The Experiences of Ontario Teachers Supporting
Female Students in Senior Physics Courses

By

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Abstract

This research paper emerged in an attempt to understand the under-representation of women in the mathematically-intensive sciences, by exploring how Ontario senior secondary physics teachers are reportedly supporting and encouraging their female students. Semi-structured interviews with three Ontario physics teachers yielded the following findings: physics educators, while aware of their positional identity, are committed to helping their female students succeed; implementing cooperative learning strategies and culturally responsive pedagogy makes girls feel welcome in physics classrooms; and extracurricular activities geared toward females in science are important in promoting girls’ interest in STEM. Several implications stem from these findings: female students may benefit from working in cooperative group environments in physics, and physics teachers may not be aware of how to implement pedagogies supportive of their female students. This study recommends that teachers should provide more female presence in classroom examples, and explicitly address subtle discrimination against women in STEM. In addition, teacher education programs, science departments and school administration need to promote gender equity in STEM by exposing teachers to relevant resources.

Key Words: physics education, gender equity, women in STEM, STEM careers
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Chapter One: Introduction

1.0 Research Context and Problem

The fields of study commonly grouped together as science, technology, engineering and mathematics under the umbrella acronym of STEM, are considered to be areas of innovation, where new development and research are bringing together the best minds and driving a country’s economic productivity and growth. The focus of many initiatives in government policies and in education is on higher involvement in STEM fields, in order to remain globally competitive. For example, in the US, the National Research Council (NRC) issued a report (National Research Council, 2010) calling for more federal support for education and research in STEM, and specifically recommending that their K-12 education system be raised to a global leader status. Similarly in Canada, a recent report (Dodge et al., 2015) by an expert panel on the connection between STEM skills and Canada’s economic prosperity stressed the importance of long-term, sustained investing in all levels of schooling as part of developing a STEM-literate society with strong fundamental skills. In Ontario, such initiatives have involved government-funded programs, such as: Scientists and Engineers in Business, Technology Development Program and Youth STEM (Federal Economic Development Agency for Southern Ontario, 2015).

While efforts are being made to encourage more people to pursue careers in science, mathematics and engineering, women are still largely under-represented in STEM degrees and professions (Hango, 2013). This may be surprising, in light of the fact that women held 66% of university degrees in non-STEM fields, according to the inaugural voluntary Canadian National Household Survey of 2011 (as cited in Hango, 2013). In the mathematics, computer and information sciences programs, the number of women graduates in Canada dropped from 35% in
1990 to 30\% in 2008, and even fewer women (22.3\%) choose to stay in STEM fields as professionals (Statistics Canada, 2010).

The path to higher education and potential careers in science is largely decided on in high school, as students who expect to have a science career while at the beginning of high school are much more likely to eventually earn bachelor’s degrees in physical science and engineering than students without such expectations in high school (Tai, Liu, Maltese & Fan, 2006).

Universities in Ontario list the grade 12 physics course as a requirement for admissions into programs in applied science and engineering, as well as physical and mathematical sciences, and a recommendation for admission into most life sciences programs. Therefore, any high school student contemplating going to university in physical, life sciences or engineering fields must start planning to take physics courses from grade 11. At that age, adolescent girls tend to be concerned about their social status within the school; in an interview study with dozens of young women across the United States, Pollack (2015) found that taking physics courses is potentially unpopular. Already at the high school stage, the knowledge and prior experiences of girls will bring them in conflict with the cultural norms of belonging to, or assuming a STEM identity.

Despite placing STEM fields at the forefront of government and industry research grants in Canada, and educational policies put in place to push for advancement in these fields in the 21\textsuperscript{st} century, there is still one significant group of people (women) that is largely under-represented in the mathematically-intensive areas of STEM. Even though women enroll in all undergraduate degree programs in higher numbers than men, they make up less than 20\% of graduates in physics, engineering and computer science (Hill, Corbett & Rose, 2010). Possible reasons research provides for the dearth of females in STEM are explored in the literature review in Chapter Two.
Regardless of the reasons, the situation in Ontario secondary science education is echoing the number of STEM degrees awarded to women at the national level. The fraction of girls, out of all the students that successfully complete the grade 12 physics course in Ontario, has been around 30% for at least the last 10 years (Caranci, 2016) despite the efforts to promote women in science and engineering careers. In my experience as a pre-service teacher observing and teaching senior physics classes, the girls enrolled in the grade 12 course are rarely interested in pursuing a degree in pure physics or related mathematically-intensive fields.

Interviewing Ontario physics teachers would contribute rich experiences of these teachers supporting girls in their physics classes to the educational community, and uncover some effective practices in addressing the problem of the under-representation of girls in senior physics courses. Therefore, the main focus of this research project is the support that secondary physics teachers in Ontario reportedly provide to their female students in pursuing and retaining interest in physics courses on their path to post-secondary education.

1.1 Purpose of the Study

This research study investigated the intentional gender inclusion practices of Ontario secondary school physics teachers, and the specific supports they provide to female students in their classrooms and to those female students who are interested in taking physics as a path to studying mathematically-intensive fields in post-secondary education.

My broad intention in conducting this research study is to shed light on the experiences of educators making STEM fields of study more equitable and welcoming to all under-represented groups, which include ethnic, cultural, linguistic, racial and religious minorities, and women. This last part is troubling, as all women, representing about half of the population, are largely under-represented in STEM, and those women belonging to other minority groups find
themselves even more on the sidelines of mathematically-intensive sciences. Improving the diversity of people in STEM fields would benefit the educational community and the workforce, as different interests, experiences and ways of thinking are brought together in creating new knowledge.

The purpose of this qualitative study is to explore how Ontario secondary school physics teachers reportedly support female students’ interest in physics and the pursuit of STEM-oriented careers. I interviewed a small sample of these teachers about: their reported pedagogical strategies for supporting and stimulating female students’ interests as well as the perceived effectiveness of these strategies; their gender-inclusive curriculum design practices; their efforts to create a gender-inclusive classroom climate; and supports and barriers they encounter in doing the above. I aim to share my findings with the educational research community in order to provide support for creating intentionally gender inclusive classroom environments, teacher practice and the STEM fields more broadly.

1.2 Research Questions

As women are still largely under-represented in mathematically demanding career fields in the twenty-first century, the central question guiding this study is: how are Ontario secondary physics teachers reportedly working to support their female students? Some of the sub-questions that are driven by and arise from the central research question are:

- What pedagogical strategies do they use and consider to be most effective in provoking interest in their female students?
- What do these teachers reportedly take into consideration when designing their lessons to increase girls’ active participation in their courses?
- What supports and barriers do they encounter?
1.3 Reflective Positioning

My personal upbringing and educational background, as well as the social environment I grew up in, provided me with the experiences that left me unaware of the issue of under-representation of women in the mathematically-intensive sciences until I moved to Canada.

The idea that there is one identifiable group (women) struggling to receive affirmation for their work in mathematically demanding careers in the 21st century came as a shocking news to me when I arrived in Canada to do my graduate degree in astrophysics. During my undergraduate years at the University of Belgrade, women represented close to a half of all faculty members in physics, chemistry, astronomy and mathematics. As a contrast to that environment, in the year 2000, when I started my graduate studies at the Department of Astronomy (since renamed to the Department of Astronomy and Astrophysics) at the University of Toronto, there were 15 male professors and only one female full professor.

While my immediate and extended family all had university and professional degrees, I was the only one wanting a career in science. Despite this, I do not remember ever hearing comments against women pursuing professions in mathematically-intensive fields, or about women having innately lesser mathematical and spatial reasoning ability than men. I got nothing but positive encouragement from my family to pursue whatever field of study I was passionate about, which happened to be physics.

Another important distinction of my university experience from those of North American universities, is that higher education was not considered reserved for the privileged few; it came free of charge for most students, including myself. Not having to worry that I had to work for my tuition or take a loan, allowed me to explore other interests I had outside of science. Although I come from a highly-educated family, I cannot consider myself “educationally privileged” in the
sense in which this phrase is used throughout the parts of the world where high tuition often means that obtaining a university degree comes with a certain sense of financial entitlement.

While women in North America in the sixties were mostly encouraged to stay at home (Clement, 2006), my parents and grandparents’ generation in what was then Yugoslavia in the sixties and the seventies had seen both men and women in the workforce as a norm. Up until my graduate studies, I had not known of any of my classmates to have grown up with a stay-at-home parent. Given the contrast I experienced in educational and professional opportunities for women in mathematically demanding fields in Eastern Europe and Canada, and since I am also perceived as a woman, I have a personal interest in seeing women be successful in the field of study of their choice, whatever that may be. I wish to see girls not feel intimidated in pursuing careers that, based on their gender identity, may not seem socially acceptable or feasible to them. I am driven to explore what gender-inclusive practices educators use to support female students who are interested in pursuing physics and related fields as a career, while they are still in high school. As an educator in mathematics and physics myself, I hope to be a culturally responsive and encouraging teacher to all my students.

1.4 Overview of the Study

In order to understand how Ontario secondary physics teachers are working to support female students in pursuing their interest in physics, I conducted a qualitative research study using purposeful sampling to interview three Ontario physics teachers.

This research study is organised as follows. I devote Chapter Two to the literature review on the themes related to women in STEM fields of study and on the suggested practices of physics teachers in supporting girls in senior secondary physics courses. In Chapter Three I explain my methodology for conducting this study, and in Chapter Four I report my research
findings and discuss their alignment with the existing literature. Chapter Five reveals the implications of this research project on my own teacher identity and practice, stemming from the findings described in Chapter Four. Additionally, in Chapter Five I offer recommendations for various stakeholders in education based on this study’s findings, and I identify areas for future research.

Before I move on to the literature review, however, a few notes on terminology are warranted. Although in the broadest sense, STEM fields include ‘human-oriented’ sciences, such as biology, medicine and psychology, for the purposes of this study I am looking closely at the under-representation of women only in mathematically-intensive STEM fields, such as physics, chemistry, engineering, mathematics and computer science. Thus, throughout this paper, “STEM” will mean to include only those fields of study that are considered mathematically-intensive.

Throughout this research paper, I use the word “gender” in keeping with its meaning in the reviewed literature, which is usually binary (male-female), as in the frequently used phrase “gender gap”. However, I am conscious of the fact that gender is a social construct (Brotman & Moore, 2008), and is viewed by many people as fluid, rather than strictly binary (either one or the other). I am also using the words “women”, “girls” and “females”, to include all persons who identify with the female gender, as well as all persons perceived as females regardless of how they identify (such as females referred to in the studies which don’t explicitly mention how the gender identity of their subjects is found).
Chapter Two: Literature Review

2.0 Chapter Introduction

In this chapter, I look at the research pertinent to the issue of what is needed to support female students in senior secondary physics courses, and how teachers can keep girls engaged and welcome in physics, where they are largely under-represented in Ontario. I organise this chapter to review the themes within literature at three distinct levels in addressing the research topic. The first level is societal, trying to understand the possible reasons in literature for the still significant under-representation of women with degrees in mathematically-intensive sciences, such as: physics, computer science and engineering. The next level is educational, where I explore best research supported practices of secondary teachers toward gender equity in STEM. I also look at the literature related to teachers as role models for girls on a path to studying STEM fields in post-secondary education. The third level is what I call ‘personal’, where I investigate the research pointing to female students’ perceptions of self and the factors indicating their motivation, engagement and feeling of belonging in physics courses. This involves research on stereotype threat and self-efficacy in female students in science.

Finally, I point to what is missing in the literature on the topic, in order to inform my research in the area, and to further guide the research questions and methodology.

2.1 Perceived Reasons for Under-representation of Women in STEM

There are two groups of possible reasons given in the literature for women being under-represented in mathematically-intensive STEM careers: the innate or biological differences in mathematical ability between sexes and other, more socio-cultural reasons. As one can imagine when dealing with the issues of systemic, broad and complex nature, it is hard to definitively point to specific reasons women tend to avoid STEM careers, and certainly, individual women
would have their own specific reasons for career choices. Therefore, I avoid overgeneralisations, and instead I point to research that attempts to uncover possible factors contributing to the under-representation of women in mathematically-intensive sciences; it is far from an exhaustive and final list. I explore both the possibility of innate ability for doing mathematics, and other possible socio-cultural reasons for under-representation of women in STEM.

2.1.1 Innate ability

When Lawrence Summers (2005), then president of Harvard University, gave a speech speculating that the reason for not having many women in tenured faculty positions in mathematically intense sciences could be in innate differences in scientific and mathematical aptitudes between males and females, his remarks sparked a public debate and invited for more research on the reasons for female under-representation in STEM. Summers’ speech shows that stereotypes about female inferiority in mathematics persist, despite much research before and since his speech showing otherwise (Else-Quest, Hyde & Linn, 2010; Fennema & Sherman, 1977; Hyde, Lindberg, Linn, Ellis & Williams, 2008; Linn & Hyde, 1989). The authors of an earlier study (Fennema & Sherman, 1977) strongly suggest the influence of socio-cultural factors, and do not support male superiority in mathematics and spatial reasoning. Gender differences in height, physical strength, career access, and earning power are shown to be much larger and more stable than gender differences in cognitive and psychosocial tasks (Linn & Hyde, 1989).

More recent studies, published after the Summers (2005) speech, have looked at the suggested innate variation in mathematical ability by gender. Two major international data sets from 2003, the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) were meta-analysed in a study by Else-
Quest, Hyde and Linn (2010), including almost half a million students 14-16 years of age across 69 countries. The authors looked at gender differences in mathematics achievement, attitudes and affect. While they found no significant mean difference in math achievement for boys and girls, they did find appreciable variation in the effect size for gender difference in math achievement from nation to nation. Similarities in aptitude for science and mathematics between males and females are likewise evidenced in Hyde, Lindberg, Linn, Ellis and Williams (2008). The conclusion of the large meta-analysis of Else-Quest, Hyde and Linn (2010) is that, on average, males and females differ very little in math achievement, and their findings are consistent with the hypothesis that gender differences in mathematics achievement reflect the inequities in educational and economic opportunities available to females in a given culture.

2.1.2 Socio-cultural reasons for female under-representation in STEM

The key factor predicting retained interest in STEM by students at the end of secondary school is the interest by the beginning of high school (Sadler, Sonnert, Hazari & Tai, 2012). The study by Sadler, Sonnert, Hazari and Tai (2012) finds significant gender effect in that female students retained interest in STEM throughout high school in lower numbers than males. The reasons behind this trend seem to be varied and complex. Some would argue that women are just not interested in mathematics as they are in other fields, and that their interests drive them out of STEM careers. Existing reviews, such as the one by Brotman & Moore (2008), show that what undermines females’ participation in STEM fields are the persistent socio-cultural norms and stereotypes about gender roles and abilities. Sexism and microaggression are reportedly persistent in the culture of physics and astronomy, as researched by Barthelemy, McCormick & Henderson (2016).
Another recent study uncovered a gender bias towards peers in male college biology students (Grunspan, 2016), which is expected to be similar in other sciences as well. Namely, Grunspan (2016) found that males are more likely than females to be named by peers as being knowledgeable in the subject. This bias is found to be a result of males over-estimating their male classmates’ performance in class, and persists even after controlling for in-class performance and outspokenness. In contrast, female students from the same class tend to nominate knowledgeable peers equitably and with no demonstrable bias toward nominating males as more knowledgeable. The authors chose to study biology classes where male and female enrolment is roughly equal. It is considered among sciences that biology is not as math-heavy, and thus math-gender stereotypes would not be invoked. The authors predict that the male bias effect would be even stronger in more mathematically-intensive STEM fields.

The literature investigated here suggests that the reasons for girls and young women avoiding STEM courses or leaving the field are subtle and more complex than overt discrimination. It is likely that the accumulation of events and stereotyping that undermine self-efficacy and confidence is what makes women eventually leave the path to STEM careers. The following section investigates some tools teachers can use in science classes to address the issue of female under-representation in mathematically-intensive fields.

2.2 Teacher Practices Toward Gender Equity in STEM

This section reviews the research on teacher practices for gender equity in STEM. In striving for a more equitable society, the Ontario Ministry of Education (2014) has published a document guiding teachers in practicing equity in their classrooms, and has identified what equity and inclusive education means:
Equity and inclusive education aims to understand, identify, address, and eliminate the biases, barriers, and power dynamics that limit students’ prospects for learning, growing, and fully contributing to society. Barriers may be related to sex, sexual orientation, gender identity, gender expression, race, ethnic origin, religion, socio-economic background, physical or mental ability, or other factors. These barriers and biases, whether overt or subtle, intentional or unintentional, need to be identified and addressed (p.6).

Guided by this understanding of equity and addressing the barriers to achieving it, I explore the effect teachers may have on their female students, and the suggested teacher practices in supporting girls in math and science through cooperative learning, culturally responsive pedagogy and addressing stereotype threat.

2.2.1 Teachers as role models for female students

The theme explored in this sub-section revolves around the questions of how significant the role of teachers is for their students, whether the perceived gender of teacher influences girls in their decision to take mathematics and science courses, and what effect teacher-student (perceived) gender matching has on the academic performance of the students. I review literature on teachers as role models and gender more broadly, rather than only in the STEM fields. Gender matching of teachers and students, and the idea of teachers as role models have been studied in many areas of educational research, and as the issue can be viewed with the lens of intersectionality, I do not restrict my overview solely to the STEM fields of study.

A study of 15 countries, members of the Organisation for Economic Co-operation and Development (OECD), which includes Canada, looked into correlations between teacher–student gender matching and test score performance for female and male lower secondary
students (Cho, 2012). The result of this study was that there is no support for the claim that teachers of the same gender would have an effect on improving test scores of students. This is in contrast to an earlier study by Dee (2007) who found that there is a positive effect of teacher-student gender matching for grade 8 students in the United States. A similar study of grade 8 students in Chile (Paredes, 2014) also showed an effect of same gender teacher on academic achievement. One explanation for the discrepancy in the results of the study done by Cho (2012) and those of Dee (2007) and Paredes (2014) could be in the difference in methodology, as Paredes’ study controls for subject-specific ability of teachers. There could also be differences in the training and the effect teachers have on grade 8 students (which were the focus of the Dee [2007] and Paredes [2014] studies) and on lower secondary students, which was the focus of the multinational study by Cho (2012).

Paredes (2014) looked at the importance of same-gender teacher as a role model for female students. Girls’ academic achievement seems to increase when having a same-gender teacher, and Paredes found no negative effect of opposite-gender teacher on boys’ performance. Paredes also investigated whether the positive effect female teachers have on girls is due to the way teachers perceive their students, and found no evidence for teacher bias on the positive performance of girls. Although Paredes’ study explores teacher-student relationships in Chile, the ideas behind the reason for the study resonate also in Canada: that is, firstly, that women are under-represented in the fields of study related to careers in math and science, and secondly, that girls perform better at language and boys perform better at mathematics on standardised tests in schools. The result from the Paredes study can be applied to increase awareness of both pre-service and in-service teachers of the effect of a teacher as a role model, especially in school subjects in which there is a significant gender gap in academic performance.
2.2.2 Cooperative learning

In order to understand ways to promote female students’ engagement in senior physics courses, I review research that connects cooperative learning strategies and gender. Cooperative learning happens when members of a group work together in a structured way toward shared goals, where each member of the group is assigned a specific role and each member is responsible and needed for the success of the whole group (Johnson & Johnson, 2009). This way of learning is in contrast to the competitive or to the individualistic learning, as defined by the authors. The competitive model is the one where students work against one another with a clear winner at the outcome, and individualistic learning has students working independently of each other to achieve a goal. Research shows that in cooperative learning environments, students spend more time on task than students in individualistic or competitive environments, and this holds true regardless of curriculum subject or topic of learning (Johnson & Johnson, 2009).

In one study, while looking at the effect of computer-assisted instruction on learning, Johnson, Johnson and Stanne (1986) placed grade 8 students in cooperative, competitive and individualistic instructional situations randomly, in gender balanced groups. They found that the females in cooperative instruction groups achieved higher status as group members, and that there was more equal participation by gender within the cooperative groups, than in individualistic or competitive instruction groups, where males dominated.

Despite the fact that the studies specifically addressing gender in cooperative learning environments are scarce, the research on cooperative learning that does cross-correlate with gender indicates that in classes where they are in minority, female students benefit from structured cooperative learning.
2.2.3 Culturally responsive teaching

A teaching practice gaining recognition in recent years is culturally relevant or culturally responsive pedagogy. Culturally relevant pedagogy was introduced as a term by Gloria Ladson-Billings (1995a) and built upon by Gay (2002), who named it culturally responsive pedagogy. Throughout this research paper, I am using the term “culturally responsive pedagogy” (CRP) as established by Gay (2002), while the term “culturally relevant pedagogy” is used only when referring to the research done by Ladson-Billings. The characteristics of culturally responsive educators, as suggested by the Ontario Ministry of Education (2013) are: awareness of socio-cultural structures and their impact on students’ individual experiences, holding high expectations, positive and affirming views of all students, having desire to make a difference, working towards more equity, understanding that learners construct their own knowledge, knowing about the lives and experiences of their students, and designing and building instruction to reflect prior knowledge and experience of learners. Even though culturally relevant pedagogy is generally interpreted to involve the practice geared toward specific cultural backgrounds of students, it can be applied to any underrepresented group of students, such as girls in STEM fields (Ladson-Billings, 2014).

Given that the research related to CRP as it applies to gender equity is scarce – likely because it is very difficult to argue that ‘gender’ functions like a heritage culture of some kind – I broaden my scope of literature reviewed to explore the research on this teaching practice. Hoping to gain some insight into the possibility of practicing CRP as a way of supporting underrepresented student groups (largely cultural, linguistic and non-male gender groups) in STEM, I review recent research addressing the use of culturally responsive teaching in elementary school science and mathematics, as well as in undergraduate courses. As research on using CRP to
include the under-represented groups in STEM related to Ontario schools is even more rare, if it exists at all, all of the research addressed in this section comes from the US.

A study of teacher candidates’ experiences in their efforts to teach mathematics in elementary schools with culturally diverse student population shows the need for teachers to incorporate the wider school community into science and math learning (Bottoms, Ciechanowski, Jones, de la Hoz & Fonseca, 2017). At the post-secondary level, the factors that lead to pursuit and persistence in STEM field of computer science among African American students in the US are largely due to culturally responsive practice, which included positive social influences, community building, and sense of belonging (Charleston, Charleston & Jackson, 2014). In research by King Miller (2015) on using CRP to integrate Afro-Caribbean females in STEM, the author finds that teachers need to set high standards and expectations of their students, and create an atmosphere that supports the students’ learning. Both research by Charleston, Charleston and Jackson (2014) and by King Miller (2015) align with the tenets of culturally responsive pedagogy of Gay (2002) and Ladson-Billings (1995a).

2.2.4 Other teacher practice suggested by research

Haines and Wallace (2002) suggest that educators in secondary schools should promote classroom practices that increase the number of female students in math and science courses, but fall short of suggesting what those practices might be. However, the finding of strong male peer bias in biology classrooms with gender parity (Grunspan et al., 2016) indicate that simply increasing numbers of females taking STEM courses in high school and university is not enough in mitigating the attrition problem for females in STEM careers.

Student interest in particular subject areas may be formed before arriving in secondary schools, as (Dare & Roehring, 2016) found that grade 6 boys tend to see themselves more in
engineering careers, even though girls of the same age are just as interested in science and have similar perceptions of physics as boys. The earlier the teachers adopt gender-inclusive instructional strategies in science, the more likely they are to retain girls’ interest in the field.

Teachers should be aware of the stereotype threat effect, and try to address it in the classroom at test time, as well as send the message that math ability can be improved, to mitigate the negative stereotyping of girls (Good, Rattan & Dweck, 2012; Huguet & Regner, 2007). They can work on improving girls’ self-efficacy about doing math and science to increase their motivation and interest (Simon, Aulls, Dedic, Hubbard & Hall, 2015). Else-Quest, Hyde and Linn (2010) also suggest that teachers should integrate many examples of female scientists as part of routine classroom practice. Teacher training and professional development programs can promote these practices in preparing educators for teaching toward gender equity in STEM (Brotman & Moore, 2008). The section that follows addresses female students’ own feelings of belonging in the mathematically-intensive sciences.

2.3 Factors Affecting Female Students’ Engagement in STEM

A significant effort is spent in schools on making sure the students are engaged in learning. In this section, I look at several indicators of engagement discussed in literature, such as time spent on task and performance during assessment, and I focus on those factors that could influence engagement in female students. One indication of engagement is through time spent being on task while in different types of learning environments. Another way to look at engagement in learning is to research motivation and self-perception in students. In this section I review research that discusses individual student factors such as self-efficacy, motivation and feeling of stereotype threat, with a lens on female students in science and mathematics courses.
2.3.1 Stereotype threat

According to the stereotype threat theory (Steele, 1997), minority groups experience additional stress when performing a task that is negatively associated with their group. For example, women would perform worse than men on standardised math tests because they are preoccupied with fears and worries of confirming the negative stereotype that men are better at math than women. As women who feel the stereotype threat get lower scores on math tests than men, the threat produces the expected negative outcome and perpetuates itself. Huguet and Regner (2007) performed a study on middle school children in France, concluding that girls exhibit performance deficit when they are simply led to believe that the task they are about to perform is mathematical in nature. They also found that the greater presence of a positive role model alleviated the impact of this stereotype threat in girls. Thus, reducing stereotype threat in the classroom would mean greater benefit for girls as potential future scientists.

As research reviewed here shows, feelings of stereotype threat in male-dominated academic fields can make a noticeable difference in the achievement of females in those fields. As a result of, or related to, stereotype threat, women are likely to experience low self-efficacy and lower confidence in the mathematically-intensive STEM fields, and would opt out of pursuing related careers.

2.3.2 Self-efficacy and self-confidence

Self-efficacy is a well-defined concept in social cognitive theory, first studied by psychologist Albert Bandura. Bandura (1997) defines self-efficacy as referring to “beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments” (p. 3). According to Simon et al. (2015), “self-efficacy represents one’s perceived capability and expectations for success based on prior achievement, rather than a measure of
personal qualities such as physical or personality characteristics” (p. 6). What I am particularly interested in exploring for the purpose of this research study is how self-efficacy affects a student’s engagement and persistence in science classrooms, and relatedly, how it affects a student’s academic achievement. As Bandura (1997) says, “a strong sense of efficacy fosters a high level of motivation, academic accomplishments, and development of intrinsic interest in academic subject matter” (p. 174).

Brotman and Moore (2008) reviewed the literature from the mid-1990s to 2007 on girls’ engagement in science and found four themes that they addressed: equity and access, curriculum and pedagogy, the nature and culture of science, and identity. The identity theme leads the authors to point out that gender is not the only trait that forms identity and that overly simplistic and binary views of girls and boys in science should be avoided. As they assert, the research on the issue of under-representation of women in STEM can fail to recognise that ethnicity, language, lifestyle, religion, socio-economic status and culture can intersect with gender to create experience of identity as essential to learning in an academic area. Hence, qualitative research emerging recently looks at intersectionality of gender with cultural and linguistic background, such as (Charleston, Charleston & Jackson, 2014; King Miller, 2015; Mejia & Wilson-Lopez, 2017).

Simon et al. (2015) conducted a study on first-year English-language CEGEP (Collège d’enseignement général et professionnel - College of general and professional education) students in greater Montreal area, and looked at their persistence in science classes as a predictor for enrolling in STEM programs further on in their education. The study found that factors such as autonomy, self-efficacy and achievement goals (mastery goal and performance goal) have a
significant impact on student participation and retention in science classes in high school (Simon et al., 2015).

2.4 Conclusion

In this literature review I looked at research on societal effects related to under-representation of women in STEM fields, educational practices that aim to mitigate those effects, and factors influencing female high school students’ interest and engagement in math and science courses. I discussed research on female students’ feelings of belonging in STEM courses, stereotype threat and self-efficacy. There is scarcity of research devoted to gender-inclusive practices of STEM educators in Ontario. The governments of Ontario and Canada collect statistical information, but there is lack of educational research on the topic of under-representation of women in mathematically-intensive STEM fields at the secondary school level, locally. I reviewed what practices have been successful in Canada and internationally, as well as what obstacles teachers may encounter in creating gender-inclusive environments in physics classrooms.

Conducting this literature review raised several questions, such as: what teacher practices in Ontario are aimed at increasing female students’ participation and engagement in physics courses? What problems Ontario physics teachers face as they try to implement the Ministry gender equity policy? This research study aims to answer these questions through interviews with Ontario physics teachers and thus fill the gap in the literature on gender-inclusive practices of STEM educators in Ontario. The chapters that follow discuss the methodology and findings from this research study.
Chapter Three: Methodology

3.0 Chapter Introduction

In this chapter, I discuss my approach to gathering data on the topic of teachers’ intentional practices for supporting female students who are taking physics courses in secondary school as a pathway to STEM degrees and careers. I explain the methodology used and the reasons behind making choices regarding the instruments of data collection and the participant sampling. I describe ethical considerations for the study and how I analysed the data. Lastly, I discuss strengths and limitations of methods used in this research project, and suggest other possible avenues of exploring my research questions which are beyond the scope of this project.

3.1 Research Approach and Procedures

Before I even understood what qualitative research entails, I had the topic for this study in mind. I wanted to investigate why there are much fewer women than men studying physical sciences and engineering in Ontario. This study’s research topic and the research questions that emerged from it, guided me in selecting the approach for this project. In social sciences, research can be quantitative, qualitative, or a mixed methods approach. As pointed out by Creswell (2014), these different approaches need not be completely separate, and form a continuum of approaches to research. Quantitative research generally involves using measurement and statistical procedures to examine data (Hill, 2012). Qualitative research is defined by Creswell (2014) as:

an approach for exploring and understanding the meaning individuals or groups ascribe to a social or human problem. The process of research involves emerging questions and procedures …, and the researcher making interpretations of the meaning of the data. …

Those who engage in this form of inquiry support a way of looking at research that honors an inductive style, a focus on individual meaning, and the importance of rendering
Since I am interested in exploring the experiences of the educators who support female students in science, the qualitative research approach is an excellent way to probe deeper into the topic. It gives researcher the opportunity to delve deeply into the experiences of teachers who are actively involved in and knowledgeable about gender-inclusive practices in physics teaching. With qualitative research, it becomes possible to get meaningful data from a small sample of participants, while allowing for results and conclusions to emerge from the data themselves.

One characteristic of qualitative research methods is the use of open-ended questions in interviews. Rather than placing constraints on participants to respond within some given frame, such as in answering predetermined questions using a Likert scale, the qualitative researcher allows participants to talk freely about their experiences in an interview (Hill, 2012). Following the interview, the researcher tries to find meaning from the codes and themes emerging from the interviews, and there is no one fixed answer to the central research question (Creswell, 2014).

Another important aspect of qualitative research is that it uses a small sample of participants. Even though the sample size is small, the participants chosen for this research were carefully selected and their experiences explored in depth. One major role of qualitative research design is constructing the sampling criteria in such a way to attract participants who can speak articulately about their experiences (Hill & Williams, 2012). The goal in conducting qualitative research is to gather meaningful and rich data while probing the experiences of a small sample of participants, and therefore the careful choices in methodology play a key role in reaching this goal.

### 3.2 Instruments of Data Collection

To obtain the data for this study, I used the interview as the only mode of data collection.
Surveys and questionnaires are better suited for quantitative social research. Some other forms of data collection outside of the scope of this research are: focus groups, observations, tests and documentary analysis (Robson, 2002). Interviews in a qualitative study typically use open-ended questions, and the relationship that forms between the interviewer and the interviewee also plays a role in gathering the necessary data. Interviews are one of three types: structured, semi-structured and unstructured. In a fully structured interview, even though the questions are open-ended, they follow a strict order and are unchanging for the duration of the interview regardless of how participants respond. As suggested in Robson (2002), semi-structured or unstructured interviews are more appropriate when a study focuses on what particular phenomena mean to the participants, and when the researcher is interested in the personal experiences and accounts of participants. The strength in using an interview as a data collection method is in its flexibility and adaptability to the circumstance (Robson, 2002). There is the possibility of following up on interesting responses, probing further when the participant seems to be giving little information, and also including the non-verbal messages observed during the interview in the data analysis. However, qualitative interviews are not without limitations. They are time-consuming and require careful preparation. They are also not without bias, and thus even harder to do for a novice researcher. There is no standardisation and no fixed number that can be assigned to a particular answer, which makes the critics of this method raise concerns about reliability. Nevertheless, interviewing people about their experiences of a phenomenon provides rich and insightful views into the research problem. Thus, the interview as a method of qualitative research data collection was the one that fully fit my research purpose.

My interviews were semi-structured, with a defined protocol (provided in Appendix B). The protocol was designed with the understanding that the wording and the order of some
questions may change over the course of the interview, or from one interview to the next. I allowed for the possibility of having some questions added or omitted, and explanations and prompts offered along the way, depending on the interviewee. I have divided my interview questions into four sections. As a “warm up”, I started with the closed questions about the participants; I asked them about their teaching experience and their educational background. In this part of the interview I also asked participants to disclose their gender identity if they wished. Since I selected the teachers who actively participate in gender-inclusive practices in their teaching, and the participants were aware of my research purpose and topic in advance, I was hoping that the participants will not be put off by my question about their gender identity. They also had the option to decline answering this, or any other question, and I reminded them of it during the interview.

I wanted to investigate the participants’ experience and thoughts on being a role model and the possibility that the female students may relate better to a teacher they also perceive as female. I also wanted to have a feel for the gender composition in their physics students over time, which made me seek teachers with several years of experience. The second section of the interviews explored the current practices of physics teachers, and the science-promoting activities they were involved in as part of their practice. Next, I wanted to understand what made the participants get involved in various activities promoting physics, and especially how their activities related to female students. Within that section of the interview I wanted to uncover their beliefs on benefits of promoting gender-equity in physics. The last part of the interviews asked about the support and the challenges the participants have had over the years in promoting and supporting female students in physics, and the suggestions for future teachers.
3.3 Participants

This section explains the sampling criteria I used to select the participants for the interviews. I also cover the sampling methods that led me to the interview the participants, whose short anonymized biographies are given at the end of this section.

3.3.1 Sampling criteria

In order to get the most information from interviewing teachers about their experiences, as they relate to my research question, I used the following sampling criteria in choosing the participants for this study:

1. The participants are teachers currently teaching grade 12 physics course, University pathway, with the code SPH4U in Ontario.
2. The teachers have had at least 7-10 years of experience teaching high school physics courses.
3. The teachers will have actively supported girls in physics through careful gender-inclusive lesson planning, mentoring, encouragement, talking about issues of women in physical and mathematical sciences, etc.

I want to explore the experiences of Ontario teachers in supporting girls who are taking physics high school courses, possibly towards a STEM education or career. Therefore, the main criterion for selecting participants for my study is that the teachers I interview teach physics in Ontario. I narrow the requirement to the grade 12 academic physics course, because this course is a requirement for most university programs in STEM, and students who wish to pursue a degree in a STEM field of study would have to take this course. I intended to talk to teachers who have had several years of experience teaching physics. Having this experience, they would have had the opportunity to get involved in physics competitions, science fairs, and activities that encourage
female students to engage in science. I also wanted to know what classroom practices these teachers find useful in encouraging girls to pursue STEM post-secondary education. Therefore, the reflexive teachers I sought to interview have actively worked toward engaging and including their female students in physics.

### 3.3.2 Sampling procedures

Before settling on a sampling procedure, the researcher must have well-defined and clear research questions (Hill & Williams, 2012). The central research question and the sub-questions will guide the researcher when deciding on a sample. As suggested by Hill and Williams:

> In consensual qualitative research, we ask people to tell us their stories. To obtain these stories, we recruit participants who have had the type of experience that we are interested in and who can describe their reactions in great detail. Hence, choosing the sample is of utmost importance to obtaining good data. (p. 71)

Qualitative research can employ different types of sampling procedures: theoretical sampling, random, purposeful, and convenience sampling. Theoretical sampling has emerged from the grounded theory of Glaser and Strauss (1967). It involves deciding on future data collection based on a theory that emerged from previous data. While Hill and Williams (2012) recommend to choose a sample randomly from among the volunteers in the purposefully selected population, completely random sampling is usually not feasible for a small scale qualitative research. In order to get the in-depth data desired in qualitative research, many researchers establish criteria leading to ‘experts’ on a topic. This type of sampling is purposeful in selecting participants who will be able to provide rich, in-depth information, and give detailed insight into the research problem and question. Patton (2002) has created a set of guidelines for purposeful sampling, which include 14 different strategies, such as homogeneous, typical case, snowball, criterion,
purposeful random, etc. Sometimes it is convenient to find participants near familiar places of work and living, or involve only those participants that are known to the researcher, although the data obtained from a purely convenience sample may not be diverse and rich enough to yield meaningful information.

In recruiting participants for this research project, I used a combination of purposeful sampling and convenience sampling procedures. The sampling is purposeful because I have a set of established criteria which I sent out to attract participants who I had hoped would self-identify as fitting them. I attended relevant professional conferences to invite the teachers I met there to participate in my research project. It would have been most convenient for me to try to find all my research participants when they converge from across Ontario to the annual conference of physics teachers, as there is a relatively diverse group of physics teachers attending – from rural areas as well as urban, from private and public schools. I had also planned to employ snowball sampling technique while at the conference, if necessary, asking teachers to recommend others they may know who would fit the criteria. I did not want to restrict myself to interviewing participants from one geographic area within Ontario, as I could conduct interviews online. To avoid relying only on person-to-person conference contacts, I also sent out emails with my sampling script to various other physics teachers groups across Ontario, including the Toronto Science Fair organisation. Lastly, I deliberately excluded one Ontario physics teacher from my potential participant list, as she is a close friend of mine. Interviewing a close friend would potentially invoke my biases and skew the data, as we had similar experiences with the same university background.

3.3.3 Participant biographies

This study had three participants. To avoid associations with any culture, ethnicity,
background language or race, the pseudonyms I gave them represent different types of matter particles: Boson, Fermion and Quark. Each participant self-identified their gender and I am using their preferred pronouns throughout the study. All three have extensive experience and recognition in teaching senior physics courses in secondary schools.

**Boson** has completed a B.Sc. in Physics and a B.Ed. She has qualifications in teaching computer science, mathematics, general science and physics. She has been teaching senior physics courses for almost 20 years, but says that effectively, she has been teaching her whole life, starting with teaching her dolls when she was little. She also taught chemistry, general science and secondary math courses. Boson created an interdisciplinary course at her school which combines different aspects of science, technology, engineering, arts and mathematics. She is a highly reflexive teacher, actively promoting equity in her classes and following current physics education research, including the issue of female under-representation in STEM fields. She frequently presents at relevant teacher conferences and is passionate about sharing her knowledge with students and colleagues alike. Boson’s message to beginning teachers: “I think you wanna read research, because it gives you more than just anecdotal stuff. And then try and apply that in your own specific classes. I think this is what we’re doing with teaching, we’re meshing the pedagogical studies and the individual people.”

**Fermion** has close to 30 years of experience teaching physics in secondary schools in Ontario. He has also taught secondary mathematics, general science and chemistry courses in his career. He holds a B.Sc. and a M.Sc. degree in physics. He has been recognised for excellence in teaching by receiving various provincial and Canadian awards. Fermion has observed a slow increase in the enrollment of girls in physics courses over the span of his career. At the start of his career, Fermion admits to having mainly lectured, but says that his teaching style has
changed drastically since, toward a more student-centered approach. His message to beginning teachers: “Don’t be afraid to make mistakes. You need to be aware of your position and who you are and do everything you can to include all genders and backgrounds, to be aware of cultural biases.”

Quark has an undergraduate degree in engineering, and since obtaining her Bachelor of Education degree, she has been qualified to teach physics (with an honours specialist qualification), chemistry, and mathematics in the intermediate/senior division. She has been teaching senior physics courses for almost 20 years. Quark is always looking for creative, hands-on activities, and labs that would not be prescribed from textbooks, to engage her students. While she strongly believes that a teacher needs to provide a variety of teaching methods and change class routines to reach every student, Quark is also on the lookout for specific extra-curricular opportunities geared toward girls in science and engineering. She maintains that being a female and having an engineering degree helps in creating a role model for her female students. Quark’s message to beginning teachers: “Just giving [the girls] that opportunity in class to stop and ask questions and then, really [giving them] that positive encouragement. Many of them need to feel validated first in the subject, especially if it’s the subject that they have some hesitation towards … even though they’re very good at it.”

3.4 Data Analysis

After conducting the interviews, I first transcribed them. In the process of transcribing, the participants were anonymised by removing any identifying information about their schools or students. The data was then ready for analysis. In qualitative research, data analysis of an interview usually consists of coding and theme development.

Thompson, Vivino and Hill (2012) describe the initial steps in analysing the data as
developing a domain list and constructing core ideas. A domain list is a meaningful and unique list of discrete topics to which raw data will be assigned, while the core ideas summarise the participants’ words within each domain (Thompson, Vivino & Hill, 2012). The interview data is coded into the domains by assigning each block of data to a domain. Creswell (2014) calls this step coding, and describes different types of codes that can emerge from the data. From there, the core ideas of the data are created using clear and concise language (Thompson, Vivino & Hill, 2012). Establishing the core ideas helps in identifying common themes across different interviews. As suggested in Creswell (2014), the small number of themes that are developed are the ones that appear as major findings in qualitative studies. This is the process I followed in this study.

3.5 Ethical Review Procedures

The idea of informed consent, especially in health care and medical research, developed since the signing of the Helsinki Declaration to prevent the horrors of World War II from happening again (Marzano, 2012). Informed consent obliges the researcher to protect the human rights of participants. As such, informed consent forms need to provide information about the research study to the potential participants. In addition, participants need to be assured that they can withdraw from the study at any time. Potential risks and benefits to participating in the study are explicitly stated in the consent form letter, and participants need to be guaranteed confidentiality (Creswell, 2014; Marzano, 2012). In social studies, risks to participants for involvement in a study are mostly moral or psychological in nature, rather than causing physical harm. To mitigate those risks, the researcher aims to gain the participant’s trust by offering measures to maintain confidentiality, such as anonymising transcripts, keeping the data under password protection and destroying the data after the study is completed.
Universities across the globe have research ethics committees who make decisions about approval of any research involving humans or animals. University of Toronto’s Social Sciences, Humanities and Education Research Ethics Board has approved my research project, which allowed me to recruit a small sample of educators for an in-depth interview lasting about 60-75 minutes. Marzano (2012) reports that sometimes, having participants be asked to sign the informed consent form can be a deterrent as it invokes distrust. However, in my research, the participants are all teachers having a post-secondary degree, who could be researchers themselves, so the possibility of refusing to participate solely based on having to sign the informed consent letter is minimal.

I informed my participants before the beginning, and throughout each interview, that they had the right to refuse answering some or all of the questions, and that they could have withdrawn their consent at any time before, during, or after the interview (up until I began the data analysis process). My interview protocol (provided in Appendix B) was approved by my course instructor. The interviewees were given a consent form, given in Appendix A, where I briefly described the topic and the purpose of my research. I also assured the participants of protecting their privacy and maintaining confidentiality. The interviews took place outside of the participants’ workplace, to make the participants feel comfortable and talk freely about events, activities and people within their schools.

Participation in this research study was entirely voluntary, and there was no reward or monetary compensation for it, other than the satisfaction of contributing to the research on women in STEM as it relates to Ontario schools.

3.6 Methodological Strengths and Limitations

Having a small participant sample can be seen as a general limitation of qualitative
research studies. Even though qualitative interview data cannot be statistically analysed in the same way quantitative data can, the small sample size allows for a more in-depth exploration of a phenomenon, and provides richness of views that would be impossible to convey in a large-scale quantitative study on the same topic.

In the case of my research on the issue of support provided to female students in secondary physics courses, I was limited by the ethical board approval to only interview educators. Interviewing students was beyond the scope of this project. To address the topic from different perspectives, I would have liked to have conducted a youth participatory action research (YPAR) (Cammarota & Fine, 2008; Ozer, 2016) with female secondary students to find out how they feel about going into STEM fields of study and how being a female in a physics course is viewed by their peers and the community.

The sample for my study was chosen using a combination of convenience and purposeful methods. This technique was promising to yield quality deep insights from participants, but was limited in that it may not have represented the population as widely as possible. I purposefully chose participants with a lot of experience and pedagogical expertise, which resulted in the participants reportedly not experiencing tangible barriers to their efforts in supporting female students. Had I included some novice teachers in my sample, I may have heard about possible barriers to implementing gender-equitable classrooms. Additionally, as a novice interviewer, I may not have had enough experience in skilfully extracting the rich, full data that makes the qualitative research meaningful.

3.7 Conclusion

In this chapter, I have described my research approach and methodology. I have gone over different methodologies used in qualitative research, and benefits of using qualitative
research approach for this type of project. Among different instruments of data collection, I
described the reasons for choosing the semi-structured qualitative interview as it fit my research
purpose and questions best. To find the participants for the interview, I used both the purposeful
and convenience sampling methods, and I described the criteria I had selected to look for
participants with extensive experience and knowledge in my research topic. I provided brief
biographies of my research participants. I went over the ethical considerations in using humans
in research, and provided concrete steps I took to protect my participants’ rights. I explained
some merits and challenges in my choice of methodology, and possible other avenues of
exploring the topic of girls studying physics in secondary schools as a possible pathway to
STEM careers. The chapter that follows reports on the research findings from the data collected
in the interviews.
Chapter Four: Research Findings

4.0 Chapter Introduction

This chapter presents research findings from the data collected in semi-structured interviews with Ontario physics teachers. While listening to their experiences in teaching high school physics courses, I was guided by the central research question: how are Ontario secondary physics teachers reportedly supporting their female students? Before conducting the interviews, I reviewed the research on possible reasons for the under-representation of women in STEM, I looked at the literature on the effects the teachers may have on their female students through their position and their teaching, and I investigated female students’ motivation and engagement in STEM. The interviews with physics teachers arose from the need to fill the gap in the existing literature on the experiences of Ontario teachers practicing gender-inclusive physics teaching.

There were three participants in the study: Quark, Boson and Fermion. All three have been teaching senior physics courses in high schools across Ontario for over 15 years. Boson, Fermion and Quark are all actively involved in promoting gender equity in mathematically-intensive sciences, and are looking to support their female students regardless of the career path they choose.

Four main themes emerged from the analysis of the interviews. The first theme is the personal influence of the teacher on their students through teachers’ awareness of their positional identity. The two themes that follow focus on concrete actions physics teachers take in their classrooms to create learning environments welcoming to female students. Therefore, the second theme describes the use of cooperative learning strategies in teaching physics to support girls. The third theme shows how physics teachers follow the tenets of culturally responsive pedagogy in reaching out to their female students. The fourth, and last, theme explores some of what
physics teachers reportedly do outside of classroom time in support of their female students, and how they promote extra-curricular activities geared toward women in science. I explore each theme in depth in the following sections.

4.1 Teachers’ Awareness of Their Positional Identity

Despite the differences in their positional identity, physics educators are committed to helping their female students succeed. Holland et al. (as cited in Moore, 2008) define positional identity as a person’s perception of self in relation to others, or “a sense of relative social position within particular contexts” (p. 685). In the context of teachers, this can include gender, race, religion, educational and ethnic background, but also the teachers’ position of power and trust in relation to their students, and at least by age difference, being more experienced than their students. The participants in this study all responded differently to the question of their gender identity in relation to their teaching practice, and how it may affect their female students. Thus, rather than focusing on whether the teacher is a good role model for female students, I discovered that the underlying theme emerging from the data shows how the teachers’ overall positional identity informs their practice. In this section, I discuss each participant’s identity story and how it relates to their awareness of teaching female students.

Fermion is acutely aware of his position of privilege as a white male teacher of physics. He puts “great effort to recognise that, and make[s] sure [his] classroom is equal for all genders and all different backgrounds.” Fermion places name cards on his students’ desks before class to welcome them to the space and to eliminate wondering who they were going to sit next to. He reports that his university-level grade 12 classes are evenly split in terms of gender, while in his college-level classes roughly two-thirds are male. Fermion is optimistic that the number of female students in physics is on the rise: “It’s getting better all the time, I expect that to
continue.” Considering that physics is an elective course in senior grades, I find that the balanced gender composition in the courses Fermion teaches speaks to his great efforts in supporting all students, while being aware of his position.

Quark interrupted with a resounding “Yes” before I even finished asking whether she thinks her gender identity matters in supporting females in her classes:

It matters to have a female teacher. Big difference for some of the girls in the amount of confidence. And for many of the guys I find it doesn’t really matter, you know, it’s not that they are necessarily looking for a male role model in some of the subjects, but for some of the girls it’s really important to see [a female teacher].

In addition to this reported boost in confidence that her female students experience with a same-gender teacher, Quark observed that “the girls very much look for somebody they can identify with.” She noticed an increase in the number of her female students applying to engineering programs in university since she started teaching them, as opposed to when the students were having male physics teachers previously. The girls would see themselves mirrored in her, being female and with an engineering background. She strongly feels that female students need to identify with a teacher, or with somebody they know who is practicing a profession, before choosing to pursue it. Quark attributes it to females being “more cautious, not going somewhere completely unknown”. Her beliefs would imply that a ‘strength in numbers’ approach, or just giving females in science more visibility, could be a good strategy to attract more capable young women into STEM fields of study, especially those that are perceived as mathematically demanding sciences.

On the other hand, Boson, who does not identify strongly as a female, takes a firm stance that a teacher’s gender identity does not play a deciding role for female students taking physics
courses. She used to “think that just by being female, and by doing what worked for [her] would help”, but over the years found that it was not about the fact that she is a female. What matters more, according to Boson, is the personal encouragement that any teacher can provide to girls to boost their confidence. She mentions that teachers need to tap individual students on the shoulder and telling them how capable they are, while trying to combat stereotype threat these girls experience. The ‘personal touch’ as a culturally relevant teaching strategy will be discussed further in section 4.3.

The theme of identity found in a review conducted by Brotman and Moore (2008) overlaps with the theme of positional identity of teachers addressed in this research. The studies reviewed by Brotman and Moore try to broaden the “gender and science” issue to not only white women’s experiences in science, but involve the intersectionality of gender and religion, ethnicity, class, language and lifestyle. While some studies (Dee, 2007; Paredes, 2014) showed an increased academic achievement in girls having a female teacher, others (Cho, 2012; Marsh, Martin & Cheng, 2008) find no impact of teacher-student gender matching on achievement. The findings from this study cannot support that just by being female, a teacher may be more likely to have girls in class achieve better, since Fermion, who is a male teacher, does not report his gender identity negatively impacting girls’ achievement in his classes. On the contrary, he “do[es] not notice the difference gender wise” in participation and achievement in general.

Regardless of their positional identity, all participants report expending great effort in supporting their female students and providing gender-inclusive space in their classrooms. The findings described in this section just make it clear that there are different paths teachers can take to provide that support, depending on their positional identity.
4.2 Using Cooperative Learning Strategies in Teaching

Physics teachers report that using cooperative group work as a learning strategy has a positive impact on girls in their classes. The literature on cooperative learning (CL) as a pedagogical tool and how it pertains to gender was discussed in Chapter Two (section 2.2.2). The five essential principles of cooperative learning, as outlined in Johnson and Johnson (2005) are: positive interdependence, individual and group accountability, promotive interaction, appropriate use of social skills, and group processing. All three participants in this study reportedly use cooperative learning strategies as part of their teaching repertoire, and although they do not gear their group activities toward the female students specifically, they all report positive outcomes for girls.

Quark understands the importance of group work as part of her varying teaching repertoire. She talked about employing informal cooperative learning strategies, where students are working in ad-hoc groups to achieve a common goal (Johnson & Johnson, 2009). In Quark’s classes, students are reportedly grouped to complete lab investigations, or to engage in problem-solving discussions. Boson and Fermion have all but abandoned direct instruction approach, and report the use of more formal cooperative learning (Johnson & Johnson, 2009) extensively, where the students work in structured, guided groups for most of the time in the course.

Although Quark did not mention whether she facilitates group processing discussions on how well the students feel they are working together, her students are reportedly given opportunities to demonstrate positive interdependence and accountability in small group in-class discussions. She occasionally varies her group compositions, but mostly allows students to choose their own groups. In her classes, girls are reportedly “better at following instruction” and pay more attention to detail, and thus come to “love labs” in her courses. According to Quark,
the variety of group activities, interspersed with direct instruction, teacher demonstrations and individual problem-solving work, spark student engagement, including girls.

Boson reports getting to know her students really well early on in the course, and is striving to be aware of the class dynamics at all times. She changes her group composition daily, and makes sure to select group members based on their personalities, assertiveness, and leadership skills, while following their group processing abilities. This is how Boson describes setting up and selecting the groups in her classes:

So we do most of our work in small groups … it could be two, three, four. I watch carefully the dynamics. So if I have a quiet, hesitant female, I won't put her in a group with two loud males. … On the other hand, if I've got a really confident mouthy female, I might. So I get to know the students and when I'm arranging the groups, I make sure that they are not overwhelmed.

This illustrates how Boson endeavours to be mindful in particular of her female students, and makes sure to balance the groups for in-class work, especially in the beginning of the course, when she may not know all her students. She reportedly strives to provide everyone with an equal opportunity to shine: “Mind you, I do that also for a male student who is very shy. I won't put him in with two [strong boys]”. Boson here refers to the selection process for groups, and just as she wouldn’t put a girl, she also wouldn’t place a shy boy, in a group with two other overconfident boys who may dominate the discussion. Fermion echoes Boson’s remarks in making sure not to let male students dominate the conversation, and says: “If it’s the same boy always putting up his hand, any opportunity I can get another voice in the classroom, … I make sure that happens.”
Fermion describes how his approach to instruction using cooperative learning benefits female students:

I think it’s more about what my class looks like, and how they interact. There’s not much time I am at the front of the classroom, talking to them. The vast majority of time they’re working together, they’re in groups, and [working] cooperatively, and I find that it benefits everyone, but girls in particular.

Additionally, Fermion found that letting the students create their own groups did not work as well, so he personally selects group members for each task. The cooperative groups in his classroom are structured so that each member in a group has a specific role by which they contribute. For example, if there is a project that involves computer programming, he makes sure that every group has a student “programmer”, and assigns students with a range of abilities to each group while taking into account personalities of students.

Not only do Boson and Fermion structure the in-class groups in a particular way, but in addition, Boson frequently surveys her classes to find out how well the students think their group is functioning. This fits the group processing criterion, one of the five elements of CL in the social interdependence theory (Johnson & Johnson, 2005). According to Johnson and Johnson (2005), group processing occurs when members reflect on their actions and make decisions about what actions to continue or change. From one of her surveys, Boson found a strong correlation between the height of a student and their assertiveness (by asking questions such as: who gets to run the equipment first, who gets to talk first, etc.), and she found the results interesting:

Recently I’ve discovered it’s also short people I need to watch out for. In terms of assertiveness, the boys in every class were more assertive than the girls … And when I look at the height and assertiveness, [there’s] positive correlation. Stronger for the girls
than for the boys. So the girls have internalised that for short people, you don't speak up; tall people, you do speak up. I've got some very tall girls, they speak up. So I watch for any unevenness there, and I try to make the groups so that no one is going to be squashed.

Surveying the classes, as Boson does, is not solely a formative assessment tool to inform content delivery, but a technique secondary physics teachers use to understand how their students interact with each other and how they feel about their contributions to the group and individual learning.

Boson and Fermion use cooperative learning strategies extensively, and they find that this provides the opportunity for all their students to get involved, and gives every learner a voice, especially the minorities in math-heavy, male-dominated sciences. Boson concludes:

The nice thing about training students to do group work is, kinda like this Universal Design thing. You not only help the females, you help the shy guys, you help the short guys, you help the racial minorities, it helps everybody, you know? You're not just saying ‘it's you against you.’ It’s like: ‘Each of you, think about how you're behaving, and how you think you should.’

Boson feels that structuring formal cooperative learning groups in physics supports not only the engagement of girls in the class, but that all other students benefit from reflecting on their contributions to achieve the common goal. The other participants also note that allowing the girls’ voices to be heard in small cooperative group discussions increases their participation in class.

Despite the lack of research literature that directly crosses gender with achievement in cooperative learning environments, some research on cooperative learning indicates that there are benefits to being in a CL environment for female students in traditionally male-dominated
fields such as in math and science courses (Johnson, Johnson & Stanne, 1986). As discussed in Chapter Two, girls can achieve higher status, more confidence, greater feeling of competence and more equal gender participation among peers, when placed in cooperative learning environments (Hänze & Berger, 2007; Hijzen, Boekaerts & Vedder, 2006; Johnson, Johnson & Stanne, 1986). Their research is supported by the findings from this study, given that the participants report using CL instructional methods in support of girls in senior physics courses.

4.3 Characteristics of Culturally Responsive Physics Educators

Educators following the tenets of culturally responsive pedagogy (CRP) in physics report supporting a gender-inclusive classroom climate. Culturally responsive/relevant pedagogy (Gay, 2002; Ladson-Billings, 1995a) as a tool to include under represented groups in STEM was discussed in Chapter Two. I use the term culturally responsive pedagogy and its acronym CRP here as it was described in Ontario Ministry of Education (2013), which draws references from Ladson-Billings (1995a) and Gay (2002). Being a culturally responsive educator is more than simply being aware of the ethnical, racial, gender, cultural and linguistic differences of students. In addition, the participants in this study are self-aware, while possessing a deep knowledge of their students, which makes them culturally responsive educators (Ontario Ministry of Education, 2013). Even while not explicitly naming themselves as such, Boson, Fermion and Quark exhibit the following characteristics of culturally responsive practitioners (Ontario Ministry of Education, 2013) toward their female students through their interview responses: knowing their students’ lives and backgrounds, building class instruction to respond to the experiences of girls, holding affirmative views and high expectations of students of all genders, being conscious of socio-cultural issues of girls in STEM, and having the desire to work towards more gender equity in STEM.
The study participants report using a variety of tactics to achieve a physics learning space welcoming to students of all genders. They reportedly get to know their students and their lived experiences in order to approach students from the point of their prior knowledge. When asked to describe how they planned instruction to support girls in their classes, all three participants responded that they did not do anything specific for girls, but used strategies for all their students that also aim to make girls feel like they belong in physics class. Fermion places name cards on his students’ desks to welcome them, and “every day at lunch [he] ha[s] students do work, they help each other out, majority of them are girls. [Fermion] think[s] it’s a welcoming classroom.” Boson brings examples of female scientists from across the globe to reflect her female students’ experiences. Quark gets to know her students really well and responds to their needs individually, sometimes by giving personal attention in class to the more reserved girls, or encouraging girls to take on more challenging problems (having high expectations).

One of the ways all three participants use CRP in their practice is in the form of personal support and encouragement. Quark frequently approaches her female students individually and allows them the space to ask a question without inviting the attention of the whole class. She doesn’t think this discriminates against boys, as she claims that the boys in her class are loud and up front about not understanding concepts or material presented in class, and they are quick to demand more explanation, so Quark does not feel the need to ask them for understanding individually as she does with girls. Boson actively takes an interest in her students and their career paths. She would say to a student: “You know what? I’m so impressed with your perseverance, with your insight.” And she would encourage them to explore possibilities in a wide range of careers, including STEM fields.
The study participants reportedly provide ample in-class mentions of science experts across cultures, genders and abilities. Fermion’s physics problems and examples are full of women astronauts, women pilots, as well as a range of genders, using “she”, “he” and singular “they.” Quark talks explicitly about connections to careers for women in engineering and physics in her classes. Boson incorporates achievements of scientists from across cultures in her class:

And the Black physicists are harder to find, and certainly there are Indian and Japanese, and Chinese, but then somebody needs to be explicit about it. I think you don't just gloss over it … A hundred years ago, women were not allowed to go to university and get degrees … We’ve only gone through a few generations. How much of it is still floating around?

Boson believes that, because of the relatively short time of women obtaining university degrees, prejudices still exist against the capabilities of women pursuing careers in science. Therefore, she feels even more important to point out in class to the existence of women of different cultures currently practising scientific research. All participants agreed that more attention in class needs to be drawn to successful physicists, engineers and computer scientists of all backgrounds in order to show diversity and open up the possibility to their students to pursue interest in mathematically-intensive STEM fields.

Using CRP as part of the gender-inclusive practice of physics teachers is a theme that emerged from conducting interviews with the participants for this study. As the interviews progressed, the researcher realised that being reportedly supportive of girls in physics classrooms is not just about how one teaches physics, but also about knowing the students well, and finding moments to respond to the lived experiences of female students. These experiences are not isolated to the students’ gender, but are intersected with their family expectations, culture, faith,
linguistic and ethnic background, as demonstrated by the participants’ consciousness of socio-cultural impacts on female students (CRP characteristic #1, Ontario Ministry of Education, 2013). There is scarcity of research on how CRP specifically promotes gender equity in STEM, but there are a few studies emerging recently that address this (Charleston, Charleston & Jackson, 2014; King Miller, 2015; Mejia & Wilson-Lopez, 2017). This study’s research findings add to the idea that culturally responsive practice promotes affirming and belonging spaces for girls in senior physics courses.

4.4 Promoting Extra-Curricular Activities Geared Toward Girls in Science

Physics educators find that exposing girls to extra-curricular science-related activities keeps them motivated and engaged in physics. All three participants showed a commitment to bringing current, cutting-edge research into their physics teaching, and taking their students outside of classroom setting to expose them to such research. They frequently advertise enrichment programs and contests for high school students in physics available throughout Ontario. They also report talking about any STEM programs and events geared specifically toward girls. All of the participants in the study reportedly also provide support to their female students outside of classroom in taking them to field trips, science competitions and contests.

Quark talked about taking a group of her grade 11 physics girls on a trip to an Ontario university, which was hosting an event with a goal to expose like-minded young women to the rewards and challenges of a career in science. Quark pointed out how the girls were very excited to attend the event, indicating her belief that it matters for the female students to be inspired by seeing other women in science careers.

In surveying her students, Boson discovered that some female students that enroll in her school’s specialised STEM program have a strong interest in art. This prompted her to include
art-related projects in her physics class. As she also teaches an interdisciplinary project-based course, she says:

I'm starting to put more emphasis on the aesthetics of the final product. Not just what goes the fastest, not just what goes the farthest, but what does it with style. So that would be my thing. Because that's something that appeals to them.

She notices that girls love to spend time working on the projects for the course, if the aesthetics of what they are making is also valued. In her practice she is essentially transforming STEM to STEAM, with the “A” in the acronym standing for the arts.

Exposing girls to the career-related, research-related and cross-disciplinary possibilities in science may help with sparking their interest in physics and related careers, as this study’s participants attest through their practice. Various research studies reviewed by Brotman and Moore (2008) provide mixed results, with some showing positive impact of extra curricular programs on girls, and others showing no positive outcome for girls. Developing interest in a field of study and career is a socio-cultural phenomenon, and supports may be missing for girls to develop interest in physics. The participants in this study provide ample support for developing girls’ interest and motivation to study physics by exposing them to enrichment activities that connect multiple disciplines in science, engineering and computer studies. Even if that practice is not directly supported by research literature to promote gender equity (as Brotman & Moore, 2008 suggest, some extra curricular activities may even perpetuate stereotypes as they are targeted toward students who are already interested in science), if it is carefully planned and followed up with meaningful discussion with the students, all three teachers who participated in this study find it a valuable addition to their repertoire of gender-inclusive practice.
4.5 Conclusion

In this chapter I presented the findings from the data collected in interviews with three Ontario physics teachers. The participants in the study are different in their pedagogies, in their positional identities – which includes how their gender is perceived to help or hinder promoting physics to female students – and in what they specifically do to welcome and support girls in their physics classes. Nevertheless, all three of them expressed a deep commitment to encouraging their female students in being successful well beyond high school physics. Additionally, all three participants agreed that the types of assessment they use largely do not affect the student performance based on gender.

The chapter that follows concludes this study by making connections between the literature and the findings from the interviews, to inform my own identity as a teacher. In the concluding chapter, I offer implications and recommendations for educators and the students in senior physics courses. I also reiterate best practices for physics educators, which were touched upon in this chapter, and identify next steps for further research in physics education.
Chapter Five: Conclusion

5.0 Chapter Introduction

This chapter offers concluding remarks and suggestions for future research on the topic of senior secondary physics teachers’ reported experiences in supporting their female students. Here I provide the overview of key findings from my research study as presented in Chapter Four, and I expand on their significance. Subsequently, I present implications of my findings both for the educational community and for my future practice as a teacher-researcher. The implications from this study lead me to offer recommendations for physics teachers, schools and teacher education programs in striving toward welcoming female students in STEM fields of study in Ontario. Finally, I discuss areas for future research on practicing gender equity in senior physics courses.

5.1 Overview of Key Findings and Their Significance

This research study grouped the key findings into four main themes. The instructional strategy of structured cooperative learning (CL) reportedly promotes girls’ interest in physics and related fields of study, which is supported by the literature that cross-investigated cooperative learning and gender. The second theme reveals that teachers who follow tenets of culturally responsive pedagogy report a positive impact on girls in senior physics classrooms. The third theme shows that physics teachers are committed to supporting their female students in physics, despite having different positional identities, which involves gender identity, class and lifestyle. And finally, this study found, as related in the fourth theme, that exposing female students to cross-curricular and extra-curricular science-related enrichment opportunities keeps them motivated and engaged in STEM fields of study.
The significance of the findings presented in this study is in the implications for Ontario educators and the wider educational community. While I started out trying to look into best practices of teachers supporting their female students in physics, I ended up having a much deeper understanding of how physics teachers can practice gender inclusivity in different ways and from different positions. All three participants in my study try to address gender inequities and are being welcoming and open to all their students. The teachers I spoke to pointed out that they don’t tend to isolate girls in their classes nor do something specific for them, but rather they used pedagogy that aims to include students of all genders through cooperative learning and culturally responsive pedagogy. Although some research notes the importance of visible female role models in physics teaching (Paredes, 2014), one of the participants in this study, Fermion, appears to defy the research. Namely, Fermion identifies as white male and thus is not an obvious role model for his female students. However, he happens to have the highest proportion of female students in senior physics courses among the three participants, and among the highest in the province (about half of students in Fermion’s grade 11 and 12 physics classes are female, while the province average is about 30% female students enrolled in these courses). The other two participants, Quark and Boson, identify as female, and use different strategies in their practice to encourage female students: Boson more through CL and culturally responsive pedagogy, and Quark through personal one-on-one encouragement and out-of-class support. Still, all three participants are aware of the under-representation of females in physics and all three are reportedly highly supportive of their female students while working to provide equitable classroom environment from their different positional identities.
5.2 Implications

In this section, I discuss the implications stemming from the findings of this research study on gender inclusive practices of Ontario physics teachers. First, I explore the implications for secondary physics students in Ontario, then the implications for physics teachers and school administrators. Following these implications for the educational community in the broad sense, I discuss the narrow implications for me as a teacher and an education researcher, coming from conducting this study.

5.2.1 Implications for the educational community

The way physics teachers in senior high school courses interact with their students, and the kind of environment they establish in their classrooms may impact the way students learn and how they feel about what they are learning (self-efficacy). The findings from this study suggest that students who are usually under-represented in senior physics courses, such as females, may benefit from learning in structured cooperative environments. Research supports this, in stating that girls are elevated to higher social status when seen as equal partners in group learning (Hänze & Berger, 2007). The teachers I spoke with, who use cooperative learning (CL) for physics instruction, affirm that the girls in their classes show more confidence in small group environments than in whole class discussions. Even though the physics teachers report that the girls in CL groups have equal status as the non-female members of their groups, I wonder about the implications of using this pedagogical strategy extensively with some students who may resist being placed in groups. Since cooperative learning, if implemented in a structured way as presented in Johnson & Johnson (2005), provides opportunities for small group interactions with each member having an assigned role, students who normally do not appreciate drawing attention to themselves, or who have identified exceptionalities related to communication, may
benefit from sharing their ideas in a cooperative learning environment. They could also learn from others in their groups without the need to ask them questions explicitly. Small groups could be the low pressure environments where both extroverted and introverted students can maximise their understanding of concepts in the physics classroom. Cooperative learning strategies may result in female students, who are normally in the minority in senior physics courses across Ontario and are frequently exposed to feelings of gender stereotype threat and low self-efficacy, feeling empowered to participate and be more confident while engaging with class content.

Another implication this study has for physics teachers, then, is that they may need to be knowledgeable in cooperative learning strategies and ways to promote gender equity through culturally responsive pedagogy and through promotion of extracurricular events geared toward girls in STEM. Some physics teachers may perceive notable difference in the behaviours of girls in their senior classes, and may notice that by the time girls get to high school, they are already socialised to feel unwelcome in mathematically-intensive fields of study. However, these teachers may not be aware of some of the best strategies, and may not have the tools to address the gender imbalance in senior physics courses.

Finally, some teachers may not be aware of the issue of under-representation of women in STEM careers and fields of study, and would not be doing much to address it, claiming gender-blindness. They may feel that there is no place in physics class to discuss gender equity and historical practices of science in different cultures, following largely Eurocentric strategies of science education and teaching, and feeling pressure to cover a lot of material in little time.

If teachers don’t share with their school administration about the activities they plan to promote gender equity in science teaching and learning, the principals and other school administrators may not be doing much to provide support. The school principals could organise
school-wide events to address the issues of female under-representation in sciences, so that gender inclusive practices toward women in STEM fields could be brought forward to the whole school community.

5.2.2 Implications for myself as a professional teacher-researcher

While conducting this research study, I have become more aware of the issues both the students and the teachers may face in terms of promoting gender equity in mathematically-intensive sciences. After talking to numerous teachers both in my interviews for this study and in the wider community of physics educators, I have decided on trying out a pedagogical approach that seems to be supportive, both in research and practice, of the under-represented groups of students in STEM, including females. Nevertheless, I do not claim that it is the best approach, nor the only one that would work for every educator involved in actively supporting girls in senior secondary physics courses. As a starting point, I am planning to implement two pedagogical approaches that, from the findings of this study, are reportedly beneficial to female students.

Firstly, I would implement structured cooperative learning in my teaching, with the five principles laid out in Johnson & Johnson (2005) as a guide. Those principles are: positive interdependence, individual and group accountability, promotive interaction, interpersonal and small group skills, and group processing. As CL implementation requires careful planning and getting the students involved in the reflective process of interacting in a group, I would design a whole course with CL principles in mind. I would get the students to reflect on their contributions to the group as well as the benefits they get from their peers, throughout the course. I would observe my students with their permission, and I would like to cross-analyse their reported feelings of self-efficacy with gender.
Secondly, throughout my teaching, I would implement the six characteristics of culturally responsive pedagogy (CRP), as suggested by Ontario Ministry of Education (2013). As I currently try to include culturally responsive ideas in my teaching, I will continue to expand on my CRP approaches as I gain experience in striving towards inclusive spaces in my classrooms. Even though the literature I consulted on CRP addresses gender equity mainly in the form of combatting gender-based violence, and although I found barely any research on how CRP can help address the subtle socio-cultural reasons for under-representation of women in STEM, some of the findings from this research study point to the use of CRP as one way to practice gender-inclusive physics teaching.

As a member of various teacher associations and organisations, I benefit from interactions with the wider community of physics teachers in Ontario and Canada. There are teachers of senior physics courses across the province who use CL strategies and follow the tenets of CRP in their teaching extensively. I would want to build a community of practice with those teachers, and share the outcomes of our teaching methods with the wider educational community at our respective schools, at conferences and during other professional development opportunities. By being a part of a community of practice, we can strive to keep improving our pedagogy and learn from each other and with each other.

I believe that publicly funded schools are responsible for promoting equity while educating, and that they are mandated to make critical thinkers out of students. While both the province and its largest public school board have strong equity policies in place, I believe that there can and should be more done in practice. Whether I teach adolescents or adults, in public or independent schools, as an educator I have a role to play in establishing and maintaining the purpose of equity. In my classrooms, I would like to create a gender-inclusive space, a
community of learners exercising mutual respect, where under-represented groups in STEM would feel welcome and their contributions relevant.

5.3 Recommendations

The implications from the findings of this research study suggest several stakeholder groups in implementing inviting spaces for female students in Ontario physics courses: the students themselves, the physics teachers, teacher education programs, school administrators and the researcher. This section lays out the researcher’s recommendations for the above-mentioned stakeholders in view of the implications stemming from this study.

Teachers in science classes, and in particular, those teaching physics courses where girls are a minority in Ontario, would benefit from starting with small steps toward implementing equitable teaching. As a starting point, those teachers should address gender inequity in STEM fields openly and explicitly in class. One of the study participants, Boson, talked about how she had interpreted girls in physics classes reacting to the awareness of gender disparity in STEM: “Oh, it’s not just me, I’m part of a thing”. This would not only empower the girls in physics classes, but also make every student, whether identifying as part of an under represented group or not, be aware of the inequalities present in STEM fields.

In creating the classrooms which are welcoming to female students, physics teachers should diversify the examples given in class to provide more female presence, and to reflect more lived experiences of their students, while moving away from the usual baseball and cars references in physics problems and examples, as seen in some textbooks. In addition, in striving for equity, it is the physics teachers’ duty to mention the achievements of women scientists from across the globe whenever possible. This requires awareness and a bit more effort on teacher’s side, but does not require compromising the time spent on quality classroom content.
The physics teachers need to make their classroom environments progressive sites of change. In order to welcome girls to those spaces, they should make it their mission to spot and address the instances of subtle discrimination and microaggressions toward females in STEM. For example, the teachers should be careful not to allow male voices to overpower the classroom discussions by allowing the time and space for more reserved students (in physics classrooms, it’s usually girls) to express their understanding of the concepts, if not by raising their hand in whole class discussions, then by written output which may be presented to the whole class. The physics teachers should also carefully and purposefully select the groups for cooperative learning in such a way to allow the female students to feel comfortable. For example, this may involve not placing a female student alone with two or more male students in a group, and making sure that all students (in particular, females) get a chance to work with the equipment.

Teacher education programs across the province have a significant role to play in training future science teachers. The pre-service programs for teaching physics in intermediate/senior division should emphasize equity as part of the training in best pedagogical practices. The course instructors for teacher candidates in physics should make sure to invite guest lecturers who will address some of the issues of under-representation of women in STEM careers, and recommend what educators can do about it at the school level. Practicum placements for pre-service physics teachers should be as much as possible with experienced teachers who promote gender equity in sciences, so that new teachers can see best practices in action.

Curriculum leaders in science departments and principals in high schools across Ontario need to make sure that teachers have access to relevant provincial and board equity policies and see that those policies are implemented. As stated in the Ontario Ministry of Education (2013) document, the school leaders need to ensure that both school climate and the classroom learning
environment are inclusive and welcoming of diversity. In the context of STEM teaching, this includes gender diversity. The school administrators should emphasize the connections between policy and practice wherever possible, including through relevant professional development for teachers. They should provide teachers with opportunities to explore practical ways senior physics classes can be made gender inclusive. As leaders, with the ability to incite change, school administrators should be setting up expectations for classrooms as welcoming spaces for female students in senior physics courses.

5.4 Areas for Future Research

My findings were somewhat limited in their scope by the type of study conducted, and the methodology used. To delve deeper into teachers’ practices in supporting female students in senior physics courses and to better understand best gender-inclusive practices, other areas of educational research could be explored.

This study focused on direct experiences of physics teachers with their students. In another study that would involve interviews with physics teachers, the participants could be asked about their interactions with parents of students, and whether there is a perceived impact of their teaching on female students which involves parents and the wider community.

Research could be done as a self study, or a cooperative participatory action research (PAR) within a department or across the province with a goal to increase awareness and promote gender equity in science. This can involve video recorded classroom teaching sessions, after which the teachers would analyse the videos and observe any instances of gender stereotyping, or subtle micro-aggressions toward females in the senior physics classrooms. Both teacher-student and student-student interactions can be explored.
Also, it would be exciting and highly relevant to hear student voices on the issue of under-representation of women in science, so a youth PAR (YPAR) study is warranted in the future. It would be helpful to have a gender cross-analysis done with the students’ feelings of self-efficacy in mathematically intensive courses and fields of study, with their own interpretation of gender stereotype threat, and their feelings of belonging in the field of physics study and research.

Considering that the local data on physics teachers’ experiences is scarce, further research needs to be focused on Ontario and Canada. More studies are needed to look at the effects of CRP on gender, especially in mathematical and physical sciences. It would be useful to gather cross-studies of CL and gender specifically for sciences and math at all grade levels in Ontario. Longitudinal studies that follow students from elementary school into university would contribute to understanding of the retention of females’ interest in STEM fields of study over their educational careers.

Future research can be directed toward broader educational community. Namely, guidance counsellors can be interviewed to obtain their perspective on pathways female students take, or are planning to take, after obtaining credits in senior physics courses. Also, it would be interesting to explore the advice female students receive from their guidance counsellors, while choosing their tertiary education and career path after taking senior physics courses in secondary school.

All of the suggestions for further research presented above would provide valuable data and insights into the physics education in Ontario, especially with a lens on gender inclusivity.
5.5 Concluding Remarks

Just like this study’s findings suggest, I will strive to support my female students by utilising gender-inclusive lesson planning in three ways. One is by bringing gender and cultural diversity into the STEM subject content, real-life examples and assessment. The second way is by active encouragement and promotion of events geared toward females in STEM. And lastly, but just as importantly, by promoting cooperative work and creating a respectful community of learners, where all students can feel like they belong. Through future research and ongoing professional interactions with colleagues, I hope to maintain a community of practice around equitable teaching in STEM.

I want to end with a reference to the title of the Ladson-Billings (1995b) article on culturally relevant pedagogy: “But that’s just good teaching!” This phrase has been with me throughout the process of conducting this research study, and especially stuck in my thoughts during the interviews with the participants who, while mentioning many excellent teaching practices in general, bring the awareness of social justice and gender equity into their regular physics teaching repertoire. I do believe that implementing some of the best general teaching methods, based on research and grounded in practice, is the way toward a more inclusive and safe space for women pursuing mathematically-intensive fields of study. I also think that in the current climate of under-representation of women in mathematically-intensive STEM fields, there is no space for gender-blindness, even if it is offered with best intentions. And while numerous research supports the general view that there is no innate difference in mathematical ability across genders, the societal effects for women in the male-dominated fields of mathematics, computer science, engineering and physics are real and tangible. It is the responsibility of educators in these fields to bring about much needed change.
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Dear ______________________________,

My name is Vjera Miović and I am a student in the Master of Teaching (MT) program at the Ontario Institute for Studies in Education at the University of Toronto (OISE/UT). A component of this degree program involves conducting a small-scale qualitative research study. My research focuses on supporting female students in physics courses on a path to choosing STEM fields of study in post-secondary education. I am interested in interviewing teachers who have the experience of being actively involved in promoting physics and STEM fields of study to their students, and who have a particular focus on helping their female students succeed and retain interest in physics. I think that your knowledge and experience will provide insights into this topic.

Your participation in this research will involve one roughly 60-75 minute interview, which will be transcribed and audio-recorded. I would be grateful if you would allow me to interview you at a place and time convenient for you, outside of school time. The contents of this interview will be used for my research project, which will include a final paper and informal presentations to my classmates. I may also present my research findings via conference presentations and/or through publication. You will be assigned a pseudonym to maintain your anonymity and I will
not use your name or any other content that might identify you in my written work, oral
presentations, or publications. This information will remain confidential. Any information that
identifies your school or students will also be excluded.

The interview data will be stored on my password-protected computer and the only person who
will have access to the research data will be my course instructor. You are free to change your
mind about your participation at any time, and to withdraw even after you have consented to
participate. You may also choose to decline to answer any specific question during the interview.
I will destroy the audio recording after the paper has been presented and/or published, which
may take up to a maximum of five years after the data has been collected. There are no known
risks to participation.

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

Sincerely,

Vjera Miović
Consent Form

I acknowledge that the topic of this interview has been explained to me and that any questions that I have asked have been answered to my satisfaction. I understand that I can withdraw from this research study at any time without penalty.

I have read the letter provided to me by Vjera Miović and agree to participate in an interview for the purposes described. I agree to have the interview audio-recorded.

Signature: ______________________________________

Name: (printed) ______________________________________

Date: ______________________________________
Appendix B: Interview Guide

Thank you for agreeing to participate in my research study. The goal for my research is to explore teachers’ practices in actively supporting and involving girls in physics classrooms. The interview should take approximately 60-75 minutes, and it has about 17 questions. The interview protocol has 4 sections. First, it collects your background information, then the questions focus on your current practices in teaching physics to female students, with the instructional and assessment strategies you use. The third set of questions explore your experiences and beliefs related to female students’ involvement in physics, and lastly, I will ask about any supports and challenges you face. I want to remind you that you can withdraw from the study at any time, and if you wish to continue, you may refuse to answer any question. Do you have any questions for me at this time?

Section 1 – Background Information

1. Which subjects do you currently teach (grade, course)?
   
   a. Which subjects have you taught in your career?

2. How long have you been teaching?
   
   a. How long have you been teaching physics?
   
   b. How long have you been teaching at your current school?

3. What is your educational background, and how long ago have you completed your degree(s)?

4. If you don’t mind sharing, what is your gender identity?
   
   a. Do you think that your gender matters in supporting girls going into physics courses in secondary schools?
5. In order for me to get a better idea of your students, can you tell me what the composition is of your physics class(es) in terms of gender?
   a. Based on your experience, how has the gender composition in physics classes changed (if at all) over the course of your career?

6. In your experience, what is the drop-out rate of girls in grade 12 physics in your school?
   a. How many students involved in (extracurricular science-related activity) take grade 12 physics?

Section 2 – Teacher Practices

7. Can you describe your typical physics class (if I was observing your class, what would I see)?
   a. Think about a class you taught yesterday (or recently)?
   b. How do you start the class?
   c. What are the typical steps? What do the students do? What do you do?
   d. Can you walk me through the process for planning your most recent unit?

8. Can you recall a time when you prepared a lesson having your female students in mind – to spark their interest in physics?
   a. What instructional strategies did you find particularly effective in provoking interest in your female students?
   b. What resources do you use to actively involve girls when you teach physics?
      i. (Online, print, journal articles, news articles, activities)
   c. If your plan to involve more girls didn’t go as well as you thought, what would you do differently next time?

9. Can you give an example of when in your class you explicitly supported girls, or drew attention to women in physics?
a. Do you mention female physicists, do you talk about extracurricular programs for girls in physics/science/computer studies, etc.?

b. (If self-identified as female) Do you think you serve as a role model to your female students?

10. Have you explicitly supported girls outside of the classroom? In what way?

a. Can you provide examples?

11. What kinds of assessment do you use in your physics course?

a. What impact, in your opinion, do different types of assessment have on girls in your classes?

12. To what extent do your students support each other in physics courses?

a. Do girls from your class get together to study and help each other with understanding of concepts?

b. (If in mixed-gender classroom) What have you noticed about students of different gender in terms of supporting each other in the physics course?

Section 3 – Teacher Experiences and Beliefs

13. What do you believe girls can gain from being involved in physics and taking physics courses?

a. Can you tell me how you think that girls in your class respond to your methods/support?

b. (If in mixed-gender classroom) Can you tell me how you think that students in general respond to your methods/support for girls?

Section 4 – Supports and Obstacles
14. What kinds of support and resources are available to you in terms of reaching out to girls in physics?

c. What kind of feedback about your practice have you received outside the classroom from colleagues, school administration and community?

15. What challenges do you face when trying to get more girls involved in physics?

16. What advice do you have for beginning teachers looking to support girls in physics?

Thank you. This concludes our interview.