of preparing students to enter the next level of education influences what they do in the classroom. Furthermore, it is interesting to consider if this type of teaching takes away from the possibility for meaningful learning in the classroom.

Preparing students for standardized exams. A third factor to consider when examining teachers' practices is the requirement for some teachers to prepare their students to take standardized exams. In the cases presented in this thesis, both Lilian and Roger were preparing their Grade 10 students to take a ministry exam, while Noah had one year of experience of teaching the Grade 10 science class. The teachers experienced the pressures of preparing their students for standardized exams in slightly different ways.

Both Lilian and Noah felt that the need to prepare their students to take the ministry exam greatly impacted their teaching practice. They felt the pressure of adequately preparing their students to succeed on this exam, which impacted how they organized their classroom activities. For example, Lilian felt that it was important to give students individual work, such as quizzes and tests, in order to give them assessments that were similar in format as the ministry exam. Noah felt that he was limited in terms of how much inquiry he could incorporate into his classroom activities, as this was not how students would be assessed on the ministry exam. Lilian and Noah taught in ways that they believe would enable their students to perform well on the exam, even if these methods went against their teaching beliefs. In these two cases, the ministry exam weighed heavily on the teachers and altered their teaching methods because of the strong pressure they felt to enable their students to succeed.

Roger felt slightly less restricted by the ministry exam than Lilian and Noah. While he recognized that his students should be prepared to take the exam, he expressed that he still tried to find ways in which to make this learning for the exam more fun. He recognized the importance of covering all of the topics mandated by the government, but even so, felt that he could change up his teaching methods and still meet these goals. There is the possibility that Roger would feel comfortable teaching his Grade 10 course using a reform-based pedagogy, such as inquiry-based instruction, even while preparing his students to take a ministry exam. It is interesting to consider what further support and guidance he would need to do so.

While most teachers are subject to follow a mandated curriculum some also have to use this curriculum to prepare their students to take standardized exams. As a result, teachers may feel great pressure to meet the requirements of these exams and teach in ways which will help their students succeed. Similar to findings from Boyd (2010), the teachers participating in this study felt that they were highly accountable for their students' performance on the ministry exam, and wanted to be sure that they taught and assessed their students in ways that mimicked what they would see on the exam. Furthermore, this focus on preparing students to take standardized exams can "sideline reform efforts in education" (Anderson, 2011, p. 117). The case of Lilian demonstrates that the pressure to prepare students to take the ministry exam may have possibly prevented her from implementing reform pedagogies such as inquiry-based instruction, out of fear that she would prevent her students from succeeding on the exam. It is interesting to consider how teaching in other ways, for example, by using inquiry-based instruction, could impact students' scores on standardized exams such as the ministry exam required of students taking Grade 10 Science and Technology in Québec.

Summary of Question 1. Teachers participating in this study felt that different factors such as curriculum, preparing students for the next level of education, and preparing students to take standardized exams, influenced their teaching practice. The weight they felt from these different factors ultimately depended on the courses that they were teaching. Lilian's teaching practice was impacted the most by these factors as she only taught upper level courses. She felt especially constricted by her job to prepare her Grade 10 students to take the Québec ministry exam at the end of the year. As a result, she made sure that her teaching practice, as well as the assessments that she gave her students, mimicked what they would see on the exam. Roger and Noah, who, in addition to teaching upper level courses also taught Grades 7 and 8, felt that their teaching practice was slightly less impacted by these factors. While they recognized that they must meet the goals set by the QEP, they felt that they had more flexibility in how they taught the content to their students. Furthermore, Roger and Noah felt more freedom to try to implement different teaching practices in their courses, such as inquiry-based instruction.

Findings suggest that no matter what courses teachers teach, they will in some way be impacted by factors of which they have no control over. The extent to which teachers feel the impact of these factors may be related to which courses they teach. Findings from this study suggest that teachers who teach across levels, for example Grades 7-11, feel the impacts from these factors less than teachers who teach only upper level grades.

Question 2: What teaching strategies do these teachers use to encourage student inquisitiveness and why do they use these strategies?

Different researchers have proposed many strategies that teachers can use to encourage student inquisitiveness. These strategies include: giving students time before and during activities to ask questions, making the learning interesting, giving students question words and starters to help them form their questions, modeling question asking, explicitly encouraging students to ask questions, refraining from judging students who contribute, asking students to record their questions, using a question board to publicly record all student questions, encouraging students to elaborate on their thoughts, and encouraging student autonomy.

The cases of Lilian, Roger and Noah demonstrate the use of some of these different strategies in the classroom, as well as why these teachers choose to use specific strategies for student inquisitiveness. All three teachers used most of the strategies described above, but to varying degrees.

Making the learning interesting. Lilian, Roger, and Noah each found ways to make the learning interesting for their students, which prompted further questioning. They did so by giving students different representation forms to explore science content and by making connections to the real-world.

Lilian and Noah both provided their students with interesting representation forms to explore science content, ultimately resulting in rich discussions taking place in class, as well as in questions from their students. For example, both Lilian and Noah used videos as a means to allow students to explore science content in a different way. As Noah explained, videos are useful as they capture students' attention and interest in a different way than a lecture might do. In addition to videos, both Lilian and Noah used different visuals to gain their students' interest. Lilian used images, while Noah used interactive websites, which gave students different means to explore the content being covered. The use of videos and other visuals were valuable representation forms to promote questioning in both Lilian and Noah's courses.

Another useful approach that resulted in many questions was Noah's effort to connect classroom content to real-world topics. As a result, students were immediately engaged, discussing with one another and asking many questions. These connections to the real world were made during in-class discussions and were also made through different assignments that Noah assigned. Students demonstrated engagement, were invested in discussions, and asked questions because they were able to relate to the content.

Similar to Lilian and Noah, Roger also gave his students different representation forms to explore science content; however, these representation forms came in the form of physical materials and manipulation of those materials. Instead of telling students how they could manipulate different tools in the workshop to achieve their desired results, Roger provided the space for students to explore these tools and materials on their own. As a result, students asked questions, discussed with one another, and continued their exploration until they found the best solution to their problems. The use of physical materials was a useful context for students to explore science content, ultimately resulting in questioning.

While Lilian, Noah and Roger found different ways to make the learning interesting for students, all methods were successful in promoting question asking from students. These methods allowed for student questioning as students were surprised, engaged and wanted to know more (Biddulph et al., 1986; Chin, 2002). Furthermore, findings suggest that it was beneficial when the teachers connected the learning to the real world, as students were able to see the influence of classroom science content in their own lives (Hampden-Thompson & Bennett, 2013; Harmer & Cates, 2008; Jocz et al., 2014; Stroupe, 2014; Tan & Seah, 2011; van Zhee et al., 2000). Indeed, all three teachers made the learning interesting for their students in different ways, which resulted in questioning from their students.

Modeling question asking. Lilian, Roger and Noah modeled question asking by demonstrating to students how they could use questions to move further in their projects or understanding of a concept. For example, Lilian and Noah modeled questions that showed students the importance of thinking about the bigger picture of what was being studied or discussed. Roger reflected on the importance of modeling questions that allowed students to think about why they are getting certain results, as he believed it was important that students are constantly asking themselves these questions to move further along in their understanding. By modeling these types of questions, the teachers participating in this study provided their students with insight into what types of questions they can be asking themselves.

Additionally, Lilian modeled questions that can be asked simply out of curiosity. She showed students that even when a question is different from what they are "required" to do, these types of curiosity questions are still useful and should be asked in the classroom. Therefore, by modeling curiosity-type questions for her students, Lilian hoped that her students would follow suit and ask similar questions and be equally curious.

The teachers participating in this study found different ways to model question asking. In order to support their students in being inquisitive the teachers modeled how questions can be asked and the results that these different types of questions can produce (Biddulph et al., 1986; Chin, 2002). By modeling question asking, the teachers also established the norm that questions should be asked during class, as they, the teachers, were asking many questions themselves (Chin & Osborne, 2008). Lilian, Roger and Noah modeled questions in different ways, therefore providing their students with different question asking tools to use in the future.

Explicitly encouraging students to ask questions. Roger explicitly encouraged his students to ask questions by making it a course requirement that they do so. For example, during student presentations of their forklift models, Roger required the audience to ask questions and reminded them that they would be evaluated on their question asking during the presentations.

Roger made it a requirement that his students ask questions because he believed that it was important that all students were involved in helping each other move further along in their projects. By asking students to ask each other questions about their individual projects, all members of the class became actively engaged in the learning process. Furthermore, Roger made sure to remind students that they should ask questions, not only because doing so was part of their final mark, but because when they are confused about something, or want to know more, asking questions is one way in which to further their understanding. By explicitly having students ask questions, Roger made it the expectation that questions should be asked, and that, indeed, questions are required during class.

Unlike Roger, Noah did not make it a course requirement that students ask questions, but instead paid attention to students' body language, especially in times when students may have had more questions. In doing so, Noah was able to recognize when a student had a question and called on that student to ask their question. Furthermore, even when their body language did not suggest that they had a question to ask, Noah reminded students that asking questions is a good thing to do in class. As a result, Noah explicitly encouraged his students to ask questions.

Both Roger and Noah found different ways to encourage their students to ask questions. Their choices in how they encouraged students to ask questions are consistent with Chin (2002), who explained that it is important to find ways to explicitly ask students to ask questions. As Chin (2002) described, both Roger and Noah found times to ask their students, directly, what questions they may have before moving on, which provided them with opportunities, and encouraged them, to ask questions during class. It is interesting to consider how Roger and Noah used their students' body language as a clue into when they had questions. As Wells (2017) found, students' body language can tell a teacher a lot about what students do and do not understand. When students understand something, their body language and gestures become much bigger and more animated, as they feel more confident with the material. In this sense, teachers can stand back while students work while still being able to observe the learning taking place (Wells, 2017). Therefore, Roger and Noah's students' body language may have signaled that they did in fact have questions, which led these teachers to encourage their students to ask their questions.

Refraining from judging students' contributions. Roger and Noah both found ways to refrain from judging their students' contributions and questions in class. Both teachers never shut down their students' questions or contributions and instead helped students realize that their contributions were valuable to the rest of the class. Roger explained that it is important that students feel safe in the classroom environment to ask questions, because all students should feel able to add to the discussions taking place, and should never be afraid to ask a question. Furthermore, even when the teachers did not immediately have the answer to the question, they reassured their students that they would find the answers together or in subsequent classes. By refraining from judging students' contributions, and by accepting all questions, Roger and Noah worked to promote a question-asking environment in their respective classrooms.

In order to encourage inquisitiveness in the classroom, teachers should be aware of the ways in which they respond to students' questions and contributions, making sure that they refrain from judging their students. Instead of judging what their students have to say, and possibly limiting question-asking, Roger and Noah received students' questions and contributions with "sensitivity and enthusiasm" (Chin, 2002, p. 63). Furthermore, by maintaining a positive attitude with all contributions and questions, these teachers demonstrated to their students that their ideas and questions were more than welcome in the class and that they were happy to hear these ideas being shared (Chin, 2004). As Stroupe (2014) found, when teachers refrained from judging their students' contributions, students were more likely to share their ideas and ask questions, compared to students whose contributions were evaluated as right or wrong. Therefore, by establishing a positive classroom atmosphere, and by receiving all student ideas and questions without judgement, Roger and Noah worked to encourage inquisitiveness in their classrooms.

Encouraging students to elaborate on their thoughts. Lilian, Noah, and Roger found ways to encourage students to elaborate on their thoughts, providing them with opportunities to reason through their thinking and ask more questions. The teachers used elaboration as a tool to determine what students were thinking and to help their students problem solve and reach an understanding of the content being discussed or of the task at hand. Lilian, Roger and Noah pressed their students' thinking in order to encourage them to think more about something and arrive at an understanding on their own, instead of being given the answer. Furthermore, by pressing on their students' thoughts, the teachers provided their students with opportunities to ask questions about what it was they were explaining. Noah believed that elaboration is an important tool to use in the classroom as it can encourage further questioning and increase student learning. By pressing on their students' thoughts and encouraging them to elaborate, not only did the three teachers gain insight into their students' thinking, but they also demonstrated what their students can do to ask more questions.

Providing students with the opportunity to elaborate on their own thoughts or questions, can increase their potential for inquisitiveness in the classroom (Chin & Osborne, 2008). Furthermore, elaboration can increase classroom talk and debate amongst students, providing others with the opportunity to ask their own questions (Chin & Osborne, 2008). All three teachers participating in this study found ways to encourage their students to elaborate on their thoughts, their ideas and their questions. Specifically, teachers in this study pressed students on their contributions to have them elaborate on their thoughts. Windschitl et al., (2012) and Hlas and Hlas (2012) both suggested that pressing on students' thinking provides more opportunities for elaboration and subsequent questioning and reasoning. Chin and Osborne (2008) found that by engaging in elaboration dialogue, students were able to build more connections between ideas and their questions, and they, as well as the teacher, were able to evaluate their understanding of an idea or concept. By encouraging their students to elaborate on their thoughts, Lilian, Roger, and Noah encouraged their students to work towards an understanding of a concept, which, in some cases, prompted further questioning.

Giving students autonomy. Participating teachers found different ways to encourage student autonomy in their courses in order to provide students with opportunities to be inquisitive in science class. To do so, the teachers found ways to encourage their students to work without their help. Lilian, Roger, and Noah also encouraged students to work with their peers and found ways to guide their students without giving them answers and instead asked them how they would solve the problem on their own. As a result of being asked to do things autonomously, students consulted and bounced ideas and questions off of one another. Noah expressed that it is important to encourage students to work independently from the teacher because autonomous work leads to a stronger understanding of the content as well as possibilities for more inquiry in the classroom. By encouraging their students to work with their peers, the teachers gave their students opportunities to ask each other questions and to work together to find an answer, before asking the teacher for help or confirmation.

Teachers can encourage autonomy by being less prescriptive in what they ask their students to do (Dunlop et al., 2013; Vorholzer et al., 2018), giving students choice in activities (Schutte & Malouff, 2019), and by encouraging students to solve problems, without the help of the teacher (Chin, 2002). Furthermore, encouraging students to work with one another can be used as a means to encourage students to solve problems on their own as well as a way to increase motivation amongst students (Chin & Kayalvizhi, 2007). Group work is an important factor in encouraging student inquisitiveness as it allows students to work together, ask each other questions, challenge each other's ideas and reach shared understandings through their collaboration (Woods-McConney et al., 2016). Lilian, Roger and Noah all found ways to encourage their students to be autonomous and usually pressed their students to figure things out on their own, or in collaboration with their peers, before they, the teachers, interjected to help. As a result, these teachers encouraged inquisitiveness in their students by having them try to reach an understanding on their own.

By allowing them to be autonomous in the classroom, teachers provide students with opportunities to ask questions and solve problems independently, which increases the potential for student engagement, curiosity and interest in science (Dunlop et al., 2013; Jocz et al., 2014; Schutte & Malouff, 2019). Indeed, teachers in this study encouraged autonomy in their classes by asking students to solve problems, or figure things out, on their own. As was also discussed by Dunlop et al. (2013), findings suggest that teachers will refrain from prescribing a certain answer or method to their students, and instead ask them to figure it out on their own. As a result of their teachers' actions, students seemed to ask questions because of curiosity and a desire to find the answer, or to know more, echoing findings in the extant literature (Schutte & Malouff, 2019; Stefanou et al., 2004). By asking students to work autonomously, the teachers participating in this study encouraged inquisitiveness in their classrooms.

Summary of Question 2. There are many different strategies that exist to encourage student inquisitiveness in the classroom. These strategies include: giving students time before and during activities to ask questions; making the learning interesting; giving students question words; modeling question asking; explicitly encouraging students to ask questions; refraining from judging students; asking students to record their questions; using a question board; encouraging students to elaborate on what they think; and, encouraging student autonomy.

While they did not use all of the strategies listed above, all three participants used similar strategies in order to encourage student inquisitiveness in the classroom. The participants in this study, no matter which course they taught, all found ways to make the learning interesting for their students. They did so by presenting the material in different formats (e.g. videos and images) and by finding ways to connect the learning to the real world. Additionally, the teachers were conscious about giving their students autonomy as much as possible. Instead of simply giving their students answers to problems, the teachers made sure to encourage the students to figure things out on their own, or in groups, while providing them with the appropriate supports. The teachers were also aware of the necessity of creating a classroom that set the expectation that questions should be asked, and they did so by modeling question asking, encouraging students to ask questions and refraining from judging their students' contributions. These actions also served to create classroom environments in which students felt safe to ask questions.

In addition to using similar strategies to encourage student inquisitiveness, there were times, when looking at the data for all three participants, where certain strategies looked similar and had areas of overlap. For example, when asking students to elaborate on their thoughts, teachers also encouraged them to be autonomous. They did so because, in asking students to elaborate, they required students to reach an understanding alone, and used similar questioning techniques to help them reach this understanding. Similarly, when modeling question asking, teachers also mimicked the types of questions they asked when using the strategy of asking students to elaborate on their thoughts. When they modeled question asking, the teachers guided their students to ask questions that required further elaboration and subsequent questioning. These similarities are interesting to consider when examining the number of strategies that exist and the ways in which the strategies are similar and different.

The ways in which Lilian, Roger, and Noah used the strategies to encourage student inquisitiveness, and number of strategies that they used varied. Because these teachers teach across grade levels and are required to meet different standards in order to properly prepare their students, the strategies they used in the classroom differed. Nonetheless, it is important to note the ways in which their uses of the strategies were similar, and where they used the strategies in unique ways. All three cases provide useful insight into why teachers use different strategies to promote student inquisitiveness in their classrooms while also demonstrating what it looks like to use these strategies in different science classes.

While the teachers participating in this study used a variety of strategies to encourage student inquisitiveness, not all strategies as described in the existing literature were used. These included: giving students time before and during activities to ask questions, giving students question words, asking students to record their questions, and using a question board. These strategies are much more structure-based, when compared to the strategies that the teachers did use. More specifically, in order to use these strategies, the teachers may have needed to carve out time from their lessons and to do additional planning beforehand to determine, how, for example, a question board could have been created and used in their classroom. As a result, the teachers might have felt like they needed additional time to incorporate these strategies, such as time to list questions or time to review how students can use question words to formulate their questions. As Snyder and Snyder (2008) noted, teachers greatly feel the impacts of time constraints, as they often have a lot of content to cover in a short amount of time. Therefore, the teachers participating in this study may have felt limited by time which prevented them from using strategies that they believed took away from teaching time. Furthermore, lack of professional development opportunities to become familiar with and develop these skills may be another reason why the teachers did not implement these strategies. As Supovitz and Turner (2000) found, when teachers have the opportunity to engage in more professional development, they are more likely to use inquiry-based teaching techniques while also encouraging an inquisitive classroom environment. It is interesting to consider *why* teachers did not use certain strategies and future research could examine more closely if not using these strategies was particular to the teachers and context examined in this study.

Major Findings

Findings from this study suggest many important considerations for teachers when determining ways to encourage student inquisitiveness in the classroom. While implementation of teaching strategies differed based on factors specific to the school context, such as location and size, this study highlights useful strategies to encourage student inquisitiveness in the science classroom. I present the major findings from this study below as suggested by the cases of Lilian, Roger, and Noah.

1. There are several factors that affect teachers' practices. These include: a mandated curriculum, the need to prepare students for the next level of education, and

standardized exams. These factors affect teachers of upper levels, Grades 10 and 11, more so than teachers of lower levels, Grades 7 and 8.

2. There are many strategies that teachers use to encourage student inquisitiveness. These include:
    a) Making the learning interesting by giving students different representation forms to explore science content and by making connections to the real-world.
    b) Modeling questions that demonstrate to students how to ask questions related to the bigger picture and curiosity.
    c) Explicitly encouraging students to ask questions, either by asking students if they have questions, or by making it a requirement to ask questions during class.
    d) Refraining from judging students' contributions and receiving all student contributions with positivity.
    e) Encouraging students to elaborate on their thinking.
    f) Giving students autonomy in class, more specifically, alone or in groups, by asking them to complete project or solve problems without the help of the teacher.

While Roger and Noah used all of these strategies, Lilian used just four. One reason for this difference may be that Roger and Noah teach a variety of courses (including lower level and elective courses), whereas Lilian teaches only upper level courses. The pressures associated with teaching upper level courses may have prevented Lilian from using all of the strategies.

3. Strategies used by the participants of this study encourage students to ask questions, but the reasons *why* these strategies encourage inquisitiveness differ. Strategies may:
    a) Encourage autonomy – This occurs when using strategies such as: explicitly encouraging students to ask questions, encouraging students to elaborate on their thoughts, and giving students autonomy. For each of these strategies, the onus is on students to guide their own learning.
    b) Create a safe environment – This occurs when teachers refrain from judging students' contributions. In this strategy, all students' contributions are welcomed and valued.
    c) Promote curiosity – This occurs when using the strategy: making the learning interesting. This strategy gives students opportunities to personally connect or interact with the content in a variety of ways.
    d) Give students tools to ask questions – This occurs when teachers model question asking. The use of this strategy supports and develops students' question asking skills through various examples of questions given by the teacher.

Limitations and Areas for Further Study

Increasing student interest, engagement and motivation in science is of the utmost importance to prepare the next generation to work in STEM careers. One such way to do so is to increase student inquisitiveness in the science classroom. My study examines three teachers from one school. More specifically it looks at the factors that influence teachers' teaching practice as well as the strategies they use to encourage student inquisitiveness in their classrooms. While this study provides useful insights into the barriers that teachers face and how these barriers may impact how they encourage student inquisitiveness in their classrooms, there are limitations in this study, based on the research design and time available to complete the study.

First, my sample size (*n*=3) was quite small and is limited to three teachers from one school. More participants, including ones from different schools, could have contributed, contested or added to the themes discovered during the data analysis. Secondly, the data was collected only during a three-week period. Had there been more time to complete this study, data could have been collected over a longer time span. Doing so could possibly add more information regarding which strategies teachers use and why they use them. Furthermore, data collection was done in the fall, at the beginning of the school year. Had the data collection been done perhaps in the spring semester, it would be interesting to see if strategies used by teachers would differ because of the impending ministry exams and final exams. Finally, a fourth limitation of this study is that it was done only from the teachers' perspectives, and it excluded the views and opinions of the students. Instead, students were observed from a distance and were not active participants in the study. As a result, it is difficult to know if the strategies that the teachers used resulted in students feeling like they had more opportunities to be inquisitive in the classroom. Had students been included in the study, direct quotes from their perspectives could have been used, in order to provide the reader with a sense of the types of questions students were asking, therefore contributing to the richness of the data. Additionally, in a future study, it would be interesting to consider the point of view of students regarding the effectiveness of these strategies. Do students realize that their teachers are using these strategies in order to encourage them to ask questions? Do students feel that they are able to ask more questions when their teachers use these strategies?

While the findings from this study shed light onto different ways that teachers can encourage student inquisitiveness in their classroom, there is, indeed, room for more research. Firstly, my study found which strategies were used by teachers who taught in Grades 7, 8, 10 and 11 science classrooms. Future research could be done to determine if these strategies work in other instances, including other science courses.

Secondly, my study found that teachers from an independent school in Canada believed that the mandated curriculum, preparation for the next level of education and preparation for ministry exams impacted their teaching. It would be interesting to consider if the factors influencing teachers' teaching practice would differ if participants had been selected from schools internationally. As schools around the world have different requirements for their students and teachers, the ways in which teachers teach may differ to help their students and themselves meet the requirements set for them. Additionally, different countries may focus more on certain reform pedagogies which may increase or diversify the strategies used to encourage student inquisitiveness.

Thirdly, future research could examine how schools' mandates affect teachers' teaching practice. For example, as described on the school's website, The Ocean School believes that it is essential for students to participate in active, hands-on learning that engages them, teaches them to work together and think critically, and allows them to express their creativity in order to become active and inquisitive world citizens. Perhaps this mandate and commitment to active, engaged learning impacts how teachers teach their classes. While this is plausible, future research could look specifically at schools' mandates to determine if and how they have any impact on teachers' teaching practice. Furthermore, future research could examine if schools provide any support to their teachers in meeting the goals specified by the schools' mandates.

Fourthly, future research could be done to determine if teachers would use all of the strategies to encourage student inquisitiveness if they were presented to the teachers before data collection. Teachers participating in this study were not aware of which strategies would be observed in their courses. They were asked to continue teaching as normal. Therefore, my study found which strategies teachers use in their day-to-day teaching to encourage student inquisitiveness. Yet, it would be interesting to explore whether teachers would use a wider variety of strategies if they are presented with a list of strategies before data collection takes place. Similarly, a future study could have a professional development focus. If teachers are presented strategies to encourage student inquisitiveness, and are given appropriate training on how to use these strategies, would they use a wider variety of strategies to encourage inquisitiveness in their day-to-day teaching?

Finally, my study did not examine how the strategies used to encourage student inquisitiveness impacted student achievement. It would be interesting to consider if using strategies to encourage inquisitiveness in classrooms, as well as inquiry-based instruction, could improve students' performance in school and on standardized exams, as well as their interest, motivation and curiosity in science class. While teachers participating in this study believed that standardized exams require a more traditional form of teaching, it is important to study how reform efforts in science pedagogy impacts students' learning and performance.

While there may be many possible areas for future research, this study has left me with many important take-away ideas as I move forward in my teaching career. I have been interested in student inquisitiveness and inquiry-based instruction since I began my teaching career in 2016. This study has provided me with strategies to use in my own classroom, in order to encourage my students to ask questions and be curious about topics being covered. Furthermore, this study has given me a glimpse into how I can begin to incorporate inquiry-based instruction in my own classroom.

Indeed, it is crucial that all science educators find ways to encourage students to ask questions and be inquisitive. Educators should equip themselves with the tools necessary to increase inquisitiveness, and hopefully increase student interest in the sciences. While the current study gave me insight into what teachers can do to encourage student inquisitiveness in their classrooms, it is just one small step towards increasing student interest, motivation and engagement in science. Future research and work with teachers surrounding inquiry-based instruction should be done to provide teachers with the tools they need to most effectively implement this important reform effort in their classrooms. The call for inquiry-based instruction is one that is important and has the potential to transform the science education experience for our students. While motivating and preparing the future generation is no easy task, we, as science educators, can work together to bring about change.

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Appendix A: Observation Tool

Action	**Does teacher do it? # of times in lesson**	**Notes/ observations (word for word, what did the teacher say?)**
Time before activity begins to have students write questions (how much time?)		
Time during activity to write questions (how much time?)		
Giving students interesting material that prompt them to ask questions		
Giving students a graph or an image on which to base questions		
Letting students spend time observing something in an unstructured way (how much time?)		
Asking students to begin to question using words such as: what if; why does; why are; how does		
Teacher models question asking		
Praise given to those who ask questions (no shutting them down, "delay judgement--neutral rather than evaluative manner")		
Ask students to record questions in a diary, journal, notebook or electronic note-taking system		
Use of a question board as a starting point to scientific investigations		
Teacher explicitly encourages student to ask questions		
Teacher encourages students to elaborate on what they think		

Other observations: