PHYSICS EDUCATION: UNDERSTANDING THE BARRIERS
FOR YOUNG WOMEN IN ONTARIO

by

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Abstract

In nearly all countries of the world, at every level of education, physics as a field of science is failing to recruit and retain women. This phenomenon is believed to relate to girls’ educational experiences from kindergarten to Grade 12, but the reasons for the gender gap in physics are not fully understood. The purpose of this phenomenological research is to explore and understand the barriers encountered by Ontario female high school students during their physics education and the meanings attributed to those barriers by these young women.

This research is guided by social cognitive career theory (SCCT) and uses the concept of physics identity as a lens through which the influence of contextual barriers can be understood. Nine participants, selected via snowball sampling from an Eastern Ontario university, together participated in four semi-structured focus group meetings and individually participated in a single in-depth, one-on-one interview. Audio data was transcribed verbatim and analyzed using a general inductive approach.

Emergent themes are descriptively presented as the findings of the research study: perceiving the high school physics experience, experiencing high school physics education, and identity and gender in the high school physics experience. Sub-themes presented include limited prior experiences, negative perceptions of physics, images of physics learners, decision-making, reactions to pedagogy, learning needs, physics identity, gender-dependent influences, and making meaning of the experiences in high school physics. The shared experience of high school physics education for young women is understood as both a richly challenging and rewarding experience.
Based on the findings of this research, recommendations are made for practical and research settings, and for future work in this area. Drawing on literature on underrepresentation of women in physics, this research contributes to the physics education research community and beyond; it offers voices of Ontario female high school students, and an understanding of the barriers and the meanings associated with their experiences in high school physics.
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# Table of Contents

Abstract ........................................................................................................................................... ii
Acknowledgements .......................................................................................................................... iv
List of Figures ..................................................................................................................................... viii

Chapter 1 Introduction .......................................................................................................................... 1
  Personal Statement ............................................................................................................................. 1
  Introducing the Research .................................................................................................................... 4
  Purpose and Research Questions ......................................................................................................... 5
  Conceptual Framework ....................................................................................................................... 5
  Outline of Thesis .................................................................................................................................. 7

Chapter 2 Literature Review .................................................................................................................. 9
  Thinking About Gender and Science .................................................................................................... 10
  Is Equity in Physics Important? .......................................................................................................... 12
  The Critical Period ............................................................................................................................. 14
  Beliefs and Barriers Inhibiting Young Women in High School Physics ............................................. 16
  Moving Forward .................................................................................................................................. 27

Chapter 3 Research Methods .................................................................................................................. 29
  Phenomenological Methodology ......................................................................................................... 29
  Methods ............................................................................................................................................... 30

Chapter 4 The Participants .................................................................................................................... 35
  Samantha ............................................................................................................................................ 35
  Rachel ............................................................................................................................................... 39
  Amy .................................................................................................................................................... 42
  Jodi ..................................................................................................................................................... 46
  Marie .................................................................................................................................................. 49
  Leah .................................................................................................................................................... 53
  Carmen .............................................................................................................................................. 56
  Paula ................................................................................................................................................... 61
  Louise ................................................................................................................................................. 66
  Summary .............................................................................................................................................. 69
List of Figures

*Figure 1.* Participants’ words indicating some of their perceptions of physics prior to taking Grade 11 physics. .......................................................... 79

*Figure 2.* Participants’ words indicating some of their perceptions of physics during their high school physics experience. .......................................................... 81

*Figure 3.* Direct participant quotations from conversation about their idea of a “physics brain.” .................................................................................................................. 83

*Figure 4.* Participants’ direct quotations from discussions about perceptions of physics learners that represent different images of girl and boy physics learners. ................................. 86

*Figure 5.* Factors that participants considered when deciding about taking physics in high school. ............................................................................................................ 90

*Figure 6.* Venn Diagram of participants’ learning experiences that are characteristic of traditional and progressive pedagogies. ................................................................. 98

*Figure 7.* Sample quotations from three participants on the discussion about what meanings they attribute to their experiences in high school physics. ................................. 147
Chapter 1

Introduction

Personal Statement

My personal experiences as a student have provided me with insights that are valuable to me now as a physics education researcher. I have lived the experience of rejecting the study of physics in high school, and I have also lived the experience of embracing the study of physics in university. Physics was a subject in high school that I almost instinctively excluded from my course options for Grade 11 and 12. Each year when it came time for course selection, I first chose the subjects that I thought would set me up for good career options, and then chose the classes I thought I would like second. At about Grade 11, when I decided I wanted to have a career in the sciences, I elected to take the sciences of biology and chemistry. Physics, however, was out of the question.

My perception of physics in high school was undoubtedly negative, but not well defined. I remember knowing that physics was a class that a lot of boys were in, and that only one of my female friends took physics in Grade 11, and she did not take it again in Grade 12. I cannot say that my perception of physics was grounded in any evidence from other students or other people I knew with physics experience. The perception was likely due to lack of knowledge about the subject, lack of exposure, and a fear of the unknown. Although I had exposure to two physics units in Grade 9 and 10 general science classes, the change in my perception proved to be unremarkable.
The decision process that resulted in me avoiding physics did not last much longer than a minute or two. Physics was simply a subject with which I did not identify and that I had no reason to study. In fact, it was a subject that I was going to avoid at all costs because of its seemingly mysterious and impossibly difficult nature. I knew physics was not a necessary prerequisite to be accepted to a Bachelor of Science program after high school, but I realized that I would need to take physics courses in my first year of university. To me, the challenge and potential failure in high school physics would be too large a cost for me to endure for whatever benefit of interest or enjoyment gained. The decision was easy for me: I would wait until I was accepted to university to face physics.

During my first year of university in a Bachelor of Science program, I was required to take a physics course in both semesters. On the first day of physics class, I immediately liked the professor because he was energetic, easy to listen to, and quite hilarious. While he taught, he would often tell jokes and laugh in his British-Jamaican accent. One of his favourite one-liners was, “Bob’s your uncle!” which he would proclaim after every single problem we solved. What I will never forget is how he would regularly give the class a verbal evaluation of the whole class’ mood at the start of each class, which of course was subjective. Near the beginning of the course, he would tell us we all looked beautiful and energetic and keen, but as the semester progressed, he began warning us all by saying, “Wait until Christmas, it’s going to get ugly, so very ugly! Oh, I can hardly wait to see you then!” And of course he would then laugh his deep-bellied laugh, making all of us students laugh, too. It was a peculiar thing for him to say, I
thought, and I didn’t like how he thought things would get ugly. On one hand, I appreciated his awareness of physics’ challenges and also his commitment to getting us through the course. Yet, on the other hand, I felt determined not to let things get ugly for myself. Even though I wasn’t exactly sure what he meant by “ugly,” I was sure it wasn’t going to happen to me.

Physics, for me, was not what I would consider simple or easy; I had to dedicate many hours to practicing it. Despite this effort and the struggle I experienced sometimes, I truly loved the way that physics allowed me to think. I found that physics problems enabled deep, creative, and resourceful thinking. I could pick and choose what physics ‘tools’ I would use to think about a concept or problem, and test my strategy until I found a solution that made sense. I had fun doing physics because I liked to solve problems, like puzzles, and I felt capable doing so in my own way.

I feel thankful to have realized a love of learning physics; however, I believe the transition I experienced as a learner of science is rare. My story does not represent the discipline-wide failure to recruit and retain women in physics; it is a record of only one young woman who avoided physics in high school until she was fascinated by it in university. However, I offer my story as evidence for the essentiality of improved physics education. My more recent experience teaching physics, albeit brief, also provides me an understanding of the nature of a high school physics classroom, from best practices to classroom culture. Altogether, I feel well positioned in my exposure to and research-based understanding of the problem of underrepresentation of women in the physics field.
My experiences in relation to physics education have ultimately led me to desire an understanding of the problem of underrepresentation of women in the field of physics from the perspective of barriers to young women learning physics in high school.

**Introducing the Research**

At every level of education, physics as a field of science is failing to recruit and retain women (McCullough, 2002). In the United States, women accounted for merely 20% of the bachelor’s degrees earned in the fields of engineering and physics in 2010 (APS, 2015). This low number is not only characteristic of the United States; Canada and virtually all countries in the world have fewer women than men studying physics (NSERC, 2010). This phenomenon is believed to relate to girls encountering barriers throughout their kindergarten to Grade 12 education (Keller, 1985; Maltese & Tai, 2011; National Research Council, 2012; Sadler, Sonnert, Hazari, & Tai, 2012; Sikora & Pokropek, 2012; Tai, Lui, Maltese, & Fan, 2006). Girls are subject to a range of barriers that persistently contribute to the low number of females in physics fields. Low numbers of females in physics result in missed opportunities for individual development and discipline-wide improvement.

Previous research has exposed barriers in physics education for female students, including those present in the school context, such as curriculum and teacher expectations (Deemer, Thoman, Chase, & Smith, 2014; Häussler & Hoffmann, 2002; Murphy, 2006), and the inherently masculine nature of physics (Hazari & Potvin, 2005; Keller, 1985). Another line of research has focused on the common experiences of women who have
been successful in science (McGrayne, 2001). The research has led to myriad developments of tactics that attempt to reverse the problem (McCullough, 2002); however, the reasons for the gender gap in physics and career decisions are still not fully understood (NSERC, 2010).

**Purpose and Research Questions**

There is a need to qualitatively explore the experiences and hear the voices of female high school physics students to understand the barriers encountered by these students. The purpose of this research is to explore the experiences of Ontario female high school students in order to gain an understanding of the barriers they have encountered in their physics education and the meanings they associate with their experiences. The following research questions guide this research: What barriers do female high school students experience in physics education in Ontario? What meanings do female students attribute to the barriers encountered in their physics education?

**Conceptual Framework**

In this research, a barrier is considered to be any factor that negatively influences young women’s ideas about what physics is and their decisions about studying physics. Examples of such factors include gender-biased learning materials, a teacher who has higher expectations for some students and lower for others, or stereotypes about what kind of students study certain subjects. Barriers can be obvious and directly influence students, or can be hidden and indirectly influence students. Social cognitive career theory (SCCT) considers such contextual barriers as inhibitors of self-efficacy and goal
choice intentions at times both near and far from active career development (Lent, Brown, & Hackett, 1994, 2000). In terms of this study, where the purpose is to understand the experiences and associated meanings of high school physics education for females, SCCT is useful because it provides a framework that connects experience (barriers) with meaning (used in decision-making). This viewpoint will be adopted as support for the phenomenological research methodology used in this study.

SCCT also indicates that learning experiences in high school physics moderate the development of students’ physics identity. The concept of physics identity is useful in thinking about the effects of barriers on young women in high school physics education (Hazari, Sonnert, Sadler, & Shanahan, 2010). Students can be said to have physics identity when they view themselves as a “physics person” (Hazari, Brewe, Goertzen, & Hodapp, 2017, p. 96). The four components that influence an individual’s physics identity are performance beliefs, competence beliefs, interest, and recognition. Beliefs of performance and competence refer to students’ beliefs that they can perform required physics tasks, such as problem solving and laboratory experiments, and have the ability to understand concepts in physics. Interest refers to students’ curiosity in and attentiveness to learning physics topics. Recognition refers to the extent to which students feel that their teachers, peers, family, and others see them as a “physics person.” SCCT suggests that many aspects of learning experiences influence the four components of students’ physics identity. For example, competence, performance, recognition, and interest have found to be influenced by curriculum elements, classroom and teacher
characteristics, student characteristics, relationships with peers and family, and other experiences outside of school (Hazari, Sonnert, Sadler, & Shanahan, 2010). Physics identity is suggested to be a predictor of career choice, persistence, and engagement in physics. Therefore, this research adopts the concept of physics identity as a lens through which the influence of contextual barriers can be understood, as experienced by young women in high school physics.

Outline of Thesis

The thesis consists of eight chapters that detail the research conducted. Chapter 1 has provided an introduction to the researcher, the research topic and problem, the purpose and research questions addressed in this study, as well as the concepts used to frame the research. Chapter 2 reviews the relevant literature on underrepresentation of women in physics and makes four assertions relating to the importance of equity in physics, the critical period for recruiting young women, the existing barriers, and how moving forward might be possible. Chapter 3 details the phenomenological research methodology and the methods of data collection for this study. Chapter 4 introduces the participants of the study through narratives of each of their personal stories. Chapters 5, 6, and 7 describe and discuss the major findings of the study, or the major themes that emerged from the data. These are perceiving the high school physics experience, experiencing high school physics, and identity and gender in the high school physics experience. Within these chapters, sub-themes are described and discussed in detail.
Lastly, Chapter 8 provides a summary and concludes the thesis with implications for physics teachers, physics education researchers, and future work related to the field.
Chapter 2

Literature Review

In today’s Canadian society, equality and diversity are largely celebrated as part of social and political agendas. In an age such as this, many Canadians might presume that young women and men have equal access to all that society offers, especially in regards to education and career opportunities in disciplines of their choice. To a certain extent this presumption is accurate: women have increasingly become seen as equals to men in many spheres of society. This fact is famously substantiated by the event of women receiving the right to vote in federal elections, in 1918, in Canada. The equality movement is also evidenced in education, where women are increasingly participating in post-secondary education and, in some disciplines, at higher rates than their male counterparts. Despite the victories for women celebrated by those who support equality and fair opportunity for all, the journey towards complete equity is a long one. This literature review hones in on one particular journey for women, the journey of females in physics, beginning in high school physics education. A young woman’s journey in physics does not offer a well-defined trajectory towards equal opportunity; rather, there are many barriers to her success, and these are reviewed here.

Although the proportion of women in the field of physics has increased over the past three decades, the growth rate of women’s representation is slow in comparison to other sciences. Physics has proven to be only marginally successful at recruiting and
retaining females within the field (Hazari & Potvin, 2005), and representation levels in Canada are far from nearing a point where women and men are equally represented in physics (McKenna, 2011). Female underrepresentation in physics is a highly frequented topic in the science education community; it has been extensively discussed and researched for many years (Clancy, 1962). There are several decades of literature on the topic of physics education that provide evidence for the longstanding underrepresentation of females in physics, which is presented in this literature review. The next two sections aim to establish a framework for thinking about the general issue of underrepresentation of women in physics, and why addressing this issue is important.

Thinking About Gender and Science

In her *Reflections on Gender and Science* (1985), Evelyn Fox Keller offers insightful views on the nature of science. Her ideas offer a foundation for thinking equitably about the issue of underrepresentation of women in physics. She makes a key distinction in thinking about underrepresentation of women in physics: the problem lies within physics, not women. Keller, as a mathematical biophysicist, shares reflections on her personal realization that science has eternally been bound in ideas of masculinity. She writes about the beginning of her study on gender and science and her amazement when she learned of the widespread assumption that a study of gender and science can only be a study of women. In her nine essays on the relation between gender and science, she writes based on her recognition that gender and science are socially constructed categories. She acknowledges that masculine and feminine categories are not biological
necessities; they are created out of a complex dynamic of interwoven cognitive, emotional, and social forces. The focus of her essays is on this dynamic and “the ways it supports both the historic conjunction of masculinity and science, and the equally historic disjunction between science and femininity” (p. 4). Keller’s work is central to the study of underrepresentation of women in physics because it offers an understanding of gender and science that accounts for complex human-generated inequities. This type of understanding is necessary in order to approach the issue of underrepresentation of women in physics appropriately.

Keller argues in favour of this need in her essay on gender and science. She presents the historically pervasive association of masculine and scientific as a topic that has not been taken seriously by academic critics. She questions how philosophy and sociology of science have failed to see this as a topic requiring analysis. She does not see how it is possible that such a familiar and deeply entrenched association is a topic only for informal conversation and popular criticism. Keller writes that the silence of at least the non-feminist academic community on this topic suggests that the association of masculine and scientific has the status of a myth, which either cannot or should not be examined seriously. She questions how myth-like beliefs in our thinking about science have survived and continue to affect our thinking in ways that we may not be aware. The presence of the mythical in science seems particularly inappropriate to Keller, and she asks, “What is it doing there? From where does it come? And how does it influence our conceptions of science, of objectivity, or, for that matter, of gender?” (p. 76). These
questions persist today, perhaps at the expense of our capacity to resist such mythical thinking and its influences. What results from the deeply entrenched “genderization” or masculinization of science is a not only a characterization of science that is coloured by the biases of patriarchy and sexism, but our evaluation of what is masculine and feminine becomes biased by the reputation of science. What requires discussion is the belief about science rather than the reality of it, because the past, present, and future reality of science is ultimately shaped by our beliefs as a society. It is clear that the past and current reality for women in science has been and is still challenging; however, a solid rationale for the importance of its study requires discourse.

**Is Equity in Physics Important?**

In Hazari and Potvin’s (2005) paper on views of female underrepresentation in physics, readers are asked to consider, “Why it is important that female representation in physics be comparable to male representation or even why we should want females to be interested in physics in the first place?” (para. 3). If various people from the general public were asked to respond to this question, a variety of responses would be expected. Some might suggest a need for equity between genders in physics based on fairness, or, on the other hand, some might suggest that gender parity is not a prerequisite for advances in physics and therefore is not a pertinent concern. One school of thought emphasizes progress for women, and the other emphasizes progress for physics. In considering this notion in light of the proposed research, a strong motivation for positive change for both women in physics and physics as a whole has been developed. The
rationale for this motivation is two-fold, because it assumes the importance of progress for both women in physics and for physics as a whole.

First, heterogeneity rather than homogeneity could result in progress in science by allowing the contribution of new perspectives (Hazari & Potvin, 2005). The participation of any particular group in physics should not be impeded, as this will only limit progress. The unfortunate reality of physics is that the participation of women is impeded, which is a major limitation given that women comprise about one-half of the population. In addition, the intellectual potential of females has been described as a significant source for furthering scientific knowledge, yet it is untapped (Kenway & Gough, 1998). The second part of the rationale is that women who choose to study physics should have an accessible path to progress in terms of academic and career options; however, this is not currently the case because there are systematic barriers that impede their progress.

The following components of the literature review provide an examination of the literature on barriers to females in physics education. In doing so, three arguments regarding the issue of underrepresentation of women in physics are presented:

1. The low numbers of women in the physics field are best explained by the decrease of physics participation by young women at the high school level of education.
2. Barriers to young women’s election and continuation of physics study exist within physics education at the high school level.
3. There is a need for research that aims to understand young women’s experiences of barriers in physics education during high school.
The Critical Period

High participation rates in the physics field depend upon a strong supply of high school students who are well prepared to enter university physics programs (McKenna, 2011). However, young women at the high school level in Ontario, for example, only represented 30% of the total Grade 12 students writing physics exams in 2008 (NSERC, 2010). Other provinces across Canada, such as British Colombia (27%), Alberta (38%), Saskatchewan (45%), Quebec (course level equivalent to Grade 11 physics, 51%) and Nova Scotia (38%), yield similar percentages that reveal a gender disparity among students studying senior physics in high school (NSERC, 2010). These numbers are not strikingly low at the high school level, however fewer girls than boys elect to study physics in Grade 12 overall.

In other subjects in high school, such as chemistry or mathematics, the participation rates for girls and boys are roughly equal to each other. In biology, the participation levels are reversed for girls and boys, where girls outnumber boys in Grade 12 biology (McKenna, 2011). The participation rates for girls and boys in high school physics are similar to those in the USA (White & Tesfaye, 2010). According to the International Study of Women in Physics (Ivie, Cuzjko, & Stowe, 2001), most women physicists are attracted to physics and elect to study it during high school. Yet, Hazari and Potvin (2005) note that the largest percentage drop of girls studying physics occurs between high school and university. The numbers of girls in physics education drops even lower after secondary physics education. It is an educational concern that most
women choose to discontinue their study of physics during high school, a critical period in education in which a strong physics interest is most likely to be sparked.

McCullough (2002) documents women’s representation in physics at every stage of education from high school to the doctoral level of study in the United States. She has found that, as the level of education increases, women’s representation in physics decreases. McCullough references a commonly used term that describes this phenomenon in physics education, the “leaky pipeline” (p. 86). In physics, she says, the leak is more like a gaping hole. Following high school in the USA, the percentage of women entering university to study physics at the Bachelor’s level is a mere 20% (APS, 2015). Similarly in Canada, women are notably underrepresented at the undergraduate level (20%), as well as the Masters level (24%) and PhD level (19%) (McKenna, 2011). Based on the declining numbers of women choosing physics following high school, it is clear that high school is a critical period for female students making decisions about studying physics. When only a small number of young women do elect to continue studying physics, underrepresentation of women in the field is a result.

In 1987, 20% of professionals in Canada working in Science, Technology, Engineering, Mathematics (STEM) were women. This figure only increased to 21% by 2004 (Statistics Canada, 2011). The percentages of women STEM professionals mirror the proportion of women enrolled in STEM programs at Canadian universities. The number of women in the physics field cannot be expected to increase much higher than the number of women entering the field. The most substantial challenge to increasing the
representation of women in physics is the large leak in the physics pipeline at the high school level. It is for this reason that physics education research needs to understand what is happening during high school, the most critical period in physics education most likely to absorb women, yet the time when the most women decide to reject physics.

**Beliefs and Barriers Inhibiting Young Women in High School Physics**

Hazari and Potvin (2005) articulated three viewpoints commonly held by physicists, science education researchers, and the broader community. Each viewpoint emerged from literature on beliefs surrounding the barriers responsible for the underrepresentation of women in physics. The three viewpoints are invaluable to consider alongside Keller’s (1985) notion of a gendered science because they reflect the socially constructed and historical association of *masculine* and *scientific*. These viewpoints are not mutually exclusive because they may interact with and influence each other. Additionally, each viewpoint may have different a weight for different individuals because the causality for the underrepresentation of women in physics can be attributed more to one viewpoint than the others. Each viewpoint, or belief, ascribes a different root cause to the problem and therefore offers different, and different degrees of, solutions.

The three viewpoints are briefly listed below, followed by an expanded section describing each viewpoint with specific examples from the literature on the issue of barriers for young women in their high school physics education. The viewpoints are *inherent differences, socialized differences, and the culture bias of physics.*
**Biology is to blame.** The first viewpoint is termed *inherent differences*, which assumes that there are genetically transmitted tendencies that differ between males and females that cause them to respond differently to physics. Hazari and Potvin (2005) refer to this viewpoint as similar to the ‘nature’ side of the age-old ‘nature vs. nurture’ debate. This idea stems from sociobiological descriptions of intrinsic elements of male and female behavioural dispositions that differ from one another. Similar to such beliefs of a sociobiologist, a physicist or science educator who accepts *inherent differences* believes that females have a natural tendency to become disinterested in physics. Biological determinism resides in these beliefs and is criticized because it often upholds racist and sexist practices (Lorenzen, 2001). This is the most challenging belief because it offers no solution to the problem of underrepresentation of women in physics. The reason for this is because a solution is thought to be unnecessary and irrelevant since women should participate in physics by will and out of interest, rather than being forced. This viewpoint does not appreciate that physics is failing women by upholding barriers to their progression; rather, it assumes women are failing to fit into physics by their very nature. It is suggested that this viewpoint is a major reason why there has been lack of progress for women in physics.

Hazari and Potvin (2005) note how discouraging this viewpoint is because “its proponents do not seem to be confined to a particular (read: older) generation but are found amongst researchers of all ages” (Inherent differences section, para. 4). The issues with this viewpoint are not hidden in the past, or under the etiquette of political
correctness, either. Meg Urry, director of the Yale Center for Astronomy and Astrophysics, spoke at the 2002 Paris International Conference on Women in Physics about the universal challenges female physicists face. She reports on her own experiences, finding discrimination to be subtle and that disadvantages add up against women. She also spoke to how frustrating the critical issue is because “we are missing good brains” (Feder, 2002, p. 25). Urry said, “My male colleagues don’t want to hear about anything affirmative action-like. The most infuriating thing is when you say, ‘Can we think about hiring women?’ and they say, ‘Sure, but our first priority is excellence’—as if there were inherent differences between the two” (Feder, 2002, p. 25). Upon examination of the literature, the inherent differences viewpoint exists as a basis for research that investigates barriers for the gender gap in physics. The literature focuses on barriers to women’s enrollment or success in physics as a result of inherent differences between women and men, or as a result of traits that one group possesses and the other does not.

For example, literature exists that describes critical differences between the nature of girls who are intending to study physics and those who are not (Mujtaba & Reiss, 2013); differences between girls and boys’ grade achievement and interest in physics (Stadler, Duit, & Benke, 2000); and differences in specific characteristics of students that predict their physics enrollment (Thomson, Wurtzburg, & Centifanti, 2015).

Through survey responses about physics, Mujtaba and Reiss (2013) investigated the characteristics of 15-year-old girls who had intentions to study physics after 16 years
of age. A large number of students, 5,034, from 137 UK schools, took part in the survey. The researchers compared responses of boys and girls and reported that differences in responses indicate the pervasiveness of gender issues in physics. Comparing the subset of girls who did intend to study physics post-16 to girls who did not, the former were found to have higher physics extrinsic motivation, more positive perceptions of physics teachers and lessons, greater competitiveness, and a tendency to be less extrovert. In terms of implications, the authors note that extrinsic motivation in physics could be the crucial factor encouraging certain girls to continue studying physics. This study shows a clear focus on what students need to possess to successfully carry on in physics and it is depicted perfectly in the title of the paper, which asks, “What sort of girl wants to study physics after the age of 16?” (Mujtaba & Reiss, 2013).

Another title, “Do Boys and Girls Understand Physics Differently?” asked by Stadler, Duit, and Benke (2000) questions inherent differences between female and male students’ understanding of physics. The authors instructed a class of 25 students on a physics topic and studied responses to teacher questions and the social and verbal behaviour of the students in group work. The major finding of the study was that boys and girls differ significantly in response to physics instruction. More specifically, the authors claim that boys and girls hold different notions of what it means to understand physics. Their study focuses on this difference as a framework to explain differences concerning interests and social and verbal behaviour. The authors write, “Girls seem to think that they understand a concept only if they can put it into a broader world view.
Boys appear to view physics as valuable in itself and are pleased if there is internal coherence within the physics concepts learned” (Stadler, Duit, & Benke, 2000, p. 417). Here, girls are written about as if they possess a limitation to understanding physics concepts, and boys are written about as if they possess an inherently perceived value for physics’ internal coherence. Consider reversing this stark depiction of boys and girls’ differences in physics understanding; perhaps it is the boys who are limited in their physics learning without a focus on application of concepts to a broader perspective.

Instead of looking at girls’ and boys’ overall differences against physics, one study looked to a particular human characteristic—empathy—as a possible predictor of physics enrollment. Thomson, Wurtzburg, and Centifanti (2015) had over 400 students in different majors (humanities, social science, life science, physical science) complete the empathy quotient (EQ). The authors report that empathy differences between females and males contributed to explaining subject major choice. They found that greater levels of empathy predicted social and life sciences enrollment, while low levels of social skills and cognitive empathy predicted physical sciences enrollment. Based on these findings, the authors argue that gender is not as strong a predictor of subject choice as empathy. Regardless of gender, students in physical science majors have lower levels of social skills and cognitive empathy, which may impact the social learning environment. This, along with women reportedly having higher levels of empathy (Billington, Baron-Cohen, & Wheelwright, 2007), could explain the low numbers of women selecting scientific
fields of study other than the physical sciences (Thomson, Wurtzburg, & Centifanti, 2015).

With the inherent differences viewpoint, the focus remains on the attributes of females and how they differ from males, rather than how physics education may be failing to support females in being as successful in physics as males. There are limited solutions offered by proponents of this viewpoint, as they generally argue for no intervention, which in itself is a barrier to women in physics. This argument is not true, however, for the second viewpoint described by Hazari and Potvin (2005), which is socialized differences. Supporters of socialized differences believe individual interests are socially trained rather than genetically inherited, and that the teaching and learning traditions of physics can be modified to neutralize socialized differences (Hazari and Potvin, 2005).

Society’s influence. Opposite to the inherent differences viewpoint, the socialized differences viewpoint is comparable to the “nurture” side of the ‘nature vs. nurture’ debate. This belief suggests that individuals are socialized to have different interests. In the case of socialized gender differences, females are less inclined towards physics than males due to social transmission of values and behavioural dispositions by society, family, education, and other influences (Hazari and Potvin, 2005). Behaviorism, which contrasts sociobiology, suggests that male and female behaviour is mostly directed by environmental trial-and-error conditioning (Lorenzen, 2001). The physicist or science educator who holds the socialized differences viewpoint believes that females are either
trained directly to feel studying physics is not for them, or that females are trained towards behaviours that indirectly lead their interests away from studying physics. Social training such as this occurs through either the education system (e.g., teachers, professors, peers, curriculum) and what is outside of the education system, such as parents, media, social norms (Hazari & Potvin, 2005).

Major barriers to females occur in these two arenas, which are recognized by those who give weight to the socialized differences viewpoint as reason for the low number of females in physics. An example of direct training from the non-education sphere is the social stereotype that portrays the physical scientist as male. Although discrimination is no longer acceptable, stereotypes undermining the suitability and interests of females in physics still permeate society and the education system.

Throughout physics education literature the socialized differences viewpoint is present as a commonly held viewpoint used to explain low numbers of females in physics. Hazari and Potvin (2005) quote one physics educator on the notion of gender: “While anatomical sex is universal and unchangeable, gender, which refers to all the duties, rights, and behaviours a culture considers appropriate for males and females, is a social invention...” (Parker, 2002, p. 13).

The ways in which the socialization viewpoint emerge in the literature are synthesized here. The literature included in the synthesis is research that has focused on the social barriers to women in educational systems that inhibit their election and continuation of physics:
• Gender stereotypes (Barman, 1997; Deemer, Thoman, Chase, & Smith, 2014; Makarova, 2015; Steele, James, & Barnett, 2002; Yanowitz, 2004; Yoder & Schleicher, 1996)

• Less prior physics experience for females (Bhanot & Jovanovic, 2009; Chambers & Andre, 1996; Jones, Howe, & Rua, 2000)

• Lack of equitable assessment (Bell, 2001; Hazel, Logan, & Gallagher, 1997; Hofer, 2015; McCullough, 2004; Rennie & Parker, 1996)

• Lack of real world and human perspectives in physics education (Jones, Howe, & Rua, 2000; Stadler, Duit, & Benke, 2000)

• Lack of encouragement for females (Alexakos & Antoine, 2003; Jones & Wheatley, 1990; Taber, 1992)

• Lack of female self-confidence and self-concept in studying physics (Gillibrand, Robinson, Brawn, & Osborn, 1999; Haussler & Hoffmann, 2002; Sikora & Pokropek, 2012)

• Lack of relevance and interest of physics for females (Alexakos, & Antoine, 2003; Barnes, McInerney, & Marsh, 2005; Bøe, Henriksen, Lyons, & Schreiner, 2011; Sadler, Sonnert, Hazari, & Tai, 2012; Stokking, 2012; Tai, Liu, Maltese, & Fan, 2006; Williams, Stanisstreet, Spall, Boyes, & Dickson, 2003)

Additional barriers to consider, which are not mentioned above, include the facts that the Ontario curriculum is overcrowded with material and that students are required to
take two senior science courses to enter a university science program. These factors influence students’ decision-making process about whether or not to take physics. Students’ decisions are often hinged on such peripheral factors, which may directly or indirectly influence their future academic and subsequent career paths. The barriers to females in physics from a socialized differences perspective result from socialization that directs females away from physics and social barriers discouraging females from studying physics. The large body of literature on social barriers to females in physics comes with many suggestions for improving the low numbers of female participation in physics. Among the suggestions are solutions that improve certain areas of physics education, but do not satisfy all of the many needs of female, and male, learners in physics.

Both the inherent differences and socialized differences viewpoints are limited in terms of improving the numbers of females in physics. These two perspectives focus on what is different about females, either in their biology or socialization, which leads them away from physics. This approach to the problem is a limitation because, in alignment with Keller’s (1985) beliefs, it is more important to question what is wrong with physics education and community because it is inhibiting the participation of diverse and able minds (Hazari & Potvin, 2005). To reiterate in other words, the low numbers of girls in physics may have more to do with the nature of the field of physics than with the nature of girls (Baker, 2002). The articulation of Hazari and Potvin’s (2005) third viewpoint, the culture bias of physics, is founded in this growing approach to the problem.
Cultural perpetuation. The culture bias of physics is the final viewpoint and is supported by literature that attributes the low numbers of women in physics to cultural bias. This viewpoint is different than the inherent differences and socialized differences viewpoints because it focuses on problems in the community of physics that cause women to lose interest or opt out of physics, rather than the differences between sexes that cause their interest in physics to be different (Hazari & Potvin, 2005). The culture bias of physics viewpoint suggests that physics is bound by masculine tendencies and preferences, and is not a gender neutral subject, meaning that any female (or male) lacking such tendencies could feel deterred from the subject and even alienated within the field. This bias is transmitted three ways: pedagogically, academically, and socially. These methods of transmission are discussed in literature that seeks to examine how, in different environments, cultural bias acts as a barrier to women’s interest in or choosing of physics. This literature aligns with beliefs of those individuals who hold the culture bias perspective, that women face active and passive discrimination and have next to no role in defining the field.

Meg Urry, in an article on the slow process of change in physics, writes, “The popular image of success, of competence, of science, is male. We are almost all prejudiced in the sense that we have absorbed the gender and race stereotypes that prevail in our society” (Urry, 2003, p. 12). Her perspective speaks to the nature of our biases and how they perpetuate the culture we construct. Research has shown the effects of such culture bias on female students in physics education. For example, a number of studies
have shown that contextual barriers in educational settings are more prominent for individuals who have been historically marginalized, including women (Fouad, Smith, & Zao, 2010; Luzzo & McWhirter, 2001). The same barriers have been shown to have negative effects on undergraduate students’ major choice (Lent et al., 2005). In terms of stereotypes about science and gender, these work most strongly against those students who care most about achievement and success, and females who identify most strongly with their gender (Kaiser & Hagiwara, 2011). Logel et al. (2009) showed that these stereotypes do not need to be made explicit to women to affect their performance and experiences negatively. Simply being in an environment that is male-dominated or that is known to relate to gender stereotypes is sufficient to undermine women’s performance and motivation. The strength of influence that the culture bias of physics has is detrimental to girls and women at all stages in their physics education or careers.

Frost, Reiss, and Frost (2005) believe that it is not enough for schools to be isolated islands of good pedagogy. Other physics education researchers, like Murphy and Whitelegg (2006), agree that current developments in physics education are not enough; they do not challenge the gender-science relationship and consequently the impact on girls’ participation will be limited. These researchers’ thinking acknowledges that the ways in which culture bias is transmitted are broad and not limited to within a school environment.

Keller (1985) would give most weight to the culture bias of physics viewpoint because of how it questions the ways that physics can help females and its
acknowledgement of physics’ historically and pervasive association with masculinity. Keller would also appreciate the argument that physics itself should be changed from within, as she believes that the belief structures we hold about physics are what will ultimately change the reality that women in physics face. The culture bias viewpoint offers the most comprehensive solutions; those that are needed to address the pedagogical, academic, and social issues. For the progress of both women in physics and physics as a science, physics requires revamping from its educational curriculum to culture. Change from within is necessary in order to “include broad and diverse worldviews, to make physics more accessible to everyone . . . and to change the social climate towards collaboration instead of competition” (Hazari & Potvin, 2005, Culture Bias section, para. 9).

Moving Forward

Despite differences in beliefs about the problem of underrepresentation of women in physics, all of the literature reviewed on the issue shares a common interest. Regardless of the approach and beliefs about causality, the shared interest of the physics education research community is to improve the reality for women in physics. Although the body of literature is extensive when it comes to physics education and equity for women, there is limited information about how women experience their physics education (McCullough, 2002). The focus of the existing literature is largely on women’s differences from men and their distant position in relation to physics. Such research is valuable because it details what women respond to best in physics education, such as
student-active curricula and pedagogies; however, the social and cultural changes needed to hold equity to physics demand that such research be accompanied with a human understanding of how females experience physics education. More qualitative research is needed to understand why some women decide to stay in physics and why others leave (Ivie & Stowe, 2000). A focus is needed on how young women experience and perceive physics during their education, enabling an understanding of how women use information from their experiences in physics to make decisions regarding subject and career decisions (McMahon & Patton, 1997). If the voices of young women as physics students are heard and their experiences are understood, there is hope in more pointedly addressing the barriers in physics education that prevent them from enjoying and succeeding in physics.
Chapter 3

Research Methods

In this chapter, the research methodology and methods are explained in detail. Included in the explanation of research methods are the phenomenological lens used in approaching the research, the recruitment of participants, the participants, data collection methods, data analysis methods, and the efforts made to ensure the trustworthiness of the research.

Phenomenological Methodology

The research methodology utilized for this study is phenomenology, which aims to investigate and describe a phenomenon as a person consciously experiences it and the meaning that is attached to the experience by that person (van Manen, 1990). The aim particular to this research is to understand how female students construct meaning of the barriers they experience in their physics education. For example, whether girls attribute a barrier such as specific in-classroom experiences to choosing a non-physics-related career is an important understanding that could help more pointedly address the problem.

Phenomenology was the most appropriate methodology for use in addressing the research problem because the central phenomenon is an experience and the intent is to describe its meaning. In other words, phenomenology supports the exploration of barriers experienced by female high school students and the understanding of the meanings female high school students attribute to those barriers.
Though much debate surrounds phenomenology as a methodological approach to research, specifically about what criteria collectively define phenomenology, this research can be considered phenomenological because the core of the research purpose is to describe (rather than explain) lived experience. The following statement elucidates the phenomenological philosophy adopted for this research, and serves to outline the research in terms of its methodology: the lived experience of barriers in high school physics for girls are described and supported by first-person accounts; through the researcher’s open attitude and reflective analysis of the data provided by participants, the general themes about the essence of the lived experience are described; lastly, interpretations, as an inevitable aspect of description, are offered about the meanings of young women experiencing barriers in physics education, specifically concerning implicit or hidden meanings of lived experience. In agreement with Finlay’s (2012), ideas about description and interpretation within phenomenology, this research adopted the view of description and interpretation as a continuum, where specific research may be more or less interpretive. In the case of this research, interpretation was used when called for; specifically, as Wertz (2005) explained, “in order to contextually grasp parts within larger wholes” (p. 175) while remaining descriptively grounded.

**Methods**

The individuals who were recruited for this study are women who have experienced physics education in an Ontario high school. The women allowed the central phenomenon to be understood best because they have personally experienced it. Nine
women were recruited in order to explore the diverse viewpoints on the experience in an in-depth manner. The participants were recruited through snowball sampling. The requirements for participation were that participants have taken at least one physics course in an Ontario high school. All nine participants did so, with the exception of one participant who went to high school outside of Ontario. All participants currently attend an Eastern Ontario university and are studying in a variety of different programs, both physics-related and non-physics related or non-science related. Via email, the participants were given information forms outlining the study indicating the topic of study and the fact that they would be asked to describe their experiences in high school physics and what those experiences meant to them. Upon indicating interest in participation, the women were also emailed consent forms and confidentiality agreements. Further email correspondence occurred to arrange meeting times for data collection, which is explained below.

The data was obtained through focus groups and interviews. Together, the participants attended four, two-hour, semi-structured focus group meetings, where they discussed their experiences in high school physics. The focus group meetings took place in a quiet room where there were refreshments and a table to sit around with paper and pens for optional note taking. At the first meeting, the participants completed their consent and confidentiality agreement forms. They were then briefed on the rules of focus groups, (e.g., allow all members an opportunity to speak, and be respectful). The first focus group meeting was attended by eight participants and the following three
meetings were attended by six, eight, and four participants, respectively. The focus group protocol included open-ended, emerging questions to allow participants to generate their own responses. The questions were designed to address the purpose of the research and answer the research questions, which both aim to gain an understanding of young women’s experiences and what those experiences meant to them. Using focus groups to understanding the experience of barriers in high school physics for young women was beneficial for two main reasons: first, participants were able to share different perspectives, which stimulated discussion and introduced new ideas. Second, the participants often clarified and checked for understanding of each other’s experiences, which served as validation for the points being raised as shared experiences. Few researchers discuss phenomenological focus groups, as the use of focus groups in phenomenological studies is uncommon; however, the benefits are noted especially in certain research fields when understanding shared experiences is the research purpose, such as nursing (e.g., Bradbury-Jones, Sambrook, & Irvine, 2009).

In order to provide an opportunity for participants to explore their experiences at a deeper level, discuss new experiences, or discuss topics brought up in the focus group meetings, they were offered an optional one-hour, one-on-one interview. All nine participants opted to participate in the interview. One participant responded in writing to interview prompts because she was out of the country during the interviewing period. The benefits of offering the interviews post focus group meetings were that participants had time to reflect on their experiences over the course of the focus group meetings, they had
already discussed their understanding of their experiences with other participants, and the participants were already comfortable with the interviewer having already spent time during focus groups with her. The empathetic interview described by Fontana and Frey (2005) was employed to avoid a stance of neutrality. The interviewer had an open, phenomenological attitude, and engaged in an active and collaborative process while discussing the participants’ experiences (Holstein & Gubrium, 1995). The interview question format was semi-structured, meaning that the interviewer mostly listened to participants, but also offered prompting questions and comments.

The audio-recorded focus groups and interviews were transcribed verbatim. The interview data was used to develop the individual participants’ stories, which appear in Chapter 4. The focus group data was analyzed using a general inductive approach. The inductive analysis described here refers to an approach that primarily uses reading of data to derive themes through interpretations of the data made by the researcher (Stauss & Corbin, 1998). Strategies used in this approach included questioning what core meanings are evident in the text in relation to the research questions (Thomas, 2006). This was achieved by carrying out open, axial, and selective coding steps as described by Strauss and Corbin (1990). The open coding phase involved reading of the data, and rereading it while making note of terms or phrases that struck the researcher as important or of the experience’s essence. The open codes were collected in preparation for the axial coding phase, in which the open codes were categorized into groups. Categorizing was carried out by grouping open codes that had similarities or common components, which then
formed the categories. Categories, or axial codes, were named based on the collection of open codes. At this stage, my supervisor was consulted to ensure the category names represented the understanding of the data. Finally, selective coding was completed when the main themes emerged from the categories created. No qualitative coding software was used in the data analysis for this research. The open codes, axial codes, and selective codes were labeled with their document location in Microsoft Excel spreadsheets and sorted manually. The coding process was stepwise and led to a smaller number of selective codes than axial codes, and an even smaller number as compared to the open codes. The themes most relevant to the research questions are the outcome of the analysis, and are presented descriptively as the findings of the research study.

The trustworthiness of the data analysis was increased through a process of coding-recoding described by Krefting (1991). The data was coded once and then revisited another time approximately two weeks later and recoded, after which the results were be compared and final themes were settled on. The data was also shared with participants to member check at three different stages, in order to ensure accuracy of transcription and writing. First, after transcription, second after participant stories were written, and lastly after the themes were reported on as findings of the study. All participant concerns, clarifications, and requests for changes were accommodated. During the research process, the researcher kept a bracketing journal as the validation strategy to minimize the potentially deleterious effects of her personal biases.
Chapter 4

The Participants

Each woman who participated in this study was given the opportunity to participate in a one-on-one interview. The interviews took place after the four focus group meetings had occurred. The purpose of the interviews was to provide participants with an opportunity to talk more in-depth about their individual experiences in high school physics, to revisit a topic discussed in the focus group meetings, or to share a personal anecdote that they were not comfortable sharing in the group setting. All nine women opted to participate in a one-on-one interview. One participant (Jodi) provided written responses to interview prompts because she was out of the country during the interviewing period. From the data collected in the interviews, the following nine narratives were developed. The stories are intended to briefly profile each woman as a student, giving the reader a sense of who the participants are as people, and to tell a short narrative of the nature of each young woman’s unique personal experiences in high school physics. By sharing stories of young women’s individual experiences of barriers in physics education, student voices can be heard in the conversation about equitable, barrier-free physics education.

Samantha

Samantha is currently a graduate student in a non-physics field. She has completed Grade 11 and Grade 12 physics in Canada, outside of Ontario. In Grade 11, Samantha loved physics. In the focus group meetings, she shared stories of fascination
with new concepts and demonstrations done by her teacher. She considered studying physics in university. Despite her high level of interest and enjoyment of physics in Grade 11, she experienced a drastic transition in Grade 12 that left her feeling glad that her time studying physics was finished for good. As a participant of this study, she could be considered to have had a strongly developed physics identity in Grade 11 that shifted to a nearly non-existent physics identity through Grade 12. Her experiences in high school physics shed light on the extent to which young women’s perceptions and decision-making about physics can shift in a short time, and why they shift. For Samantha, these experiences were full of meaning.

Noting the importance of critical thinking skills for successful physics learning, Samantha recalled, “I really don’t think they taught [critical thinking] to me before getting to these classes.” Looking back to her memories of early education, “I don’t have any memories of thinking critically, I’m just trying to think back to what we did in school and it was a lot of busy work.” Overall, Samantha felt like her school experiences as a child were lacking. She explained, “As a kid, I didn’t really learn anything in school.” Approaching physics education with high interest, which stemmed from her interest in math, she feels she was not well prepared or not yet resilient enough to succeed in physics with little critical thinking skills. She explained, “Back then, I probably did shy away from challenges.”

Samantha felt that her “enjoyment definitely went down” at the start of Grade 12 physics as compared to Grade 11 physics. She said, “There was just something different
about Grade 12… the content seemed so much more difficult…I thought that I didn’t have any tools to help me figure it out.” Samantha also “wasn’t as comfortable, with no friends in Grade 12 physics,” a feeling that inhibited her from asking the teacher questions as she normally would have.

Socially, Samantha’s experiences influenced her feelings and behaviours in Grade 12 more than they previously had in school.

My friends used to make fun of me a little bit, too, because a few of them went through this rebellious stage in Grade 10 and 11. I didn’t join them on their rebellious journey, which I certainly don’t regret, but I kind of get the feeling that they really despised me for a while.

In Grade 12, Samantha explained, “I was starting to actually do things outside of school besides homework…I finally did take the time to do that stuff, then it ate away from my academics.” Social activities and extracurricular activities, such as being part of the yearbook committee, brought Samantha another kind of enjoyment at school, unrelated to academics. She felt that her “reputation was moving away from this very grades-oriented person.” She looks back on this time, saying, “I definitely wasn’t as determined in Grade 12; in Grade 11, I was neurotic about grades.”

During Samantha’s interview, she shared that she always felt like a smart student, but she never felt exceptional compared to her peers. These feelings, combined with competition with friends in Grade 12 over “who could get the best mark with the least work,” left Samantha feeling less competent. She said she “never won, because things
didn’t come naturally” to her. Samantha’s grades in Grade 12 physics came as a shock to her for two reasons: firstly, because she was used to achieving well and her grades were lower than she preferred, and secondly, because she was used to her teachers confronting her if she was achieving grades uncharacteristic of her usual performance.

Normally when a teacher would see, this isn’t normal, a drop in grades, they would come to you and say, “this is where you’re at,” but he didn’t do that…I didn’t think I was doing that badly until parent-teacher interviews…He said, “She’s at about a 70%.” It was a shock to me. You mean I’m not magically pulling this off? I’ve always been able to pull it off before.

Samantha thinks that it is a problem that she did not know how she was doing in the course, and she attributes the issue to the fact that teachers “don’t teach you how to reflect on how you’re doing.” As a result, students “don’t know how to figure out their issues.” She feels that her needs for continued, successful physics learning would include finding out about resources to help understand challenging concepts, such as online physics videos. She thinks if she were to have known about helpful resources, her enjoyment of physics in Grade 12 would have increased. Contributing to Samantha’s decision making about physics education, in addition to her feelings about physics in Grade 12, was a general readiness to be finished with high school and not being ready to take on new challenges after feeling defeated by physics. The university programs she applied for also did not require physics to be taken.

Today, Samantha thinks that “physics is really cool.” She said, “I do wish that somehow I could be involved in it because I really did enjoy the stuff I learned in the first class.” Today, she feels empowered by her successes in areas outside of physics and feels
that if she had to take high school physics now, she would “have the skills of how to fix the problem of not understanding the concepts.” She believes that the skills of advocating for oneself and working through problems come with age.

Through the lens of this research’s purpose, which is to understand the meaning of experiencing barriers in high school physics education, there is something of tragedy in Samantha’s story. A girl who was fascinated by physics at first, and who still is fascinated, somehow fell out of touch with her love of physics in her last year of high school.

**Rachel**

Rachel is currently a graduate student in a non-physics field. She has completed Grade 11 physics at an Ontario high school. The events in Rachel’s life during her Grade 11 year were challenging, and she feels they prevented her from having the right approach to physics. The events of her experience in Grade 11 mostly represent emotional challenges. Rachel’s grandmother was seriously ill and living in another country; her father was to leave home for some time to be with Rachel’s grandmother. The same day her father left home, Rachel also experienced the emotional turmoil of breaking up with her first boyfriend. During this school year, Rachel’s mental health worsened and she struggled with anxiety and depression. Her mental health challenges created barriers to Rachel’s thriving; she said, “Depression definitely…was tough to work through because I didn’t feel like I had the right support from my parents, from my teacher, from my guidance counselor, or from my friends.” In general, the struggle
Rachel was having in Grade 11 made her feel different. She explained, “I was not my best self.”

Rachel identified other factors she believed were barriers to her success in physics; some relating to her feelings about physics, like her competence, and others relating to the influence of people and events at school. When Rachel would ask her mother what she was talented at, Rachel was always “praised for being smart.” Rachel said she was “going into physics already [having] that mindset,” which she believes was limiting. She explained, “I had a very fixed mindset.” This mindset prevented her from thriving in the challenge of physics. For the first time in school, Rachel said, physics “flipped my identity on its head because I was so used to seeing myself as this smart person, and being perceived that way by everyone around me.”

Initial challenges in conceptualizing physics left Rachel feeling like she did not belong, and couldn’t be recognized by herself and others as a physics student: “A lot of the time I felt like, I don’t know what I’m doing here and I don’t feel like I can fit into this class.” Rachel attributes these feelings to the status of her mental health and subsequent low feelings of competence in physics: “My mental capabilities were not very high functioning, I couldn’t really grasp anything.” She explained, “I felt like I was having some trouble with the content,” which led to the challenge of “not being able to feel like I could succeed.” Rachel had not experienced the same combination of challenges at school before physics, she said, “This was the first time I think I was [realizing]...I have no idea what’s going on,” and “I didn’t feel like I was excelling. That
really caught me off guard.” Rachel ended up getting extra help outside of school from a physics tutor, but had negative feelings about having to do so. She explained, “for me, that seemed like a failure. Having to go to a tutor was only something the dumb kids do.”

Rachel’s teacher also contributed a great deal to what felt like, to Rachel, barriers to her success in physics. The influence of her teacher, combined with Rachel’s low feelings of competence and recognition, resulted in Rachel feeling helpless. “She expected a lot of us and I didn’t feel like I could rise to the occasion.” When describing characteristics of her teacher, Rachel said, “she was so unpredictable,” sometimes “cranky,” but sometimes “goofy and funny.” Rachel remembers the feelings she had about her teacher. She explained, “She kind of scared me,” and “I felt intimidated by her most of the time.” “I would come into class and already have a sense of dread,” Rachel recalls. She also remembers feeling like she was not able to ask her teacher questions because of intimidation and lack of understanding: “‘Miss, I have no idea what’s happening’…I don’t think I could have really said that.” Rachel’s teacher used the same test sheets year after year, and created a hostile test environment with strict rules. Rachel remembers test days, explaining, “The environment in test mode was very frightening.” Rachel preferred to stand while writing tests, which was not met with support from her teacher.

Intimidating…how she operated during tests. I already had a hard time writing tests and with her being so strict with her, you know, ‘I have to get all the papers back’ and ‘You have to sit down, you’re stressing me out standing at the back bench.’ I’m [thinking] ‘I’m just trying to cope here, lady!’ That’s basically how I felt. Well, if you’re not accepting how I’m dealing with things, how are you
going to respond if I just come up to you and [say], ‘I know you spent a lot of time telling us already in class, but I have no idea what’s going on.’

In listening to Rachel’s story, success in and continuation of physics seemed an improbable outcome for her, considering the lack of supports she had and the barriers she faced both personally and in physics class. Reflecting on the lack of support she had in facing the challenges of Grade 11, Rachel explained, “This was a huge roadblock. I was going through this blizzard and trudging uphill, you know? And there is no end. The end came when I handed in my final exam and I said I never have to worry about this again.”

Today, Rachel recognizes what could have helped her in her first exposure to physics. Regarding her teacher, Rachel explained, “If she had followed up,” or “if she had given me some support…some scaffolding,” and “actually show[n] concern.” She also felt “the environment of the classroom…could have been a more supportive environment.” Knowing her needs for successful physics learning, Rachel explained, “[If] for some reason I needed to relearn all of that content, I could do it. I feel empowered to do it…I know I could do that. I feel like since then I’ve come really far.”

She is energetic and ambitious, and still carries her interests related to physics with her, enjoying space-themed movies and reading mathematics books.

Amy

Amy is currently an undergraduate student in physics. She has completed Grade 11 and Grade 12 physics at an Ontario high school, and she has studied university-level physics for five years. The context of Amy’s story in high school physics is important to her; she grew up in a “mining town in northern Ontario.” There, Amy explained, “it
wasn’t really expected for a student to go and study science, and go into academia or anything.” Amy explained, “All the girls stay there…to go to nursing, or the guys take up a trade or do some kind of mining.” However, Amy was not a student who followed the assumed trajectory for the young women and men of her town.

Much earlier than when physics was a course option for Amy, she excelled in school. She explained, “Growing up, there wasn’t anything that didn’t come easily to me.” It became obvious to her that she was different than her peers because she was consistently learning higher level material in her classes than was being taught to her peers. She explained, “I was advanced…I was separated,” both physically (moved into the classroom of the grade above) and in terms of different learning material. The early awareness that Amy had of her abilities helped her later on when deciding what she might do after high school because she did not feel the need to be doing similar things to her peers. Amy explained, “I never felt stimulated…I never had intellectually stimulating conversations with my peers.”

When Amy got to high school she was still not challenged enough. She explained, “High school wasn’t challenging for me at all…and I knew I was capable of doing something more.” “None of my friends took physics in high school,” Amy explained, but she took physics because she was interested in the sciences and because she felt her high school did not offer a large variety of other courses. Achieving nearly 100% in all three science courses at the end of high school, Amy explained that she “really excelled in high school and everyone knew it.”
The courses in high school that most stimulated Amy, she explained, were “calculus and Grade 12 physics, for sure.” Physics seemed to stimulate her interest because of the novelty of it compared to any other course she had taken.

In Grade 12 physics, I remember specifically the unit on relativity. I thought that was the coolest thing. That was probably the most interesting thing I learned in high school because it was so abstract and it was…thought experiments, like the train…all the thought experiments that have to do with relativity, I just loved them…being able to solve a problem by thinking about it.

Amy finds that problem solving in general is highly satisfying, especially after working on a problem for some time. She explained, “When you figure it out, it’s the most rewarding thing.” The Grade 12 physics teacher that Amy had influenced her interest in physics. Amy said, while talking about electromagnetism, “I think the reason that it’s still one of my favourite areas in physics is because of him…you could tell it was his favourite area and he was so excited to teach it.” She looked back on her time in physics class and described a unique memory that allowed her to learn in a way that was different than copying notes.

He would spend the longest amount of time drawing diagrams on the board…half and hour drawing this really intricate diagram…we would just sit and watch him draw on the board…it was interesting to see what he was drawing…he’d teach us by just drawing a picture…it was fun, fun for everyone.

Although Amy excelled in her courses in high school, including physics, she felt that she needed to be challenged further and recognized some barriers to her growth in high school. One aspect of her experience helps to explain why her interest in physics
was not even greater: “I would only go talk to a teacher if I needed help…I feel like it probably would have ignited my interest in physics earlier if I had went to talk to my teacher about something interesting going on opposed to just an issue I was having in class.” One of the reasons that Amy did not talk to her teacher more often or about topics of interest was because she did not feel comfortable; the discomfort was partly due to her gender and the fact that her teacher was a man. She explained, “It felt weird having one on one time with that teacher, that was definitely something I felt that the guys didn’t feel as much…I felt like I was doing something wrong if I was going to talk to a teacher one on one.” Amy found that approaching or meeting her teacher after school was “frowned upon for some reason. After class was fine, but at the end of the school day, outside of school hours, it felt weird to ask questions and stuff, which is kind of a shame.” When asked if it would have been different with a female teacher, Amy explained, “I would feel more comfortable.” This aspect of Amy’s story is a reminder of how pervasive the ideas and feelings surrounding gender can be.

Amy also shared her experiences in the Advanced Placement (AP) program in her school and how she felt that the program was ineffective in challenging her. Amy explained that since there were not enough students in the AP program at her school to have separate classes, students would “just be in the same class with all the other students and [they would] go after school once a week and do extra ‘stuff’ with the teachers.” She said, “It just felt like an extra, bonus lab time.” Amy was given textbooks and told she could write the AP exams if she wanted to, but she did not end up writing any of the
exams. She explained, “I wasn’t ready,” because “I didn’t feel like it prepared me just reading my textbooks,” and “I didn’t really have extra time to read those AP books.” She wished that the “programs had actually been utilized” to “challenge the kids who weren’t being challenged,” but felt that her school did not have “many resources.”

Amy has continued her physics education since high school and strongly identifies with physics today. Her story offers the voice of a young woman who studies physics because it gave her an opportunity to marvel and challenge herself. She defied the norms of her peers and the place that she grew up, and was undoubtedly encouraged by her mother. Amy said, “My mom was always supportive, really wanted me to go away to school, do something else.”

**Jodi**

Jodi is currently a graduate student in physics. She has completed Grade 11 and Grade 12 physics in an Ontario high school, and completed an undergraduate science degree in physics. Physics was something in high school that Jodi enjoyed greatly; an enjoyment that carried her through to her continued physics education today. Thinking back to her experiences in high school, Jodi explained, “If it wasn’t for my experience of enjoying physics so much in high school, I would have never taken that first year course, and [would] never be where I am now!” She remembers that her interest had “definitely increased by the end of high school,” because she “viewed physics as a fascinating and exciting subject.”
Jodi had a strong identification with physics that she recognized early in her educational experiences through her general science interest. However, she felt an additional challenge that she attributes to her gender.

I felt strong in my competence and performance, as I did well and worked hard for that. I generally received good recognition, objectively. However, subjectively, I never felt that I was exceptional as I often stood in my twin brother’s shadow, and felt I needed to prove myself more being a female. Jodi felt that she needed to prove herself and her intelligence being alongside her male peers. When she did prove herself, she believed she was viewed as something exceptional. Part of the reason for this is because of the ideas that Jodi had about how the boys in her class learned. She explained, “The boys in the class would understand things more naturally, so it felt [like] it was viewed as a feat to do as well as them.”

Jodi believes that her teacher’s actions were also related to her feeling that gender made a difference in physics class. She said, “I think it surprised my teacher more if girls did well.” She also explained that she did not find that her teacher engaged with her because of her tendency towards male students: “My teacher never really made it all that exciting for me, or wouldn’t engage in deeper physics conversations with me. I didn’t seek it out, but she did gravitate to the boys in the class to engage in such conversations.”

At the end of high school, Jodi explained that she did not think she “would pursue physics.” She explained the reasons for not imagining a future in physics.
I think that I felt that I was done with physics. I don’t think I really saw where one could go further with physics, nor was I given any guidance or perspective into what physics looked like beyond high school. I don’t think a deep love for physics was yet instilled in me.

Jodi’s overall positive feelings towards physics, specifically her enjoyment of it in high school, were great enough for her to take additional physics courses in university. Today, she looks back on her high school physics experience as “an empowering experience.” She shared some of her fondest memories of a close friend with whom she “worked closely together on problem sets and labs.”

We loved talking about the material together, and looking for the application in real life. It was exciting to be doing something different and to be doing it well. We worked hard, and it paid off. It wasn’t necessarily strenuous hard work, however, since we enjoyed it so much! She and I still look back at our physics classes fondly!

The experiences that Jodi had in high school physics proved to be highly meaningful to her. She considers her high school physics experiences to be a success of hers, especially as a woman. She also finds that her experiences still lend her reminders of the lessons she learned, such as determination.

My success in high school, I think, taught me that even though the odds are perhaps against you, or at least [if] others don’t expect you to do well, that ultimately doesn’t mean anything. If you want to do it, put your mind to it, and work hard, you can do anything! And, who says you can’t enjoy it along the way, too? I think this course largely impacted my determination and work ethic throughout the rest of my schooling.

Jodi is currently experiencing happiness in her chosen field of study and thanks her first-year professor for his influence on her. She explained, “Now, after finishing my
undergrad in physics, I absolutely love it. I think my first year professor was the person who made the biggest difference for me; he made it so exciting. That course really opened my eyes even more to how physics is really all around us.”

Today, as a physicist, Jodi has some meaningful insight on the issue of underrepresentation of women in physics.

I am much more aware of the lack of girls in physics and the general intimidation that others have towards the subject. Most people, it seems, are scared of it before they even learn anything about it, and that seems unfortunate to me. I see how this existed in the high school atmosphere as well, perhaps without students even realizing their hesitation towards physics, and whether [or not] it is merited.

Marie

Marie is currently a university undergraduate student in a non-physics field. She has completed Grade 11 and Grade 12 physics at an Ontario high school, and has studied university-level physics for three years. The story of Marie’s experiences in high school physics is guided largely by her experiences in the social context of school. Marie went on a journey through school that led her to find strength in her personal identity. Peers and teachers influenced her, but in looking back to high school, she feels she ultimately maintained resilience in identifying with what she believed was important to her.

Marie had an unfortunate experience in elementary school, when her girl friends said to her, “You care about school too much.” For Marie, this was an ultimatum to choose either her friends or school. “That was so heartbreaking,” she said, thinking back to that time. However, the choice was clear to Marie. She explained, “Well, I’m not going to change who I am for a couple of friends.” These early experiences affected Marie quite
deeply because in continuing school she paid close attention to the way she was perceived by others. She explained, “I was known as…a smart person…but I didn’t want to be just that.”

Similarly, in high school, Marie noticed “no one perceived you as anything more in depth, or more complicated, or as a variety of different things.” Rather, Marie noticed students were perceived to be one-dimensional, which is a perception she fought against having cast onto herself. She especially hoped to avoid being a “nerd…because of the negative connotation with the term nerd.” Marie explained, “I just want people to think I’m a friendly person and that's what I was…But, I was never and I never wanted to be that girl who people were jealous of.” Because of the way Marie wanted to be recognized, she felt she had to “spread [herself] really thin [sic].”

Some of the experiences and ideas that Marie shared were dependent on ideas of gender. Marie said, “Girls tend to be smarter than guys. That’s…up until an age. That starts to change.” She shared her feelings of her femininity as a young woman: “I think I was not the most, not the most feminine person when I was younger.” Marie also shared some personal feelings about the way she viewed her body as a young woman.

The thing I remember being so ashamed of was my arms. Any sort of strength about my body…and people are always like, “It’s so great, it’s so nice that you can do pushups and you can do chin-ups.” But in my head, that’s taking away from my femininity for sure, right there…So that’s something that I’ve always tried to hide or I’ve felt uncomfortable with. But then, it’s important to be good at sports.

Despite Marie feeling as though she was lacking in femininity, she saw benefits to the way she identified. She explained, “I think I was actually able to gain my intelligence
because of my lack of femininity.” She found that she was closer to her male peers because of these feelings as well, because “boys are intimidated by girls, but boys are less intimidated by girls who aren’t super girly.” She explained, “[If] you’re one of the guys…you go up and ask them a question…they’ll be more inclined to help you, rather than trying to impress a girl.”

In speaking about the factors in her experience that were clearly gender-dependent, Marie understands the importance of women being recognized as more than solely “smart” or “feminine.” She said, “As a woman, we need to be not just smart, but all of these other things. I think, as a person, you need to be not just smart, but all these other things.”

“In my head, it was like, physics was just a fun course. The things that we were doing were obviously very simple…easy to wrap your head around.” Marie found physics simple, and stimulating. Interestingly, she explained a realization about her interest in physics: “I almost didn’t realize how much I liked it until I talked to people [in the focus group] and realized how much they didn’t like it.” She remembers “working really hard” outside of physics class; however, she explained, “I think the only reason I worked really hard was because I was so stimulated inside the class.” Marie thought that physics was “really fun” and believes that “if you view it as fun, then it’s fun.”

Part of what Marie attributes to her positive experiences in high school physics is the influence of her teacher. She described him: “He was very exuberant, very outgoing, made everything real. He would touch things; build things, all that kind of stuff. Which
made it much more exciting to me.” She found that her teacher’s character was “approachable,” and she doesn’t recall feeling “intimidated.” Marie explained her reactions to her teacher, saying, “Watching someone else get really, really excited about it makes me [think], ‘yeah, me too, let’s get into it!’”

The “collaborative” activities that Marie did in physics class were positively memorable: “[In physics class] we worked together. So I think that’s the idea of teamwork and viewing everyone [as having] different contributions. Maybe some people are smarter than others but we each have different things that we can contribute.” Marie believes the aspect of teamwork she experienced in physics class was highly beneficial because working together as a class was “breaking social barriers down completely.” Working on labs also positively influenced Marie: “Labs, getting up and moving and going outside and going to the park and doing things outside. Which, to me, that’s the thing that strikes me the most because that’s where I’m happiest, is in the outdoors.”

Marie’s experience in high school physics was supportive of her connection with physics in terms of interest and enjoyment of the subject. The teacher that Marie had was a great teacher in her view, offering diverse and exciting learning opportunities. As a young woman who loved school, wanted to be likable to her peers, and enjoyed sports, Marie showed strength in her identity being rooted in her beliefs. Her story is powerful for numerous reasons, but especially because it reveals how deeply students are aware of how they are recognized by others, and the lasting emotional effects that can result.
Leah

Leah is currently an undergraduate student in a non-physics field. She completed Grade 11 and Grade 12 physics at an Ontario high school, as well as a first-year university-level physics course. The reasons for Leah taking Grade 11 physics include the fact that her school, teachers, and parents pushed the idea of taking physics. Leah explained that those people heavily encouraged science because “the idea was to keep your options open; you take all three sciences.” Despite the push for science, which included physics, Leah said that in Grade 12 physics, “there were very few girls in the class.” She explained the reasons for girls taking physics: “The girls in the class were taking physics as a prerequisite, rather than something that was feasible as a career option or something they could pursue.” As a result of this trend, Leah explained, “I didn’t see a lot of other girls in my physics class going into physics.”

Having decided to take physics in high school, Leah felt that making that decision prevented her from taking other courses of interest to her. She explained, “[Taking physics] closes off other doors… I’ve never taken a business course, a philosophy course.” Courses in the humanities are the courses Leah found she “was more gifted in,” such as “languages or in English.” She explained, “I always found that those came easier to me and that I enjoyed them more so than science.” Leah chose to take science because she thought it was wise to do so; however, she was also attracted to the type of thinking she could do in science. She explained, “I do like the challenge of it to a certain extent.”
And I do like the process and way of thinking and reasoning and logic of it, and I think that’s why I went into science.”

Enjoying thinking like a physicist was an encouragement to Leah in physics; yet, she felt that her enjoyment was not a great enough benefit compared to the costs of taking physics. She explained, “The stress and frustration I felt from it kind of discouraged me from pursuing it.” Leah attributes these negative feelings she was having in physics to her challenges with the mathematical aspect of physics and her attitude about her own abilities in physics.

I found there was a really big gap between grade 10 and 11 sciences. I found that really hard. I remember Grade 11 physics was a whole new way of thinking and it took me a couple of months to get used to that. And I did well, but I didn’t get it.

Leah found that there was a “huge gap” between the math skills required in Grade 10 and Grade 11. She said that she enjoyed “communication questions” or “explanation of concepts,” but when questions involved “equations and numbers,” the “math was hard.” In physics, Leah found herself experiencing “feelings of ‘I don't get it, I’m so stressed because I’m so confused and everyone else is picking up on it and I’m not.’” She explained, “I really didn’t like that feeling of frustration.” These feelings occurred for Leah in physics, but not in other courses she described as “languages or English.” Leah struggled with feeling able in physics and continues to have weak beliefs in her
competence today. She explained, “Even to this day, I am always putting my science ability down, despite the fact that I’m going to be graduating soon with a B.Sc.”

Leah did share a positive experience that she had at the end of her physics education in Grade 12 while she was writing the final exam.

In grade 12…there was a physics exam that I was writing at the end of the year and I saw it as a puzzle. I thought, “this is so cool, I get this!” And I was very relaxed while I was writing it, which never happens to me during exams. I thought, “I got this,” and your brain works so much better when you're calm and I thought, “I can work this out.”

Despite her feeling like she conquered a physics exam and actually enjoyed writing it, Leah said, “The initial months of physics from Grade 11 really stuck with me.” Although by the end of Grade 12 Leah had “a supportive group of classmates and a supportive teacher,” and was feeling as though she was “kind of getting it,” she said physics still left a “bad taste” in her life from the initial parts of her experience in high school physics. Leah identified two other barriers to her success in physics: perceiving physics learners as a certain type of student, and not seeing a future in physics as a potential for her.

Leah generally remembers her peers in her physics class fondly; she explained, “My physics classmates, I remember being really great, really getting along well with them, and that it was a really supportive environment.” Leah’s perception of her male peers differed from the perception of her female peers. She explained, “In my head, there was a perception that there was this group of guys in physics that were you know…I would always go to them and ask for help with assignments and stuff. And they were the smart guys.” She said she believed that “guys are the ones that are good at this subject.”
In other subject areas, Leah remembers her teachers bringing in professionals working in the field to introduce career options. Talking about physics class, she said, “I don’t remember in physics ever having…anyone come in and talk to us about a future in physics. Even my physics teacher, I think he had studied something else that wasn’t physics…there was no presentation of physics as…something with career options…I never really saw physics as a viable future option.” Today, Leah knows of peers “specializing” in “other cool areas of physics,” and “niche, interesting areas of physics” that she realizes she was not exposed to in high school.

As a high school student, Leah was attracted to the type of thinking she could do in physics; today, she finds areas of physics interesting and enjoys scientific thought. However, barriers that Leah experienced in high school physics, especially to her beliefs of competence, discouraged her from pursuing further physics education.

**Carmen**

Carmen is currently a graduate student in a non-physics field. She completed Grade 11 physics at an Ontario high school. Before taking Grade 11 physics, Carmen perceived physics to be an “intimidating class” and had heard that it was “quite difficult.” Going into the course, she felt that she “didn’t have that excitement” she had for other sciences because she considered physics to be “this unknown course.” Carmen explained, “physics wasn’t presented well in Grade 9 and 10,” and said, “We didn’t know what it was going into it.”
Carmen’s experience in Grade 11 physics contributed to her feeling uninterested in physics. She explained, “It wasn’t geared to produce interest in the same way that the other two sciences were.” Her lack of interest influenced her decision to not take Grade 12 physics the following year. Carmen said, “If I had been more interested I would have taken it.” Some of the reasons for Carmen’s disinterest in physics she attributed to the classroom events and environment.

Having a female teacher allowed Carmen to be “more comfortable,” she said. However, Carmen felt that her teacher did not “work to foster a passion or love for physics” in the students. As a result, Carmen felt less engaged in physics: “It just wasn’t as exciting for me, or as supportive, as my other two sciences classrooms.” Mostly, Carmen’s learning in physics was from “textbooks,” “workbooks,” or in “lecture-style” classes. Carmen felt that there “wasn’t the hands-on portion as much as the other two sciences,” which she enjoyed. Carmen explained, “I would have appreciated more variety.” Overall, Carmen found that her learning experiences in physics class did not resemble science learning: “I remember we were in a science class but it never felt like we were because we did spend a lot of time at your desks.”

Carmen experienced difficulty in learning physics at first, especially when her teacher struggled to explain physics concepts in alternative methods. She explained, “There were a lot of instances where we had to learn from our peers and find alternative methods because the way that she would show us wouldn’t work, it wasn’t clicking.” Carmen also noted how her teacher often did not have time to answer her questions.
because “it was difficult for her to get around and answer them all.” Carmen said, “I would have appreciated a bit more time with her…I would have just liked extra help, I think.” Carmen’s experiences with her teacher did not support all of her needs for successful physics learning.

I would say I was robbed some of the physics experience unfortunately. I wouldn’t have been surprised that my interest had been more piqued if [physics] had been more hands on and related to the real world. Because it tended to be just a lot of abstract problems and you’re sitting there thinking, “When am I going to use this? What’s the connection to this and me studying biology?”

Carmen’s memory of “the class dynamic was surprising” to her because she “expected it to be warmer…all learning together and promoting each other’s thinking.” Instead, she found the environment to be “competitive.” This was something Carmen said “bugged” her in high school.

One of my biggest interactions with peers was after handing back a test or assignment or lab, they wanted to come over and see how I did because I had that reputation of being a very strong student. I just found that they were mostly interested in my performance, rather than learning from each other or promoting learning.

Carmen believes that creating an experience in physics education that leads to student success is the responsibility of the teacher: “It falls back on the teacher and their responsibility to, you know, address the misconceptions around physics and create a really positive, dynamic classroom environment.”

Gender was an important aspect of Carmen’s Grade 11 physics experience. She remembers “all the girls sitting at the back and the guys sitting up near the front.” The fact that “fewer females took [physics] than males” influenced Carmen’s comfort level
negatively. She explained, “It impacted my comfort level. I didn’t feel as comfortable.” Carmen felt that her teacher did not support the comfort of the girls in the class. She explained, “I wouldn’t say she did a great job of making everyone feel comfortable and welcome…I found she was catering most to just the strongest students, which happened to be the 3 or 4 guys.” Carmen said she “did not know where [the guys in the class] got their knowledge.” Yet, she explained, “They were always the ones who monopolized the class. The teacher allowed them to monopolize the classroom and questions so I remember there wasn’t a lot of room to ask for clarity.”

In speaking about her male peers, Carmen said that physics “came naturally to them.” She explained, “Especially new, novel content, where others would be spending the period wrapping their head around it…for them it seemed to come very, very quickly.” Carmen’s perception of male physics learners was influenced by the actions of the boys in her class. She explained, “They were always done the quickest…talk about how easy they found the material…I would say they were bragging about it.” The idea about learning physics that Carmen believed in Grade 11 was that a student’s “mind was either geared towards physics or it wasn’t.”

Carmen’s experience in physics class in Grade 11 was largely spent, as she said, “sitting at my desk a lot.” She recalls how her habit of sitting near the back of the room was “uncharacteristic” of her. She explained, “I remember sitting at the back…which is the exact opposite of all other classes. I think I went in with less of a comfort level and this expectation that I might not do as well as I would like.” She believed that where she
chose to sit was a “coping” or “defense mechanism.” However, she explained, “I never felt like that in any of my other courses…I sat in the front because I was comfortable asking questions.” Carmen experienced some difficulty with the “non-prescriptive problems” and “thinking outside the box,” but felt quite competent in physics overall.

To Carmen, Grade 11 physics ended up being less difficult than imagined. She said, “It wasn’t as hard as I thought it was going to be,” and “I remember sitting there thinking ‘okay this is not as bad as people have made it out to seem.’” At the end of Grade 11, Carmen felt glad she took the course; she explained, “I was happy I took it. I was proud of myself for doing as well as I did.” Her performance was sometimes better than other times. She explained, “I found I had the two extremes. I either did really well on the tests, like high 80’s or 90’s, or I just seemed to miss something and I was in the mid-70’s.” Nonetheless, the lack of enjoyment of physics inhibited her from continuing physics in Grade 12. She explained, “My experience in Grade 11 wasn’t positive enough that I felt like I needed to take it again.” Her overall experience of physics in Grade 11 “wasn’t super meaningful…a result of the lack of enjoyment in general.”

Besides her own decision to discontinue physics in Grade 12 and onward, Carmen was also influenced by members of her school community. She said, physics “didn’t seem to be promoted at our school,” particularly by her teacher, peers, and guidance counselor. She explained, “There wasn’t the encouragement from my guidance counselor or peers to take it.” Her guidance counselor said to her, “focus on the other two [sciences], you seem to be more passionate about them.” Carmen valued her guidance
counselor’s advice while considering her “heavy” workload, “scheduling,” and applying for “scholarships.” She was not sure whether she should “gamble in terms of scholarships,” because of the risk of having an “anomaly” on her report card. When Carmen found out physics “wasn’t mandatory” for the post-secondary program she was applying to, she thought: “Why would I have this in my schedule just because I’m going into science when I could take something a) to lighten my load, b) that I thoroughly enjoy and c) I would get a much higher mark in.”

Ultimately, Carmen chose not to continue with physics; however, she has feelings of “regret not having taken at least Grade 12 [physics].” In thinking back to her decision about Grade 12 physics today, Carmen views it differently. She explained, “I really hoped to continue on, so for me to not continue on with physics–I kind of felt like I had failed a bit, and failed myself.” She remembers the “gut feeling” that she had, that she should not take further physics, as “uncharacteristic” of her as a student. Unfortunately, she remembers “thinking and being quite upset [with herself] from not taking Grade 12 physics.” Based on her personal experiences, Carmen offered a powerful message about the power of experiencing barriers in Grade 11 physics. She said, “I think the fact that I didn’t continue on is the important bit, because I’m not someone to quit.”

**Paula**

Paula is currently an undergraduate student in a non-physics field. She has completed Grade 11 and Grade 12 physics at an Ontario high school, as well as a first-year university-level physics course. Paula was incredibly driven as a high school
student and was highly involved with extracurricular school activities. As a typical young woman, part of what Paula desired to be recognized as in high school was “pretty,” along with her other characteristics. However, Paula found that the social norms of high school dictated that “you could either be pretty or smart, and they were kind of mutually exclusive.” She explained, “I was the really involved, smart girl, and that was it.” Paula found this unfortunate, given that she was “concerned about [her] perception” in high school, and said “It did change how I focused in school.” She explained how her behaviour changed: “There was a year there where I was trying to look feminine and portray a feminine persona so people would see that, instead of just the smart side.” In high school, she said the accepted belief was that “if you’re not an object of desire then you’re not an object, you’re not really anything, which is problematic.” This idea proved to be problematic for Paula given the way she changed her behaviour. She explained her efforts, saying, “I would definitely try to dress in a way that was more feminine than what I had been beforehand, which was really ill-fitting skinny jeans and band T-shirts. So I distinctly remember [wondering] if I’ll get a compliment on my outfit today.”

Paula found it troublesome connecting with her peers because she was exuding over-confidence to compensate for her feelings of self-consciousness. She explained, “Even if I was self-conscious, I was portraying this overwhelming confidence that wasn’t necessarily factual, but it does make it difficult for people to interact with.” Additionally, Paula felt that she received attention from her peers for her intelligence and achievement in school, not for the person she was. She explained, “Rather than getting to know me as
a person…it was very focused around school and grades and how I can help them. It was more about what they could get from me rather than about getting to know me as a person.”

At some point in high school, Paula said to herself: “I’m smart, but I’m never going to be considered a pretty girl, so I won’t bother trying anymore.” The fortunate aspect of this thought that Paula had was that she reached a point where she re-focused on what truly mattered to her, even if she did not yet believe she was a pretty girl. She knew that she “could spend a lot of time worrying about what other people thought” of her, but decided she would “get focused” again. Important to note, Paula accepted later, in university, that “you could be who you wanted and not worry about what other people were thinking.” Paula believes that the friend group that she was a part of in high school had a positive influence on her academics. She said that the “super smart group” of friends she had were “constantly challenging each other to do better,” and that there was “definitely a level of competition.” She explained, “The people I had around me in high school were pretty much the driving force pushing me to succeed; it was the external force making me want to succeed.”

High school physics was something that Paula said she enjoyed “to a point,” but was mostly something she “found frustrating.” She enjoyed the conceptual aspect of physics; she explained, “All of the concepts behind it made sense to me…I could think of that in the context of real life.” However, the quantitative aspect of physics changed Paula’s feelings about physics.
You could actually tangibly visualize and think about how it would relate to real life. And because of that, I feel like it was really accessible in terms of the concepts. But, as soon as the math was thrown in there and knowing what equations to use and memorizing...made the concepts seem secondary to the math.

Paula felt that physics “was more about the equations rather than the actual understanding of the system.” The emphasis on math was evidenced by the fact that Paula would learn “the concepts for one day and problems for three weeks after that.” Not having a strong conceptual understanding of physics felt like a barrier to Paula. She explained, “You need to know the concept to apply the equation, but because we didn’t necessarily have a conceptual basis, it was hard for a lot of us to apply those math equations properly.” This challenge resulted in Paula feeling like she was unable to communicate her understanding of physics. She explained, “If I can’t do the math then I can’t show that I understand the concepts.”

Paula remembers enjoying studying physics concepts, but also when her enjoyment was thwarted by the math demands of physics. She explained, “I would love looking over the concepts sheets and seeing all the different things and as soon as I got into the math I thought, ‘Oh great, more math. Awesome.”” Paula imagined enjoying “a physics class that was more theoretical, and not having the numbers involved.” She explained, “Because that’s where I always got mixed up.” Paula thought, “It would have been very interesting to talk in terms of concepts.”

It was in Grade 9 that Paula said she had decided she wanted to “do medicine” as a career. Because of her ambitions, she feared that taking a physics course would hold her
back from being academically successful. She explained, “If I continue taking physics, that could be detrimental to my grades, and if that’s the case then it’ll be a detriment me getting into medical school…so it was almost an academic barrier knowing I couldn’t excel because of the career goals I had.” She remembers how much grades meant to her in high school; she said, “It’s funny looking back at how grade focused we were.”

Although Paula sees humour in the importance she attributed to grades today, she was serious about high achievement in high school and was highly motivated: “You just have to continue to work hard to make sure you don’t get left behind. As others move forward, you can’t just rest on it and say this is fine, you need to continue to work hard to continue to improve.”

Her impressive work ethic and dedication to her goals served Paula well in academics and continues to do so today. However, Paula’s goals remain unrelated to opportunities in physics, which she attributes to lack of exposure to opportunities. She explained, “I don’t think I could see myself in any of the careers associated with physics because I didn’t know about them.” From participating in the research focus groups, Paula feels she has learned that role models are what is needed in physics education to support young women in physics, and her message is inspiring.

The one thing I’ve taken away from this is that there’s a lack of female role models in physics…we never touch on the idea that there are women in physics…And I think if you don’t have the ability to see yourself in a role through a role model then it’s really difficult to actually work towards that goal…Bringing that to the forefront would be really good for young girls to see. You can totally do this; you can absolutely excel at and make a contribution to [physics].
Louise

Louise is currently an undergraduate student in a non-physics field. She has completed Grade 11 and Grade 12 physics at an Ontario high school, and has taken university-level physics courses for three years. As a student, Louise remembers having positive feelings towards school. She explained, “School never stressed me out…I just love school and I love learning so much.” She viewed the majority of her school experiences positively as a result of her love of school. The experiences that Louise had in Grade 11 physics differed greatly from her typical school experiences, and her experience in Grade 12 physics.

Grade 11 physics was not Louise’s “forte.” She said, “I hated it.” She experienced “frustration and anxiety” in the course, and felt that the mark she received “was a really bad mark.” Louise explained her beliefs about why Grade 11 physics was something she disliked so much: “What I liked and didn’t like I think it all has to do with theory versus calculations. I think I really liked doing the calculations in physics more so than the theory.” Because of this preference, she felt that “physics is a lot harder than math because it brings in concepts,” and students “have to apply them into a theoretical mindset, which is really, really hard and challenging.”

Another challenge for Louise learning to apply concepts, she felt, was the way her Grade 11 physics teacher moved too quickly. She explained, “He jumped to answers really quickly so I didn’t have time to think about the concepts behind the math…I knew how to solve for equations. That’s not the problem, I knew how to do math. But,
understanding why those two equations were put in place would help so much more.” Louise still felt that her Grade 11 teacher “was awesome,” but also felt frustrated at his reaction when she asked him questions because “he would laugh or smile” at her. She explained, “I don’t really remember getting help ever.” Louise felt that her frustration was largely due to her “high school mindset,” meaning that if she did not “know the answer right away” she would not come to understand it at all. Partly for this reason, Louise felt that she was “very bad with word problems.” Persevering in Grade 11 physics gave Louise meaningful insight; she said, “It’s very important to practice even if you don’t understand it…I think I learned that even though I don’t understand it, doesn’t mean I never will.”

After her Grade 11 experience in physics, Louise explained that she was not feeling “stressed going into Grade 12, or feeling anxious about taking physics.” She was worried about biology, however, because “it’s a lot of memorization.” She explained, “I don’t do well with memorization. I do better with understanding.” Since Louise knew physics did not involve much memorization, she was at ease in the months before her Grade 12 physics course. She does not remember the reasons for why she decided to take Grade 12 physics after not enjoying it in Grade 11, but she is thankful that she did. She explained, “I’m very thankful that I took Grade 12 physics. I don’t know what compelled me to take it…I have no idea. I loved Grade 12 physics.”

Part of her decision to continue with physics in high school could have been influenced by her familial circumstance. Louise explained, “I think I had the fortune of
having my dad as a math and physics teacher, and my mom was good in sciences. My sister got all of the science and math awards in high school, so knowing that my family could do physics, maybe that compelled me.” She remembers how “homework was stressed” in her “very academic-minded family.”

Louise remembers Grade 12 physics very fondly, she said it was “so interesting,” especially when she was “applying the context” in physics. In doing so, she “could see why math was useful.” Louise explained, “The reason I love it is because it did bring math into a real and tangible thing that I can see. And I love when that happens. I love when you can visualize math and can see why math is important.” She talked about the key turning point for her: “All your life you learn about ‘y = mx + b’ and then you get into Grade 11 and Grade 12 and you can see that math come out and be useful.”

What Louise attributes most to her success and enjoyment in Grade 12 physics is her teacher. She spent time in her Grade 12 teacher’s “office during lunch and getting help.” She appreciated his character, which she described as “quieter,” “gentler,” with “swift movements” as compared to her Grade 11 teacher. Louise explained, “I learned how to love physics in his class…because of his gentle nature…he let me, let us, think in his class.” Some of the in-depth learning activities that Louise did in Grade 12 physics supported her enjoyment in physics. She explained, “He had us do the month-long lab on momentum and energy conservation and I really enjoyed that lab.” Learning activities that Louise considered creative also allowed her to enjoy learning physics, such as one project in which she had to “build a bridge,” and “make up a story about the bridge.” She
said, “I remember that being kind of nice.” The format of the learning happened almost always in groups in Louise’s Grade 12 physics class. She considered how working with her peers benefited her: “I remember studying in groups, doing labs. I never really remember doing anything on my own in that class until I got to the midterm and final. I wonder if teamwork helped me understand the course even more.”

The drastically different experience that Louise had in Grade 12 physics speaks loudly to the power of pedagogy. Louise gives thanks and credit to her Grade 12 physics teacher for her great experience: “After Grade 12, I was ready to take on physics in university. I remember thinking, ‘this is so much fun.’ I really enjoyed it. I’m so thankful; I can’t get over how I’m so thankful that I took it. Somehow my Grade 12 teacher turned it right around.”

Since her successes in high school physics and in university, Louise believes that if she could try Grade 11 physics again, she would “do much better.” She looks back on her time in high school and realizes that despite her efforts in Grade 11, she simply did not believe she “had a physics brain.” A rich insight that Louise has come to appreciate over time is that “you don’t have to do well in a course to enjoy it.”

**Summary**

Barrier in high school physics are experienced in different ways, as revealed in the uniqueness of each participant’s story. The stories can serve as a reminder to physics teachers and the physics education research community of the deep and varied needs of students. Physics education is called to diminish barriers and support young women
experiencing barriers to their identification with physics, their place in the social context of school, their mental health, their perceptions of physics and what type of students can study it, their reactions to pedagogy and other school events, and many other experiences that negatively influence their feelings or beliefs about studying physics. The stories that the participants tell through their experiences contribute student voice and rich meaning to the understanding of experiences of barriers in high school physics education.
Chapter 5

Perceiving the High School Physics Experience

This chapter describes and discusses the first major theme of the research concerning young women perceiving the high school physics experience. Specific sub-themes presented include participants’ lack of prior experiences with physics phenomena, their negative perceptions of physics, and the images of physics learners.

Note on Citation System

Throughout the remaining text of this thesis, direct quotations are often included for the purpose of sharing participants’ own words with the reader. When the quotation is taken from an experience unique to an individual and it could be useful for the reader to know the identity of the individual, the source of the quotation is included at the end of the quotation including the focus group number, page number, and line number in the following form: (1-2-3). When the quotation can be considered to contribute to an understanding of the shared experience and is not unique to one individual, or is not a complete statement, no source for the quotation is included.

Limited Prior Experiences with Physics Phenomena

A barrier to young women in high school physics education can be their lack of prior exposure to or experience with physics phenomena. During the focus group meetings, participants discussed their minimal early experiences with physics and their ignorance to what physics was, even after early high school science education. The common theme was that a lack of prior experience with physics created a barrier to girls’
knowledge of and comfort with physics as a science subject. Physics often remained a mysterious subject to students until they were well into a physics course in Grade 11. Participants generally did not recall spending much time in their Grade 9 and Grade 10 general science classes learning about physics. As a result, they felt they had little physics knowledge going into the Grade 11 physics course. In agreeing with other participants, Rachel explained, “we didn’t have a ton of time to cover it” (1-1-45). Paula, referring to the optics unit she completed in a previous science course, said that physics was “the thing you did for three days and [then] moved on, and that was it” (1-3-33). The participants recalled the topics they touched on in their general science classes: “optics,” “circuits,” and “kinematics and dynamics.”

Leaving their general science classes feeling equipped only with a surface-level introduction to physics and minimal physics knowledge, participants wished that they had a better sense of physics—that they “knew what it was going to be like” in later grades. They discussed how an explanation of the “linear connection” between all three sciences would have “motivated” more students to take physics because they would appreciate that there was a need to study it along with other sciences. Participants suggested that teachers “reaching out to students” is a necessary practice to inform students about what physics is. As Marie said, “making it really clear that this is physics” would be helpful. The participants said that they “knew what chemistry and biology were,” but they had “no definition” of what physics was. Participants indicated that their lack of knowledge about physics contributed to their misconceptions and negative ideas about physics.
Rachel explained, “It’s really easy to perceive it in a different way if you don’t know much about it.” The overall perception that the participants had about high school physics was that “it’s hard, but what the heck is it?”

In earlier school years, participants discussed how they “got used to memorizing” and “regurgitating” information. They generally had the “conception of science” being all about finding “the right answer.” Rachel explained the danger of holding this belief when she said, very powerfully, “It can feel like all of the answers are already out there if no one ever pushes you to come up with your own questions.” Participants discussed that to avoid creating such limiting feelings for students, “using your mind,” and doing physics-like “exercises could be encouraged a lot earlier in education.” They also felt that “more exposure to abstract thought in science” could be highly beneficial for learning physics in high school. Because of the rather unchallenging and rote nature of their education, participants generally felt that they had not had prior experience with failure before high school physics. Two lessons they wish they had learned prior to learning physics are “failure is part of everyday life,” and “how to deal with that failure.” By teaching students critical thinking skills and how to persevere through challenges, they might be better prepared for learning physics.

The participants suggested that interdisciplinary education would increase student interest in physics. Marie’s thought on this was to “stop making all of the courses so defined” (4-14-25). When upper-year high school courses are structured by discipline, participants found that opportunities for creativity were lost. Leah explained, “Earlier on
[in school] there is a lot of communication involved in classes in terms of presentations and creative elements, and I feel like the further and further on you go in school, the more that gets lost” (2-15-46). Creativity is an aspect of education that participants identified as important in maintaining their interest in a subject. Providing opportunities for students to be creative in physics can be considered key in both stimulating and sustaining young women’s interest in physics.

Participants discussed their very early experiences with learning, specifically as children through their play with toys. They identified an interesting aspect of their early play experiences with toys that was related to the gendered nature of the toys they played with and the nature of the learning that resulted from that play. Participants generally felt that “build-it toys” are uncommon for girls to play with. The participants suggested that the issue with this fact is that there is a difference in the utility of boys’ and girls’ toys that is detrimental to girls. The toys such as “block sets” that have “so much potential” for children to create and experiment with are types that participants felt boys play with more commonly than girls. Marie explained that, as a result, girls do not gain the skills and knowledge through play with such “useful” toys. She explained that girls “don’t get the experience and they don’t build the knowledge so that’s not able to [be] applied in the future” (1-13-15). For example, learning experiences with “trial and error” were identified by participants as valuable prior experience to have; however, many participants did not have such experience.
In the early years of their formal education, many participants felt that they did not have learning experiences that were related to physics or that prepared them for physics. They noted that in order “to have prior knowledge in physics, you need to have experience ‘doing’ things” that are different than what occurs in the image of a traditional classroom. However, most remember learning passively in class rather than participating in dynamic, hands-on learning experiences. Participants discussed how traditional learning experiences actually “cater” to girls in the way that this learning style aligns with gendered norms of young female students, which is learning by quietly sitting still. Leah explained her idea that such learning experiences socialize students in a gendered way, which translates into the characteristics of stereotypically male and female careers.

[Girls] are maybe the ones who are able to sit still more and do things in a more–a very methodical way. Whereas, you see those male-dominated fields like physics or computing or things like that, and you may not necessarily have to sit there and be able to get a step-by-step to be able to do well in it. It’s that idea of being able to do things hands-on and able to apply things to it that you’ve done from other areas in your life; that you can get good at it that way. Whereas, things like biology when you have to learn to be able to memorize and sit still and take it in, you see more girls in that (1-19-23).

It can be suggested to teachers that diverse learning experiences are desirable in classrooms for many reasons; however, the rationale in this case is that students gain an image of learning that is much richer than quietly sitting still. Students need to realize that learning occurs in many forms and each student may enjoy learning through different types of experiences.

Participants generally felt that the way their male peers learned through prior experiences lent itself more to physics learning later on. When some participants began
physics in Grade 11, they said that they felt “super thrown off” by male peers in their class having “all of this prior knowledge.” Amy described her sense that she had no prior knowledge compared to her male peers:

I remember feeling intimidated. It also seemed like there were a lot of people in the class. Like this one group of guys that seemed to have all of this prior knowledge already, and every class they would come to class with some news article about CERN [The European Organization for Nuclear Research] or something and they just knew everything going on in physics, and I didn’t even know what a force was (2-6-17).

Not all participants felt that they were intimidated, particularly not by the fact that their peers were male. Some participants’ lack of feeling intimidated was attributed to being comfortable with male peers throughout their younger years. Marie explained, “The reason why I wasn’t as intimidated goes back to the fact that when I was younger I was a tomboy, and I had more of the experience dealing with boys and trying to figure out how they thought” (4-1-42).

The lack of prior experience with physics phenomena can pose a barrier to young women because they face physics challenges for the first time during the course. The barriers can exist in the form of the perception of physics as mysterious and difficult, the lack of developed learning skills helpful in studying physics, and early school experiences that could frame subjects as gendered. Additionally, lack of knowledge about opportunities in physics can pose a barrier to students. Participants generally felt they “did not know what other careers there were in physics other than being a physics teacher or professor or researcher in physics” (4-12-10). Especially for young women, not seeing role models of female physicists is a barrier to their aspirations in physics. Most
participants agreed, based on their memories of early life and education, that they were “never exposed to women in physics.” Paula explained the consequence of this, and her feeling of physics as a potential career for herself: “That’s not necessarily an option for me, nor did I know if there were any options that I would be interested in” (4-13-12).

**Negative Perceptions of Physics**

Throughout the focus group discussions, participants shared what perceptions they had about physics as a subject of science. The major theme was that their perceptions of physics were generally negative, especially during the time prior to beginning a physics course. Two or three participants experienced a change in their perception of physics to a more positive one as they moved through Grade 11 physics to Grade 12 physics. However, the images that participants had of physics were largely negative.

The participants suggested some reasons for their negative perceptions of physics. Based on little prior experience with or knowledge of physics, participants felt that misconceptions and negative perceptions of physics were easily acquired. “The giant question mark that physics was” made it difficult for participants to form positive ideas about the subject. Without prior knowledge and experience in physics, participants expected the common conceptions about the subject to be true. The barrier to young women thinking positively about physics is perpetuated by the widely held negative perceptions of physics.
In discussing the negative ideas about physics from a cultural perspective, participants expressed some amazement and bewilderment while questioning where exactly the negative ideas about physics come from.

I think it’s really funny to me because nobody really knew what [physics] was, but everyone said that it was hard! How do you know that it’s hard if you don’t even know what it was? I don’t even know who started saying it was hard. It’s just this idea. I think that it’s very interesting that some things we just believe, but we don’t even know where we started getting that impression from. It’s just an idea that is ‘there’ (1-3-47).

Participants discussed several ideas about sources of negative ideas of physics. Paula said, “I had Grade 11 and 12’s tell me when I was in Grade 10 that physics is really hard and it’s going to be a real challenge” (1-3-47). The influence of upper-year students’ ideas of physics was strong on most participants’ ideas. Students face a barrier in thinking positively about physics when the information passed on about physics is more overtly negative than positive. Besides the communication to younger students from students who had already taken physics about the challenges of physics, participants believed that there is a general negative “social perception” of physics that influences schools. Their experiences with perceiving that physics is hard and mainly a man’s field suggest that the social perceptions of physics are particularly meaningful for young women in high school.

Drawing from data collected in the focus group meetings, the following collection of direct quotations in Figure 1 represents the participants’ perceptions of physics before
beginning their Grade 11 physics course.

Prior experiences and knowledge, which participants generally lacked in physics, contributed to their negative perception of what physics is and what it would be like studying it in high school. Some participants, as mentioned, experienced a change in their perceptions of physics through their high school physics education. These participants still found that they held negative perceptions about physics before being a physics student, but could also understand why they were attracted to the subject. For example, the idea of physics as an “experimental” and “hands-on” science helped participants feel interested, despite their existing perceptions of the subject. It is important to note that in referring to ‘perceptions of physics,’ the emotions related to physics identity, reactions to
pedagogy, or other related topics that participants discussed, have not been included in the theme of perceptions of physics. It is important to note this here in order to clarify for readers that the participants’ negative perceptions do not necessarily equate to negative experiences. Some participants had mostly positive experiences but perceived physics mostly negatively, and vice versa.

After participants had started their first physics course, which was the Grade 11 level for all participants, the large majority of their perceptions of physics remained more negative than positive. Participants discussed their discomfort with transitioning into Grade 11 science and how physics was a “different” kind of science that they were “unfamiliar” with. They discussed the challenges with the content of physics, both in Grade 11 and in Grade 12. They also shared their feelings about the nature of their physics classes, the learning that they did in this setting, and their perceptions about physics today. The discussion on perceptions of physics during high school physics was closely related to participants’ experience of barriers in physics. The major theme of participants’ discussion on perceptions of physics was that the experience of barriers in physics education negatively influences students’ perceptions of physics.

The following direct quotations in Figure 2 come from the participants’ discussions in focus group meetings and represent the perceptions of physics that participants had while experiencing high school physics.
In high school, experiencing a variety of barriers in learning physics influenced many participants’ ideas of what physics is and their feelings about studying it. Such experiences, along with the social or cultural perception of physics, can be considered to have had a long-lasting impact on some participants, given their perceptions of physics today. Samantha explained that in high school she “would have thought physics majors were more intelligent than an English major or a geography major” (4-22-30). Other participants have similar thoughts today. For example, they feel “a sense of awe of people

Figure 2. Participants’ words indicating some of their perceptions of physics during their high school physics experience.
who are in engineering, doing physics,” or they “always associate being good at physics
with being brilliant.” Holding a largely negative view of physics in high school can
certainly pose a barrier to young women electing physics, whether as part of future
education or as a career.

Images of Physics Learners

Based on the participants’ discussions of their experiences in high school physics,
a distinction can be made between their perceptions of physics as a subject of science and
their perceptions of what type of students study physics or what characteristics of
students are required to learn physics. Participants formed ideas of the characteristics of
physics learners through their experiences in high school physics. Based on participants’
observations, the resulting image of a physics learner or a physicist often did not
correspond with the images or characteristics that the participants felt they possessed and
portrayed in high school. Combined with little prior exposure to physics phenomena and
negative perceptions of physics, the image of a physics learner also posed a barrier to
participants’ choice of physics as a course to take.

Interestingly, participants’ image of a physics learners included having a “physics
brain,” that boys are more likely to have a physics brain than girls, and therefore boys
were generally seen as more able physics learners. The following graphics were
developed from participants’ direct quotations on the topic of physics learners.
Specifically, Figure 3 shows participants’ perception or image of a learner with a physics
brain. Figure 4 compares participants’ perceptions or images of a girl physics learner and

82
a boy physics learner during high school physics. A discussion of the image of physics learners follows the graphics.

Figure 3. Direct participant quotations from conversation about their idea of a “physics brain.”

The participants’ idea of a physics brain included characteristics that they felt were helpful in learning physics, but the characteristics were somewhat distinct from that of a non-physics brain. The participants discussed how, in high school, some felt that “either your brain worked that way or it didn’t.” For example, regarding mathematical skills, participants explained that “you either have math skills or you don’t.” To participants, the idea of a brain suited to learning physics was not something that all students had, or could even develop. Part of the participants’ beliefs about this during high school was related to the social image of physics. Paula explained, “There is
definitely a social connotation that is associated with physics…you’re in physics, so you must be brilliant or you must be super, super nerdy” (3-24-45). As a result of the social image of physics that some participants held, they believed that physics was not a subject that could be taught to just anyone, particularly because they thought that “you can’t dumb it down.”

Unfortunately, the idea of a physics brain only being possible for some learners puts those students who are having difficulty in physics at odds with learning the subject. Some participants recognized many peers in their physics class as “gifted,” and could generally recognize peers who could be said to have a physics brain. Leah described such peers: “People like that, they get it, they don’t have to try hard” (1-9-9). Participants found that peers who excelled in problem solving, for example, had an ability to “understand the question,” and “make sense” of problems in physics. Based on the participants’ experiences, they found that the students who had such skills, or who had a physics brain, were most often boys, and the students who most often struggled learning physics, or who did not have a physics brain, were girls. It is important to note that participants did not feel that these generalizations held true in all cases and for all individuals; rather, this was a general observation they were making.

Some of the participants’ comments during the focus group meetings exemplified the observations that they made as high school students about girls and boys as physics learners. Leah explained her thoughts on “the idea of someone just getting [physics]”: “Maybe those [students] are more likely to be guys than girls” (2-6-32). Jodi described
her awareness of the perceptions of girls and boys in physics in these words: “There was a heavy perception that I was aware of that there’s a difference between girls and guys” (2-15-11). She also commented on the specific perceived differences between girls and boys in physics: “There was a perception that guys have the ‘right brain’ for it and girls didn’t” (1-8-29). Amy explained how the perception of physics as being more suitable for boys decreased physics’ popularity for girls: “It was really not that popular because it was definitely perceived as something more suited to the way guys’ brains work]” (1-9-48). Based on her observations in physics class, Amy described why she held the belief that the boys had physics brains: “The boys’ brains work that way because it seems like [physics] came more naturally to them than it did the girls in the class. Just knowing the appropriate scenario for a given equation” (1-12-40). Leah explained her similar perception of boys’ abilities in physics: “The guys who are in physics, I saw as more naturally gifted in these areas” (1-10-13). Like other participants, Rachel felt the boys “just knew a lot. It seemed like it came easier for them” (1-10-27).

Participants largely agreed on their perceptions in high school about physics learners: there is a certain brain required to learn physics and boys commonly appeared to have what participants called the physics brain, or at least the right mindset for physics. In addition to sharing their perceptions of physics learners with a physics brain, participants compared their perceptions of a girl physics learner and a boy physics learner. Drawing on participants’ direct quotations, Figure 4 compares the image of a girl and boy physics learner.
Figure 4. Participants’ direct quotations from discussions about perceptions of physics learners that represent different images of girl and boy physics learners.
Based on conversations about physics learners, especially within the context of gender, it is obvious that the images of girl and boy physics students are different. Particularly, the differences in images of physics learners seem to portray that boys in physics are seen as capable and enjoying physics, whereas girls in physics are perceived as somewhat out of place and even exceptional if it is the case that a girl is thriving in physics. Clearly, these two images of physics learners are gendered, as opposed to objective and hardly distinguishable without the labels of “girl” and “boy.” More importantly, the two images of physics learners represent different experiences in high school physics. Girls’ experiences as physics learners included feelings such as intimidation and uncertainty, along with much effort and work. The experience that boys have as physics learners included feelings such as enjoyment and interest and a sense of comprehension. Part of the reason that the experiences of girls and boys in physics are different, which is unfortunately often to the detriment of girls, seems to be due to girls’ minimal prior experiences with physics phenomena and their perceptions of physics as male-dominated and highly challenging. Considering such characteristics of experience as common barriers to girls in high school physics, the following can be recommended to physics teachers and all educators to improve the overall image of physics for girls:

1. Provide early experiences exploring physics phenomena (e.g., motion, electricity)
2. Communicate a clear definition for physics
3. Point out to students when they are engaged with physics topics
4. Invite women in physics-related careers into classrooms
5. Educate students on diverse career options in physics
6. Identify and correct misconceptions about (or in a topic of) physics
7. Frame learning physics as possible for all students
8. Support students through all challenges learning physics
9. Provide opportunities for students to work with a variety of peers
10. Encourage a team environment in the physics classroom
Chapter 6

Experiencing High School Physics

This chapter describes and discusses the second major theme of the research concerning young women’s experiences in high school physics education. Specific sub-themes presented include the experience of barriers relating to participants’ decision-making about physics, their reactions to pedagogy, and the requirements of learning physics.

Making Decisions about Physics

While deciding whether or not to take physics in high school, it was found that the participants considered, or felt the influence of, many factors. All participants ultimately chose to take at least Grade 11 physics, and the major themes of decision-making factors were interest in science, appeal of physics, future preparation, lack of alternative course options, and other influences such as teachers and parents. Figure 5 depicts the various types of factors that contributed to the decision-making process for participants and includes direct quotations from the participants’ discussions of decisions about physics.
<table>
<thead>
<tr>
<th>Interest</th>
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<tbody>
<tr>
<td>- General interest in science</td>
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<tr>
<td>- I just love sciences</td>
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<tr>
<td>- I was keen to learn more about sciences</td>
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<tr>
<td>- I wanted to explore other areas of math</td>
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<table>
<thead>
<tr>
<th>Appeal of physics</th>
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<tbody>
<tr>
<td>- Perception of fun labs</td>
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<td>- Hands-on component</td>
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<tr>
<th>Future preparation</th>
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<tr>
<td>- University preparation</td>
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<tr>
<td>- Keep my options open</td>
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<tr>
<td>- I need to take this for University</td>
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<table>
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<tr>
<th>Lack of alternative options</th>
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<tbody>
<tr>
<td>- There weren’t a lot of options for electives</td>
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<td>- I took all the sciences because there wasn’t really anything else to take</td>
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<tr>
<td>- My school didn't have any fun classes</td>
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<tr>
<td>- I don’t know what else I would’ve been taking</td>
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<td>- I was really opposed to English and arts</td>
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<table>
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<tr>
<th>Other influences</th>
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<tr>
<td>- Everyone wanted to take physics to prove that they were smart enough</td>
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<tr>
<td>- Mom...she encouraged me to take physics</td>
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<tr>
<td>- I liked having that really clear balance [of course types]</td>
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<tr>
<td>- Science was, I feel, pushed by school and parents</td>
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<tr>
<td>- I had friends taking the course too so I thought it would be fun to take physics</td>
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<tr>
<td>- Parents' fields [of work]</td>
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When making the decision to take high school physics, participants had considered their interest in science, what taking physics might prepare them for in the future (i.e., university science program), other course options, and other factors such as parental and school encouragement to take physics. Sometimes, the reputation of the teacher who would teach physics also influenced their decision.

Although all of the participants elected physics in Grade 11, they discussed some of the consequences they felt as a result of their decision. Leah explained her feelings about missing out on other course options because she chose to take physics: “I feel like by taking physics I closed off other doors…I had never taken a single business course or a philosophy course” (1-3-11). She felt that taking all three sciences “was what you did when you weren’t exactly sure where you were applying, and needed to have all your prerequisites” (1-3-13). With such a heavy science course load and no room in her schedule to explore other interest areas, Leah explained, “I had to take a night music class just to fill that sort of void that I felt” (1-6-27). As a result of all of the science courses Leah was taking, she felt that she “resented the sciences” (1-6-1). Paula shared similar feelings about being limited in course variety because of taking physics as another science class: “It was a frustrating thing that I had to deal with, the fact that I could like other things, but I couldn’t actually explore whether I liked them enough to go into them” (1-6-17). In choosing to take physics in Grade 12, Paula explained that she “couldn’t take Grade 12 drama,” and “couldn’t take Grade 12 world history” (1-6-13).
The math and science courses that participants selected for interest or as preparation for university were found to be demanding courses and sources of stress for many participants. Paula explained her feelings: “I’m doing a lot of science and math right now, I’m kind of stressed out right now. It would be nice to take something that would be a little less taxing” (1-6-22). Carmen remembered discussing her schedule with her guidance counselor and scheduling the “easier courses” in the same semester as her physics class. She explained that in doing so they were “trying to overcompensate” for the difficulty of physics.

Participants also discussed their ideas about why their peers chose not to take physics. They suggested that because since physics is viewed as the most difficult science, “physics is the one to go” from the list of course options. Participants also discussed, based on some of their own experiences of not having their friends in physics class, that being in a physics class could be “a little bit intimidating, not having familiar peers around” (2-4-6). Others said that their female friends did not elect to take physics because of its perception as a male-dominated course. Marie explained, “I know a lot of my female friends were too intimidated to even take the course because of the fact that it was so male-dominated” (4-1-44). Among the many other factors discussed, participants identified gender as a factor in decision making about physics in high school.

As young women in high school, most felt aware of the gender difference among their peers and in classes. They also recognized that for physics, specifically, there seemed to be different reasons for the boys to take physics than for the girls. Paula
offered her insight on how decision-making about physics is different for girls and boys because of the utility of physics.

The gender part goes back to the fact of why we took physics in the first place. [For] the majority of girls in my [class]...it was a means to an end, rather than the beginning of something else. It was a way to get into what [university program] we wanted to do that was not physics related. And for the guys, for the majority of the guys in my class, it was so that they could get into engineering, so they could do more physics (4-2-13).

Part of young women’s decision-making about taking physics hinged on what the utility value of physics was perceived to be. For many participants and their peers, physics was taken strictly to leave opportunities available later on and to gain acceptance into university science programs. Participants felt and observed, however, that the boys in their physics classes were taking physics to lead into a physical-science-related career. Few participants and few of the girls in their physics classes continued in a science career in physical science. Amy explained, “I think I’m the only girl that was in my physics classes who went on to do something that wasn’t life-science related. Maybe that’s just part of where I’m from...if you’re a girl, you go into nursing, and the boys going to mining, it’s just a standard (1-16-36). Marie also mentioned that she was the only young woman from her high school cohort who went on into an engineering program.

Participants discussed gender in the broader context of their high school, not only within physics. They felt that the course options that schools offer might inadvertently perpetuate the idea that school subjects are gendered, as they noticed how students tend to segregate based on gender when they make decisions about course electives. Amy explained the pattern at her school when students chose their practical electives.
We had to take one applied class in Grade 10 and our options were shop, auto or fashion, where you designed clothes, or hair and aesthetics…That was a really obvious example of how our school was very divided and gendered. There were maybe one or two girls and in auto class…there was obviously no guys in the fashion hair and aesthetics class (1-16-24).

Participants were not advocating for schools not giving students choice; rather, they were noting the different outcomes of decision-making opportunities. Marie compared her experience with Amy’s in which all students were required to take a condensed component of all electives, which included an art course and a design and technology (DNT) course. Marie explained, “A lot of guys would’ve been nervous to choose art over DNT, and that would’ve been stereotypically embarrassing. But they didn’t have a choice, so they got that chance” (1-17-10). Perhaps schools could work to remove the association of gender with subjects by providing opportunities for students to try multiple electives through one course; this could relieve decision-making stress for some students wanting to try a course that is socially not associated with their gender.

Participants identified many factors that influence young women’s decision-making processes for electing a physics course in high school. Some factors pose barriers that can negatively influence young women’s decision to elect physics or continue studying it after Grade 11. Because all participants of this study elected to take at least Grade 11 physics, it might be assumed that similar young women who did not elect physics at all in high school could have experienced additional barriers before arriving at their decision to reject physics as a course option. If participants’ experiences are a good guide, many young women experience stress when taking on a science- and math-heavy
course load, can be frustrated by lack of opportunities to take other courses of interest, and may also view physics as primarily useful for boys. In subsequent chapters, more participants’ experiences in high school physics are explored.

Reactions to Pedagogy

The physics teacher and pedagogy. Participants needed little prompting before they began discussing their high school physics teachers; not surprisingly, they viewed their teachers as an integral part of their experiences as a physics student. Participants described positive and negative characteristics of their teachers, their day-to-day classroom routines, and learning experiences they found more helpful and less helpful.

The participants described teachers who were generally “good” or “bad,” and acknowledged that no one teacher was entirely good or bad—terms that participants used to describe ideas they held about their teachers before taking a physics course (passed on from upper-year students), during their physics course, and afterwards. Participants appreciated characteristics and practices of some teachers and thought less highly of others. For the purpose of providing readers with a clear idea of what young women in high school physics perceived to be good and bad about their physics teachers, these perceptions are discussed separately and elaborated with associated experiences and emotions.

Teacher characteristics. Characteristics of teachers who were favoured by the participants included traits such as helpfulness, friendliness, being approachable, caring and genuine, having a sense of humour, and seeming “cool.” These teachers were very
good teachers in the sense that they had strong explanation skills, fostered a comfortable learning environment, had many interests outside of physics, and held no preconceived ideas about students while giving fair chances and encouragement to all students. Such teacher traits contributed to a learning environment that Amy fondly described by saying, “I don’t think any student ever felt uncomfortable in his class” (3-11-39).

Characteristics of teachers that participants thought of as less favourable included traits such as intimidating, weird, and “wacky.” Using few descriptors to discuss the unfavourable teacher, participants focused on specific reasons for disliking a teacher or for holding a perception of a teacher as bad. Reasons for disliking a teacher tended to be rooted in participants’ awareness of the teacher’s tendencies, especially those that participants felt were exclusionary. For example, participants were aware of teachers’ affinity towards male students or smart students. Jodi recalled that her teacher “showed favouritism towards guys” in the class, and said that her teacher “got along better with them.” Paula and Marie, respectively, used these words to describe their male teachers really liking students who excelled: “The people he perceived to be successful in the future. Those are the students who he liked a lot” (3-11-35). “He was a really good teacher, but you could definitely tell that he liked people who were smarter” (3-12-7). Marie described an experience in which her male teacher responded differently to wrong answers from male and female students, and this adversely affected her participation in class:

My physics teacher, I was so nervous to put my hand up because—it wasn’t even if I answered the question wrong—it was if a boy answered a question wrong, he
would get made fun of. If I answered the question wrong, he [teacher] would say ‘nice try.’ That, to me, felt more...guilty. Like a brushoff, but also because it was like, ‘it’s O.K. because you’re a girl and you tried and you put your hand up anyways’. So then I just sat there and thought, I’m not going to ask you any questions because if I get them right, I’m going to get applause and if I get them wrong then I’ll still get an O.K., but that’s not fair...So I wouldn’t even go up to him and approach him at the end of class, even if I did have questions (3-12-36).

In analyzing participants’ recollections of the characteristics and habits of their teachers, it became apparent that students are sensitive to, interpret, and make decisions based on the messages their teachers’ actions convey, despite the teachers’ intent or character. It is a barrier to girls’ sense of belonging and vision of success in learning physics if they feel excluded from what they observe to be the preferred physics student. It is also a barrier to girls’ physics learning when they choose to disengage because of the ways they are treated differently than boys.

**Pedagogical characteristics.** Events in the classroom, as discussed collectively by participants, revealed a pedagogical continuum from their perspectives as learners; this continuum ranged from traditional pedagogy to more progressive pedagogy. Some learning experiences could have involved both pedagogies. The participants’ learning experiences related to pedagogy are depicted below in Figure 6, which presents a Venn diagram that compares various features of traditional and progressive pedagogies.
Participants generally reacted negatively to traditional pedagogies and positively to progressive ones. As students, participants generally found learning experiences associated with traditional pedagogical instruction to be less enjoyable and less supportive of their learning than the experiences associated with more progressive pedagogical techniques. The more favourable classroom, according to the participants, resembled progressive pedagogy because it was a dynamic environment with “movement and discussion” that felt like active learning: “It was so exciting and so different from normal, just sitting in the classroom and not really doing much” (3-2-48). Such learning happened when students were moving around the class and working at lab stations, using trial and error, when peers could collaborate during group work, or when students
participated in peer teaching activities. Leah recalled an occasion in which she and her group members each played different roles in problem solving; she played the role of a skeptic.

Participants found learning particularly engaging when they were using technology such as computer software to work through laboratory experiments or watching exploratory and investigative videos such as Veritasium and Minute Physics on YouTube. Participants also emphasized strongly that they were most engaged in learning physics when learning involved applications to real-life contexts: “Seeing physics in real life motivated me to do physics.” Overall, participants found engagement in physics was easy when the teacher was entertaining and obviously enjoyed teaching. A distinct memory of Marie’s was shared of her teacher “climbing on his desk.” She explained, “Almost every day he would just end up standing up on his desk to reach for things to show us... it was very entertaining” (3-7-34). Participants also responded positively when they could connect physics to other disciplines. Marie enjoyed writing about physics through a historical lens, and Rachel loved the opportunity to apply physics to biology through a presentation on the microscope.

When discussing concepts or problem solving, participants found it helpful when the teacher encouraged the use of common sense and asked questions to develop students’ critical thinking skills, such as the simple question, “Does this make sense?” Questions like this are among other aids that the participants referred to as “tools” that helped in the physics learning process. Such tools introduced by the teacher, such as
drawing Free Body Diagrams, checking units, following steps in writing out what is known about a problem, and using a formula sheet were perceived as helpful aids for physics problem solving. An emphasis on communication skills on tests and during physics teaching was also appreciated by the participants, most of whom felt like strong communicators.

The less favourable classroom was characterized by traditional pedagogy. This classroom had rows of desks near the front with lab benches at the back. Participants recalled the daily routine beginning by taking up homework questions from the previous day, then listening to lectures, “copying a lot of notes on lined paper,” filling in handouts, looking at problems on the board, and doing “problems with a paper and pencil.” Both inside and outside of the classroom, participants had clear memories of continually working through “time-consuming problem sets” and textbook practice problems. Doing laboratory experiments was one aspect of participants’ physics learning experience that was lacking. Many participants said they remembered “the occasional lab,” “few labs,” or “no designated lab time.” As Amy said, “I don’t really remember any labs at all” (3-2-21). Jodi remembered only a single lab-like project that happened at the end of Grade 12. It was also noted that doing labs was often the only time participants worked in a group with their classmates.

In discussion about learning experiences in physics, some that were remembered as unhelpful revealed teacher actions that created barriers to participants’ physics learning. According to participants, the “bad” teachers sometimes lacked explanatory
skills; when a teacher could only explain one way, it “could cause mass confusion and panic” among students in the class. Participants remarked that when “teachers don’t think we’re capable of learning it,” or when “[physics] wasn’t taught to me in a way I connected to,” learning was less enjoyable and more difficult. Participants also discussed the struggle of not being fully interested in physics, which they felt was associated with “never learning what the point of physics is, [because] teachers don’t answer that question.” There was also an issue with a teacher’s wait time, specifically after asking the class if they had any questions about the topic being taught. Participants recalled that the silence that followed the teacher’s question was usually not because the students were understanding perfectly; rather, they were often so confused that they did not know what questions to ask the teacher in order to improve their understanding. The teacher ended up moving on right away, thinking the students had no issues with the material. Another bad teaching practice, according to participants, was “using jokes to reflect people’s intellect,” which separated students and caused embarrassment for those who did not catch the joke. Marie recalled that separating students with a seating plan based on their academic ability inhibited student collaboration: “He almost segregated us to the point we couldn’t help [each other].” These recollections of their physics classes reveal a general disconnect between the students’ needs and a teacher’s practices.

Rachel described an experience depicting a disconnect between teacher practice and student needs that negatively affected her comfort in the class. She described how her teacher gave the same tests to her classes year after year using the exact same sheets of
paper. Rachel has terrible memories of test days in an unwelcoming and hostile environment:

You couldn’t write on them because she was going to collect them back and use them again for next year so you had to write on another sheet of paper. She would literally just collect them back and I remember after a test one time she couldn’t find one of the sheets of paper: “Who took it?” We sat there until the sheet of paper was found. I think it had fallen on the ground somewhere and slipped under some shelf or something. I don’t remember exactly what happened but it was kind of hostile and I didn’t feel very welcomed into this class. I had no idea what we could do, we were just sitting there through our lunch waiting until that sheet was found…It was terrible. Every single test was like that, she would always hand them all out and make sure you didn’t write on them because she would collect them all back at the end (3-10-3).

In her physics class on test days, Rachel found it helpful to stand at the back of the class at the lab benches while writing the test. She said it helped her feel less jittery and stressed, but she remembers her teacher urging her to sit down, commenting, “You’re making me stressed standing.” Rachel also found that on these tests, questions were often worded ambiguously and she identified this as a barrier to her ability to perform well.

In their discussions, participants noted other teaching practices that could pose barriers to students feeling competent and able as physics learners. They discussed how teachers, both knowingly and unknowingly, “put students into bubbles of good and bad students,” which can make some students “feel like they aren’t good enough.” Teachers and guidance counselors were also remembered to have “labeled students based on their ability” and even discouraged some from taking challenging courses such as physics. Carmen shared a memory of her science teacher encouraging her pursuit of the subjects
she performed best in, rather than subjects she was passionate about, and this influenced her beliefs about herself:

Unfortunately, I would say that was kind of reinforced by science teachers at my school. Even though I was most passionate in sciences in general, my highest marks were in languages, so I remember at parent-teacher interviews my mom came home and was furious because one of the science teachers had said, “Well, even though [Carmen] does well–she gets As in science–she’s winning all of the English and French awards so she should go into languages in university.” So that was reinforced, unfortunately, at the teacher level. So I guess for a little while I genuinely believed that I was just more inclined towards other areas even though my passion really lied [sic] within the biological sciences (1-14-39).

In general, it is clear from the participants’ memories of experiences with their physics teachers that various barriers challenged their comfort and their feelings of competence, performance, recognition, and interest. The barriers associated with the experiences discussed above could apply to all physics students; however, some of the experiences reveal gender-dependent barriers as a result of what the participants consider to be bad teaching. Such experiences acted as barriers to these young women as physics students.

Participants generally agreed with the perspective that “teachers are unaware of how they treat girls and boys differently.” Some participants said they knew that the physics teacher favoured male students. This is an idea that they had acquired before taking a physics course and exemplifies the consequence of treating female and male students differently. Jodi felt that teachers “train” students’ thinking by asking certain things of boys (e.g., take the recycling out of the classroom) and girls (e.g., writing notes for an absent student). The ideas participants held about teachers treating girls and boys
differently before they had taken a physics course were confirmed for most participants when they did take a physics course.

Participants noticed that, when they answered questions incorrectly in class, they were coddled by the teacher, which, felt more like condescension. Leah gave an example of her teacher’s response to female students’ wrong answers: “Girls answer the question and it’s either, ‘Oh good job, you got it right! That’s amazing,’ or ‘O.K., you tried’” (3-23-35). In contrast, teacher responses to male students’ wrong answers were of a teasing nature, as if to say, “you should have known the answer.”

Another aspect of pedagogy that the participants felt posed a barrier to their efforts in physics class was praise. Participants reported that the high praise they received in class, especially in contrast to the reprimands the boys often received, minimized the significance of their hard work and struggles while learning physics. Paula explained, “My teacher called on me and another girl for excelling in organizing our work” (1-16-45). Marie, having been praised for being “great” and hearing predictions that she would do great things, felt that this kind of praise was detrimental to her success in physics because she felt it was only by virtue of being female that she received the praise. As she put it, “No, I’m working hard, too. I’m struggling, too” (3-9-29). In fact, Marie’s decisions about her future education were affected by her experiences of being praised by her physics teacher: “This is possibly why I went into chemical engineering instead of the physical side of engineering, because I had a chemistry teacher who was really all about
learning and asking as many questions as you can, but my physics teacher said, “Oh you’re smart, you’ll be fine, you can do anything” (3-9-38).

The differential treatment of male and female students by teachers, whether intentional or unintentional, poses gender-dependent barriers for female students. Specifically, female students have gone into physics class believing that their teachers favour male students; as physics students, the young women felt coddled and praised, even when they did not believe it was appropriate or deserved.

Throughout the focus group discussions, conversations relating to teacher characteristics and pedagogical characteristics occurred in which the participants shared emotional reactions they had to experiences with their teachers and their teaching. These emotional reactions resulted from what participants considered to be good and bad teachers. Good teachers generally had progressive teaching styles and were preferred by students, while the bad teachers generally had traditional teaching styles and were not preferred by students. Some bad teachers were associated with gender-dependent pedagogy, which participants identified as detrimental to their physics learning. The bad teachers and associated pedagogies can have a strong negative influence on students’ feelings of belonging, comfort, enjoyment, and purpose in physics class. Female students’ physics identities, that is, their feelings of recognition, competence, performance, and interest, are also negatively affected by such teachers and associated practices. The overall understanding gained from discussing female students’ experiences with their physics teachers is that individual teacher characteristics and poor pedagogical
practices may pose barriers to young women’s success in and continuation of learning physics.

Requirements for Learning Physics

Although individual teacher and pedagogical characteristics may pose barriers to young women’s success in learning physics, the participants provided insights for teachers about young women’s key learning needs. Throughout the discussions, participants regularly identified factors that support successful physics learning during high school physics. Suggestions for such support were discussed voluntarily by participants in all of the focus group meetings; the participants showed great awareness of what they felt was, or what might have been, helpful for their physics learning as young women in high school. Most suggestions given by participants were discussed in terms of “needs” for successful physics learning, as if successful learning would be unlikely to occur without that support in place.

Aspects of support for successful physics learning could be grouped into several categories. In other words, participants discussed needs in terms of supporting particular aspects of the high school physics learning experience, including conceptual understanding, comfort in class, critical thinking, problem solving, relevance of physics, and support for learning. These categories seem to reflect what young women in high school physics feel most strongly about in terms of what can be most helpful for successful physics learning. The following lists were developed based on participants’ comments during discussions about needs for successful physics learning. As a
conclusion to this chapter, the items in the lists are recommended as elements for physics teachers to consider when supporting students’, especially young women’s, learning needs in high school physics.

Conceptual Understanding
1. Videos for visualization and alternative methods of explanation
2. Having another person explain a concept
3. Learning concepts through examples
4. Using concepts to answer physics questions
5. Discuss concepts and physical situations
6. Discuss conceptually what is happening in a physics problem before introducing math
7. Free body diagrams

Comfort in Class
1. Surrounded by peers
2. Being able to ask questions and talk aloud
3. “No stupid questions” classroom environment

Critical Thinking
1. Not giving students the “easy way out,” or giving answers too quickly
2. Encouragement of question asking
3. Teaching students to “ask good questions”
4. Situations where students have to use the information they have to determine further information
5. Teaching students to recognize “known” and “unknown” information leads to question asking

Problem Solving
1. Methods for checking answers
2. Unit conversion methods
3. Teaching students to ask: “is this realistically possible?” E.g., negative time
4. Students rather learn from real situations than diagrams
5. Practicing and discussing with peers
6. Group work is comprehensive and preferred vs. isolated learning
7. Variety in problems and applications
8. Open-ended problems
9. Teaching students what to look for in problems in order to solve problems

Relevance of Physics

107
1. Social relevance through laboratory experiments
2. Gaining an understanding of how the world works
3. Identify physics in activities during early science learning, e.g., egg-drop and airplane activities
4. Utilizing class projects and learning on field trips
5. Opportunities to enjoy and have fun while learning physics

Support in Learning
1. Extra lunch hour help from teachers
2. Collaborating with other students
3. Offering students diverse opportunities to show learning, e.g., communication questions on physics tests
Chapter 7

Identity and Gender in the High School Physics Experience

This chapter describes and discusses the third major theme of the research: young women’s identity and gender in the high school physics experience. Specific sub-themes presented include the experience of barriers relating to participants’ physics identity (i.e., interest, competence, performance, recognition), gender-dependent influences, and the meaning of participants’ experiences in high school physics.

Physics Identity

The construct of physics identity is used in this research as a lens through which the influence of barriers can be understood, as experienced by the participants during their high school physics education. Students can be said to have physics identity when they view themselves as a “physics person” (Hazari, Brewe, Goertzen, & Hodapp, 2017, p. 96). The four components that influence an individual’s physics identity are performance beliefs, competence beliefs, interest, and recognition. Beliefs of performance and competence refer to students’ beliefs that they can perform required physics tasks, such as problem solving and laboratory experiments, and have the ability to understand concepts in physics. Interest refers to students’ curiosity in and attentiveness to learning physics topics. Recognition refers to the extent to which students feel that their teachers, peers, family, and others see them as a “physics person.”
Issues of Interest

A student’s physics identity is influenced by the degree to which she feels interested in physics, that is, feeling curious or being attentive and eager to learn more about the subject. A strong interest in physics would strengthen a student’s physics identity, and a weak interest in physics would weaken it. The idea of helping to develop a strong physics identity among young women is to provide engaging opportunities for students to marvel and be fascinated in order that their interest is stimulated. The findings of this research reveal that feelings of interest were very important for participants in determining how engaged or disengaged with physics they felt. Feelings of interest and disinterest proved to be meaningful to the participants in decision-making about physics education.

Throughout the four focus group meetings, the participants discussed their physics identities, talking about each of the four components of physics identity and how these feelings changed over time. The themes of the discussion about interest, as one component of physics identity, are presented as they occurred in the focus groups. First, participants discussed the feelings they had before their first physics course, then their feelings at the start of the course, during the course, and finally at the end of the course. The interest component of physics identity was one of the most extensively discussed components.

Before participants took their first physics course, their feelings related to interest ranged from general excitement to dread. The participants who were interested in physics
before the course began said it was because they wanted “to find out what it was,”
because “it was something new and uncharted,” or that it was “something new and
exciting and it was a mystery.” These participants found themselves “excited about
physics” and feeling “general excitement to take physics.” Participants also shared
reasons for their interest going into high school physics. Some said it stemmed from
“interest in problem solving,” or remembering that they “enjoyed the Grade 9 and 10
aspects of physics.” Others saw older students “working in the hallway,” which made
physics look “cool” and acted as an advertisement for the course. Many participants said
they felt a strong scientist identity, which included an interest in taking physics. Jodi
explained that she felt free to be interested in physics because her parents did not pressure
her to take certain courses, only those she expressed interest in.

At the beginning of the course, interest was high for some participants. Amy
remembers “being super excited,” seeing that the walls of her physics classroom had not
one blank spot because there were “pictures and paintings everywhere related to physics
concepts.” Samantha recalled her first fascination with physics during an inertia
demonstration by her teacher: “That one particular moment, it was fascinating for some
reason, even though it was a simple thing…I just felt like it answered a lot of questions in
general life” (2-9-48). For almost all of the participants, connections to the real world or
everyday life were enormously important in increasing their feelings of interest in
physics. Amy described a trend she noticed in herself, saying, “I wasn’t that interested in
it when I started physics in Grade 11…the more I learned about it and the more I could
make connections with either math class or the real world, the more interested I got in it” (2-14-38). Louise shared a fond memory that she knew increased her interest in physics so much that she hoped to continue studying physics.

We basically did a month-long lab and it actually took a month, on momentum…we looked at all different components. It tied several components from our course into one lab, and I loved it. I thought, this is so much fun because for one, it’s math and I like that, and because I saw what was happening…I saw physically what was happening and I could understand that. I think that was definitely a drawing factor, that that lab drew me to want to study physics more (2-9-5).

Other participants, like Rachel and Samantha, also recognized when their interest in physics spiked. Rachel said, “My interests definitely spiked when I had different opportunities to learn, like when I had a chance to do a presentation or listen to other people’s presentations” (2-12-43). Samantha recounted a story of a ketchup bottle, emphasizing the power of demonstrations; she said, “That ah-ha moment with the ketchup. My interest spiked very much so. I wanted to learn more about physics, all kinds of physics” (2-12-21). Some participants who experienced interest in physics initially have pleasant memories of sharing their interest in physics with friends outside of class. Jodi told the group, “I remember liking talking about it. Outside of class our group of friends would always be talking about it outside of class and thinking, ‘oh, that’s so cool.’ Realizing and pointing out the physics of it” (2-5-25).

During the participants’ physics courses, what seemed to keep their interest in physics high was applications of physics to real life, doing physics projects (hands on and in-depth), and opportunities to have fun while learning with peers. Jodi explained that
“seeing it in real life just made it so exciting to talk about and have it be relevant” (2-10-21). Rachel agreed, remembering a time when she took her textbook to the beach over March break: “Reading my physics textbook about waves while being near waves, I just remember that I thought it was the coolest thing” (2-5-35). Louise and Samantha both remember marveling at a topic in physics class, Louise while observing light interference patterns and Samantha while realizing the physics behind speed limits: “The teacher explained why there are speed limits and I thought, that’s fascinating!” (3-3-38).

Experiencing how physics applies to everyday lives stimulated participants’ interest in physics, as did doing hands-on and in-depth physics projects. Louise recalled doing an involved, week-long experiment using ramps and a ball: “We had to try to get the ball into a tin can…it was a week-long exploration thing and I loved it” (3-2-45). Rachel commented during this discussion that, although projects were stressful sometimes, she “did enjoy the building,” which happened during one car project in Grade 11. Continued conversation and collaboration with peers outside of class was something participants felt was important for maintaining interest in physics, for example, working together in the library and talking about homework and assignments. Fun with physics never hurt, according to participants, many of whom went on a physics field trip to an amusement park. Rachel reflected on the outing, saying, “I remember having a really good day. I really enjoyed doing physics that day because I was outside, I was with my friends at [the amusement park], which I really loved. That definitely made me much more interested” (2-11-3).
Looking back to the time when the participants’ physics courses in high school were coming to an end, certain memories stood out for them. Rachel found she was most interested in physics when she got to do a presentation on the microscope, since it involved another field of science she loved. Paula and Marie both found that their greatest interest in physics developed when concepts were applied to the human body: “It’s cool to apply to the body.” Framing physics this way, Paula said, “made physics make a lot more sense…it made me a lot more interested in it” (4-14-40). Marie’s favourite memory from high school physics was the following: “We had a really cool project that I will always remember; it was a potato cannon. It was to reinforce the concept of projectile motion and I always thought projectile motion was so interesting” (3-4-45). Her fondest memories of physics occurred when she got to do experiments and work with others. In her last year of high school, she had an experience doing one physics lab that was fascinating and a lot of fun for her: “In Grade 12 we did a Rube Goldberg machine, which is a series of reactions, and it was the most fun I’ve ever had. I’ve never worked harder on anything in my life, even in university, just because I was so fascinated with it” (3-6-22).

The enjoyment in physics that Marie and other participants experienced supported their interest in physics and ultimately strengthened their identity in physics. Participants who finished high school physics feeling that they were still interested in it and who identified with physics generally “loved Grade 12 physics.” The course might have even
“sparked an interest” that went beyond topics explored in high school, as it did for Marie and several other participants.

Unfortunately, for many students, including most participants in this study, lacking interest in physics presented a significant barrier to their success and continuation in physics. Although participants shared emotions and experiences revealing their moments of interest in physics, most described emotions and experiences that revealed their lack of interest in physics and the challenges associated with studying it. In this section, the experiences of those participants who were not interested in physics are explored. Often, the reasons for participants’ disinterest are related to other aspects of physics identity, such as feelings of performance, competence, and recognition, or other general factors. Such influences that are indirectly related to feelings of interest are explored later, as they are important factors contributing to the participants’ experiences.

Participants who were not interested in physics before the course began said that they did not remember “having the interest in it that [they] did in the other two sciences.” A couple of participants felt “indifferent” towards physics because they were only taking it to fulfill university program prerequisites. Some felt strongly disinterested in physics, were “quite nervous for physics,” or had a “dreading-it mentality.” Leah mentioned that she actually “hated science and math growing up,” and as a result she said she “didn’t have a strong physics identity” (1-20-27). The “mystery of physics” was a negative influence on some participants’ physics identity because they did not have interest in the unknown. When discussing the hands-on component of physics class, which was often an
interest-inducing aspect, Samantha attributed the fact that she has no memory of lab experiences to her lack of interest: “If we did do labs, I obviously wasn’t interested” (3-3-25).

Paula shared with the group her idea about what happens to students’ feelings of interest: “There seems to be this endpoint, and then after that the interest stops” when the material gets difficult. Rachel explained one of the reasons for her lack of interest: “That ah-ha moment… I never ended up getting that in physics… I never felt like I had an end goal” (3-18-8). Amy attributed her lack of interest coming out of high school physics to the limited interest in physics that she began high school with: “There were a lot of good experiences that made me more interested, but I guess I had started with such little interest that it didn’t make me want to pursue it past high school” (2-10-17).

Rachel said her “interest was low” at the end of Grade 11 physics: “I didn’t leave [the course] thinking I want to take it next year.” Samantha, at the end of Grade 12, said she was “so disinterested.” Similarly, Paula described her feelings of interest at the end of Grade 12 physics as “very done.” She explained, “I knew I had to take it the next year [at university] and was just dreading it.” Leah shared similar feelings; sadly, her feelings about physics turned to annoyance: “I was tired of having to try really hard and I was annoyed that I had to take physics again in first year, I just wanted to be done with physics” (2-14-1). Leah stopped taking physics in university as soon as her science degree requirements for physics courses were fulfilled.
It was not difficult to uncover the negative feelings that the participants had towards physics, especially near the end of their Grade 11 or Grade 12 courses. The evidence of participants’ disinterest in physics is strikingly obvious and quite moving when viewed through the lens of female under-representation in physics. It is no wonder that females are choosing to neglect physics; they associate feelings of disinterest, dread and annoyance with the subject after first exposure. The strength of these young women’s negative feelings towards physics represents a loud call to physics teachers and the physics education research community. These participants’ accounts of their experiences confirm that low interest in physics acts as a significant barrier to successful and continued study of physics. To participants, experiencing this barrier meant dropping physics. In order to not only remove this barrier, but also to nurture and further develop young women’s interests in physics, the following steps are recommended:

1. Demystify physics
2. Provide a purpose and goal for learning physics
3. Offer exciting and fascinating learning opportunities (e.g., demonstrations)
4. Offer hands-on learning opportunities
5. Offer in-depth laboratory explorations or projects
6. Frame physics as fun
7. Apply physics to the human body
8. Apply physics to the real world and everyday life
9. Connect physics to other subjects (e.g., biology, history)
10. Encourage physics learning through discussion
11. Encourage students to collaborate with peers
12. Support other components of physics identity (performance, competence, recognition) so they do not impede the component of interest
Issues of Competence

Among the components of physics identity, competence and performance were discussed as very closely related to each other in the focus group meetings. Often, participants talked about their beliefs or feelings of competence alongside those of performance. Beliefs that they could understand concepts in physics were associated with beliefs that they could perform physics tasks, such as problem solving and laboratory experiments. Beliefs of either high or low competence or performance generally corresponded with a similar level of the other component. The participants suggested that the two components share a correlational relationship; when beliefs in one component fall, the other follows, and when beliefs in one component rise, the other follows. The participants showed great awareness of this trend, for example, by attributing the low beliefs in their competence to poor performance in a laboratory experiment. Poor performance, to participants, was almost always evidenced by lower grades than they were accustomed to. For some participants the trend was reversed. For example, once they felt they understood the physics concepts, they believed (and often received evidence in numbers) they could perform well doing physics tasks. In this section, beliefs and feelings of competence are discussed separately from those of performance, which are discussed later.

Participants’ beliefs and feelings of competence changed during their physics courses, and no one participant had beliefs of competence that remained entirely strong or weak from the beginning to end of studying physics in high school. Although a range of
beliefs existed, the participants’ beliefs and feelings of competence are presented here as those that resemble students’ beliefs that they are competent and those that resemble students’ beliefs that they are not competent.

Overall, participants were found to have many fewer beliefs of competence than beliefs of lacking competence. Students who believed that they could be competent in physics before the course began generally felt that “competency would come with hard work” and physics would be a “big learning curve.” Leah, for example, felt that physics would be a challenge to her, but not something she could not do: “I didn’t see physics as something natural and intuitive to me, but I would do O.K.” (1-9-6). Samantha transferred her feelings of competence in math, a related subject, to physics: “I thought I would be pretty competent actually, given that I thought it was mostly math that was involved. Math was always my best subject in high school” (1-8-23).

In the beginning of Grade 11 physics, Samantha remembers “feeling really smart.” Amy had similar feelings when learning about relativity in Grade 12, saying that she remembered “feeling really smart, especially explaining it to other people,” and she felt like she was “a really serious scientist” (2-10-10). To feel competent, participants explained that it was helpful to learn by “discussion,” “talking” and “wrestling” with ideas. They found that, as students, they “definitely had to practice,” particularly because they believed that a physics student cannot “actually understand anything in physics until you apply it in a question.” As Amy explained, “I only know that I’m really grasping the material if I have a lot of questions about it” (3-16-9).
Leah described a meaningful memory of her last experience with high school physics, which was her Grade 12 physics exam. She explained, “I remember loving it. It was so weird. I sat there in the exam and was [thinking] this is the coolest puzzle! You know when you get it, and it all fits? It was the best feeling” (2-11-7). These examples represent what the participants remembered from their experiences as believing and feeling competent in high school physics. Among the participants who expressed beliefs and feelings of competence in high school, most feel strengthened feelings of capability and competence today compared to what they felt in high school. They agreed that if they had to take high school physics again, they “would figure it out,” and “be able to get through it.” Rachel explained: “I feel so much more empowered now and certain with myself that I can learn something if I want to learn it” (4-13-45).

For those participants who did not feel or believe they were competent in high school physics, that lack of a sense of competence posed a barrier to their strong identification as physics people. Not feeling competent in high school physics was often, for many participants, the greatest influence on their decisions to stop studying physics. For many, if not all, feeling incompetent in a subject occurred for the first time in their education when they took physics. The challenges that accompanied lack of feeling competent in physics, including the hindrance of the other components of physics identity, created barriers that were so great that they had little chance of rooting their physics identities in strong feelings of competence.
Although Amy knew she was a strong student at the time she was going into physics, she said, “I wouldn’t say I felt super competent and ready for it. I was nervous…I knew it was different than the other sciences” (1-8-39). Marie, who was also a strong student, was excited about the mystery of physics, yet said, “I didn’t think I was going to be competent” (1-8-46). Leah shared a general comment about the poor beliefs she had in her abilities in high school: “I never felt like I had one thing that came very naturally to me…one talent…I tend to underestimate my abilities a lot of the time” (1-9-4). Such feelings revealed some of the participants’ self-doubt in their abilities before they started studying physics.

Once they began their first physics course, their feelings of competence were challenged. One of the challenges participants faced was that physics demanded a new type of learning that was different than regurgitation of facts. Paula shared that this change was “a source of panic,” and remembers asking herself, “Why am I not getting this?” Leah experienced a new type of frustration in school when she “spent probably at least 10 hours trying to build” a project for physics class: “I remember I could not figure it out for the life of me” (1-5-38). Rachel remembers the confidence that she had at the beginning of the course diminishing: “Very quickly, maybe within the first couple of weeks…I very quickly started falling behind, not understanding the first couple of major concepts. I felt like that held me back from learning things from that point on” (2-4-20). After these initial challenges, Rachel was unable to catch up to where she wanted to be.
She explained, “I completely lost my footing and I didn’t know how to change it or fix it, I felt really helpless” (2-12-39).

Participants discussed the specific aspects of physics that caused issues for them in understanding, which ultimately affected their feelings of competence. In general, these women believe that it is harder to gauge understanding of physics compared to other courses. They found that “physics was a big learning curve” and was challenging to “wrap your head around.” For example, the concept of vectors was very challenging for some participants to grasp, and when building projects for experimentation, it was difficult for some to conceptualize what needed to be altered on the project to accomplish the desired task. When Rachel was no longer able to keep up with understanding the concepts, she explained, “I just felt like the rug kind of got pulled out from under my feet” (2-5-42). These challenges underscore the importance of taking time to develop students’ ability to think conceptually about physics.

Problem solving challenges are a specific aspect of physics that contributed to participants feeling less than competent. Many participants, who did not feel competent in math, suffered “math anxiety” in physics, and felt a “panic” when they did not see a clear path to solving a problem or could not see how to begin a problem. With too much information provided in a problem, participants said it was “really difficult distilling information” in order to make sense of a problem. Participants generally did not find it helpful when teachers would “just smile” or give minimal guidance when they approached with problem-solving questions, or when they had to read their textbook to
understand how to do problems. Doing problems was generally a source of stress for participants, as they explained they felt obligated to practice and understand physics problems, especially as homework.

Participants shared some experiences that were obvious barriers to their feeling competent in physics. Leah remembers her teacher running a “mental math contest” that was intended to teach students “how to use rounding…to simplify math problems and simplify mental math.” Leah thought that this was a good skill to have; however, she remembers how the activity turned into a competition of who could do mental math the fastest. Leah explained that one male student “ended up battling the teacher,” and the scene sadly left her thinking, “Well, I’m an idiot, because look at them going at it.” Leah explained further: “Some people literally have a calculator in their head and that’s not me…both guys, and the competition of it, the idea of someone just getting it. Maybe those [people] are more likely to be guys than girls (2-6-24).

Samantha also shared an experience that she remembers making some students in her class feel frustrated at their lack of feeling competent in physics.

[The teacher] would explain some kind of physics concept and then he would make some kind of joke about it. So, if you understood the concept he was talking about, then his joke was absolutely hilarious, but if you didn’t understand it, then hearing his joke probably would have just frustrated you even more because several people are laughing because they get it” (3-11-11).

For the participants who did not feel competent in physics, after facing such challenges such as those discussed above, their feelings of competence were diminished further. Some participants sought help with physics during their lunch hour, but never for other
classes, and this was difficult to accept. Similarly, it was difficult to accept for Rachel that she was seeing a physics tutor, because she saw this as her own “extreme failure.”

Leah explained her own struggle: “I get very, very frustrated with things I don’t understand. I get discouraged very easily in terms of thinking I’m not good at something” (2-11-12). Similarly, Louise said, “When I had to think about it for more than two minutes, I just kind of got frustrated” (3-7-18). Other participants felt incapable of asking for help. Leah said it was impossible to ask the teacher for help “if you don’t know enough to ask a question” (3-16-16). Rachel shared a similar experience: “I just didn’t know what questions to ask, so I didn’t ask” (2-6-44). Marie explained that even when there was enough knowledge to ask a question, it was extremely difficult to admit needing help, as if it meant admitting incompetence: “That’s also really hard to do, to admit defeat, to admit that you don’t know what’s going on and to go up and ask for help. It takes a lot of guts” (4-16-7). Overall, participants were found to share the experience of finding it difficult to formulate questions to seek help from others and, if they had questions, it was difficult to admit a need for help in understanding physics.

Another barrier to participants feeling like they lacked competence in physics was the learning mindset many felt they had in high school: a fixed mindset. A fixed mindset, opposed to a growth mindset, was defined for the group as follows: “You encounter something that you can’t really wrap your head around right away, or it doesn’t really come naturally to you, and then you just shut down instead of working past it, that’s a fixed mindset” (1-12-47). Rachel reported that she “definitely operated on that level, for
sure, in high school” and believes that it “was a huge barrier” for her (1-13-2). For many participants, like Rachel, learning in physics felt like the opposite of a growth opportunity. Rachel described “feeling like I just have to get through this. It wasn’t like I was learning for the sake of the learning experience, it was like I was learning so I can just scrape by on the next test” (4-8-35). Participants agreed that having a fixed mindset in high school inhibited them from developing feelings of resilience and ultimately competence in physics.

Feeling a lack of competence was considered a barrier to participants because they felt that they “had never had experience with actually having to fail” before taking physics. Similarly, in both Grade 11 and Grade 12 physics, it was the first time for many participants that they felt they were “not getting” physics, and they thought they were “not going to do well.” As a result, some participants had a weakened physics identity and simply disliked the subject altogether. Rachel described her last year in physics as a “really rough year,” and Paula said, “Grade 11 physics wasn’t the greatest experience...the whole course I couldn’t get my head around the concepts” (2-5-47).

Participants attributed a lot of meaning to their experiences of challenges in physics, especially the challenges that created barriers to their feeling competent. Three participants directly stated that they felt “not very competent,” “so incompetent,” and “very incompetent” after finishing Grade 12 physics. Participants explained that they had less desire to study physics because they “didn’t understand anything” in Grade 12. Some participants described how their lack of feeling competent in physics prevented them
from having a physics identity, or how they were no longer a physics person because of their low feelings of competence. For example, Samantha experienced a drastic transition after having loved Grade 11 physics and feeling highly competent.

Then physics in grade 12, when everything changed, it very much had a negative impact on me. Because all of a sudden I was like “O.K., I guess I’m not really as good at this as I thought, I will change my plans for university.” It really brought me down, so by the end of my high school experience it was pretty awful. I just really did not feel good about [physics] at all (4-8-28).

Samantha also commented on her perception of physics after Grade 12: “Physics was…something for smart people and I just didn’t fit into that category.” Paula, too, struggled with identifying with physics after her experiences feeling a lack of competence: “After I took physics, [my perception] was that I wasn’t good at it and that was O.K. with me” (4-20-36). Many of the participants’ experiences of feeling lack of competence in high school physics meant that they were no longer “physics people.”

From a physics education research perspective, it is important that students leave high school physics believing they are and can continue to be competent in physics. The following steps are recommended to support beliefs of competence in young women taking high school physics:

1. Provide opportunities to practice applying physics concepts
2. Take time developing students’ ability to think conceptually
3. Portray understanding physics as an attainable goal
4. Allow students to discuss and wrestle with ideas with peers
5. Regularly check in with students about how well they are understanding
6. Offer students extra help (e.g., through extra time or different resources)
7. Avoid competition in the classroom
8. Frame learning as an ongoing process
Issues of Performance

The association between beliefs of competence and performance offers a deepening of the understanding of the participants’ shared experiences of barriers in high school physics. Most, if not all, participants felt that their performance in school in general was measured by the grades they received. The association between grades and performance that participants held as students acted as a barrier to many in feeling like they could identify as physics people. Beliefs of performance, mainly characterized by grades according to participants, had significant effects on participants’ beliefs of competence, interest, and feelings of recognition. Participants discussed their feelings relating to performance in high school physics classes in depth; their experiences are presented as generally positive feelings of performance and generally negative feelings of performance.

Most participants said that they felt relatively confident that they would perform well in physics, especially when they looked back to themselves as students at the beginning of their physics course. Jodi said that she felt confident she “would do well in most classes, especially the sciences.” Other participants believed they would perform well in physics because they generally performed well in school. Paula said she “was used to getting really high grades,” so there was no reason for her to not achieve the same in physics. Similarly, Rachel said she expected to do well in physics because she “tended to do really well” in most of her classes. Carmen approached physics thinking, “I’ll do well enough,” because she considered herself a very strong student, but foresaw her
interest waning. She explained, “I’ll do well enough, but physics likely won’t be my lifelong passion.” Marie, on the other hand, planned to use her interest to maintain her strong performance in physics: “I didn’t think I was going to do well, but I thought maybe if I motivated myself by being interested in it then I would do well” (1-8-47). Jodi also used motivation as a strategy to perform well in physics, using her twin brother as a source of motivation.

Part of me was kind of competitive…I’m going to prove to them that I have that brain too. I have a twin brother…he’s definitely really quite a lot smarter than me, but I always felt…he’s kind of my standard to prove that just because I was the girl…I could still get there. So I was very motivated. I’m going to do fine even that [sic] there was that perception (1-8-30).

Gender perceptions play a role for participants in their beliefs of performance because performance, like recognition, is a component of physics identity that can be perceived by others. Participants generally felt feelings of external stress and pressure to perform well in physics, which for different students could be positive or negative. Leah expressed knowledge that the boys in her class generally achieved the highest grades, and she was proud of herself when she could alter the norm: “Sometimes I would do better than the smart boys in the class would…Sometimes I would get a better grade. It was a nice feeling because even though I’m not as good as you are at physics, I can do really well” (2-11-19). Louise also had positive memories of her performance in high school physics; she said her grade increased 15% from Grade 11 physics to Grade 12 physics.

Other participants shared aspects of their experience related to beliefs of performance that they found helpful while learning physics. Marie described a “really
exciting open-ended problem” she worked on in class that involved trial-and-error. She appreciated that her “mark wasn’t based on how close you got to the target…it was a fun project” (3-5-2). Paula found that her feelings related to performance were positive when she saw that her teacher “gave marks” if she made “a legend of all of the variables” in problem-solving questions on tests or assignments. Leah also underscored the importance of deemphasizing grades for students to maintain the goal of learning and positive feelings of performance: “He wasn’t going to give you a grade on your homework…it was really for you” (3-20-26).

Despite these positive feelings of performance, most participants were feeling less positively about their performance at the end of their physics course than at the beginning. Samantha said that she felt like she “performed O.K.” in the end, but it wasn’t until university that she had this realization: “I switched over to thinking there’s something more to me besides grades” (4-19-1). Paula also explained her feelings of performance in high school physics: “When I got my mark back I was [thinking], ‘O.K., I’m not terrible at this,’ but I didn’t really feel great about it” (4-16-43). Paula experienced growth through this experience because she learned that “sometimes you have to work hard and it’s O.K. if you have to work hard” (4-9-1).

Participants discussed how feelings of performance were influential to them as students. They agreed that when their performance increased (i.e., grades), their feelings of competence increased, which in turn increased interest in physics. The orientation in which participants ordered the influence of components of their physics identity can be
considered a result of what is prioritized in physics education. In order to feel a strong physics identity, students need to feel that they are able to perform physics tasks; however, if a strong physics identity hinges on beliefs in performance ability, there is a risk of some students losing interest, recognition, and belief in their competence. For the participants who believed they could not or did not perform well in physics, loss of physics identity and rejection of physics was usually the outcome.

As alluded to, for many participants who did not have positive beliefs about their performance in physics, their identity was rooted in the grades they received. Their stories resemble those of students who only consider grades as a measure of their performance, not their physics abilities or beliefs in themselves as physics people. For example, Paula said, “My physics identity was definitely tied to how well I was doing in the course” (2-14-21), “In Grade 12, my entire concept of myself and how intelligent I was, was based on numbers” (4-22-18). In Samantha’s experience, she explained, “I didn’t feel much like a physics student whatsoever and it was all based on my marks…I was so fixated on what my marks were I let my marks determine how I thought about myself” (4-18-37).

When students define their beliefs about themselves with the grades they receive, feelings and beliefs of performance become a barrier to students’ believing they can achieve what they hope to and that they can be physics people. The barrier of negative performance beliefs was a significant barrier for almost all participants. Samantha explained, “Once my performance in physics was declining, it was challenging my entire
self-perception” (2-12-33); “I wasn’t doing well and that deterred me” (4-14-15). Rachel also explained her feelings after receiving an unsatisfactory mark on an interim report card: “I remember sitting in class feeling like my parents are going to kill me, this is terrible. It was the end of the world for me at the time and that made me even more turned off of physics” (2-9-23). The significant, deep impact that negative feelings of performance made on the participants’ views of themselves as smart, young women was clearly meaningful.

A number of participants referenced the number grades they were receiving in physics class that caused them to feel like poor performers or like they were not physics people. Potentially surprising is the fact that none of the participants under-achieved in physics to the degree that they failed a course or were considered to not be meeting standards. Participants associated grades ranging from 70% to 94% with phrases such as, “disappointed,” “failure,” “wouldn’t be good enough,” “scraped by,” and “devastated.”

Some participants struggled with the idea that their grades did not represent their beliefs of performance. In other words, participants felt that they either a) did not deserve the grade they received, or b) that even when they felt competent, they did not believe they performed well. These participants described themselves as feeling like “a fraud,” or “dishonest,” because their actual performance did not align with their beliefs about their performance. It is clear that participants’ confidence about being a physics person was greatly affected by the association of grades and performance in physics.
Additional barriers related to beliefs in performance that participants held as students; these included stressful, performance-based tasks, being judged against other students, and the general competition to achieve the highest grade. Stressful situations included quizzes and exams, as well as performance-based tasks such as projects in which students were given “three tries” and when the “best of three was graded.” The stress level in these situations worsened when students tested their projects “in front of the whole class,” because it would be embarrassing and “obvious [that] yours didn’t work.” Leah remembers her high stress level and that she was not focused on learning: “I was not appreciating any of what it was about I was just stressing so much about satisfying this requirement to make it go closest to 10 meters as it could” (3-5-11).

Similarly, feeling defeated, Rachel’s negative beliefs in her performance worsened when her grades were compared to her peers. She explained, “My mom, specifically, would ask me, ‘Well how did your friends do?’ If I did really well it wouldn’t matter how they did, but if I didn’t do well it was like, ‘Well your friends did better than you.’ You could never win” (4-8-15). Again, it is clear that participants strongly associate their grades with their abilities and, in turn, often have a negative physics identity. In order to combat the barriers that negative beliefs of performance pose to young women believing they are physics people, the following steps can be recommended:

1. Deemphasize the importance of grades
2. Give qualitative and constructive feedback to students in assessments
3. Stress that learning is the goal in physics
4. Work to align students’ positive beliefs in performance with actual performance
5. Offer a wide variety of opportunities to perform in physics (e.g., labs)
6. Avoid performance-based learning tasks
7. Decrease stress and competition in the classroom
8. Support other components of physics identity (interest, competence, recognition) alongside positive beliefs in performance

Issues of Recognition

Regarding emotions associated with recognition, participants rarely discussed their physics identity as being positively influenced by their recognition as a physics person. There were no comments overtly conveying that participants’ physics identity was grounded in or supported by recognition from others. Largely, the participants did not feel that they were recognized as physics people. Positive recognition from others generally came in the form of reinforcement for being a good student and a friendly peer, and was unrelated to participants’ identity in physics.

One instance of recognition that is considered to be a positive influence on physics identity was provided by Leah. She recalled her mother attending a parent-teacher interview with her physics teacher, who said to her mother: “She’s doing great, she gets it, she’s good!” (2-11-26). Leah felt that “it was nice to get that reinforcement” of being recognized as a good physics student. Other factors were discussed that are indirectly related to physics identity but could be considered positive influences on students’ identity. For example, some participants shared that they were recognized as a “nerd,” but they felt proud to be recognized as having that “positive quality.” Being someone who was recognized as interested in school was not a negative influence on Rachel’s general identity; she proudly said, “I wasn’t closed off about my admiration for school” (4-7-14).
Most of the discussion surrounding issues of recognition did not indicate that participants felt recognized as physics people by their peers, family, teachers, or even according to their view of themselves. When participants did feel that they were recognized in association with physics, negative emotions often accompanied the experiences.

Participants generally did not view themselves as physics people. Instead, their discussions revealed conflicting feelings of identity that prevented them from seeing themselves as physics people. Marie recalled her hopes of recognition in high school, explaining, “I wanted to be known as a friendly, outgoing person…That is part of my personality and that’s what’s important to me…I wanted to have that sort of perception” (4-4-45). Similarly, Rachel explained, “I had a lot of different friends…it was really important, this idea of being liked.” In terms of how one is recognized by others, participants explained that being smart does not align with being socially outgoing and friendly, because “normally, being smart is quiet and sort of pensive, not the person who is putting their hand up and getting really involved in the class” (4-4-48). As a result, to be recognized as socially apt, which is often a priority for high school-aged students, participants felt they had to “hide that side” of themselves that included their interest in physics.

Paula shared similar feelings about her high school experience; she felt conflicted in her struggle to prioritize both her academic and social identities. In other words, she struggled to be recognized as both smart and sociable. She explained, “You want people
to like you and I never felt like people liked me because I was smart and because I felt like I was an insufferable know-it-all” (4-4-38). Instead of accepting Paula’s efforts to engage in a conversation about a mutually interesting topic with her peers, Paula’s peers assumed that she had negative intentions: “Oh, you just want to show off how smart you are” (4-5-20). Because of this, she painfully assumed that her peers would say, “I don’t want to talk to her.” She remembers “feeling othered, almost, by being someone who cared about school” (4-6-37). These experiences left Paula in a difficult place, feeling torn between the two identities that she felt were equally important to her, but were recognized by her peers as disjoined; one was undesirable (smart) and the other, desirable (sociable).

As a student who was generally proud of her admiration for school, Rachel told a story of her struggle with recognition as a physics person. The story involves an embarrassing experience in physics class that created a giant barrier to her sense of belonging in physics. When Rachel was having trouble figuring out how to use a clamp while standing in front of the class, her teacher encouraged her to “play with it and figure it out.” This happened while “everyone was watching” her, and she remembers being “completely red in the face” out of utter embarrassment, and thinking in the moment that “this is making me hate this even more.”

Overall, I think it declined my sense of…I didn’t feel like that was where I belonged. It really kind of shook me up into the following year…so should I be
in sciences? Is this something I’m actually good at? Questioning what I believed my whole life (2-13-23).

Ultimately, Rachel’s feelings of embarrassment pushed her to feel recognized as incapable, and further, caused her to question her beliefs about her ambitions and abilities in science.

The participants were strongly influenced by how they were recognized in school by their peers. They also associated negative feelings or lack of feelings of recognition with experiences with their teachers. Paula has memories of how her physics teacher recognized physics students at her school: “I remember my physics teacher putting everyone who is in physics on a pedestal above everyone else in our school” (3-8-39).

Within the classroom, Marie remembers her teacher “pointing out the students who were doing the best” (3-8-16). She said that the seating arrangement was organized by the teacher and based on student performance: “there was a row in the back and those were for the people who were doing the best in the class, and he wanted the people who weren’t doing the best in the class at the front” (3-8-18). Marie remembers being recognized as a strong physics student, but said that “even a good perception of you can be damaging…it almost puts more pressure…you feel like you’re going to disappoint him or he’ll be upset. I won’t live up to the standard of being the best in the class” (3-9-11). Participants generally felt that recognition was given to strong physics students, as these students could be recognized as physics people. Participants discussed how recognition could have both a positive and negative influence on students’ sense of
identity in physics. They also explained that neither strong nor weak physics students prefer to be segregated based on their performance in physics class because the feelings associated with recognition pose barriers to both groups of students.

Participants briefly discussed their feelings of recognition at home. No participant reported feeling viewed as a physics person by the people at home. They did, however, report their early desires of finding an identity in something they were good at. Rachel said, “I worried about that my whole life, I remember being little [and] asking my mom, ‘What am I good at?’ or, ‘What are my talents?’” (2-13-31). Rachel’s mother would respond to her saying she was good at school. Leah remembers the response she received to the same question put to her mother: “She would say, “You’re good at school,” and I would say, ‘I want a cool talent like gymnastics!’” (2-13-33). Recognition as a good student in childhood later proved to be problematic, according to the participants in this study. Rachel remembers thinking, “well, if I’m not so good at school, what am I good at?” The problem existed within the fact that their identity was tied to being a good student, which brought feelings of both expectation and limitation: an expectation insofar as that they had to meet the requirements for being recognized as a good student, and a limitation in that their recognized identity did not extend into other realms beyond being a good student. Samantha exemplified this idea well when she said, “When people expected you to be a good student, when you’re known as the academic type, when that kind of gets taken away from you…what am I left with? That was my thing, academics, and now I don’t have that…it really sends you for, you know?” (2-13-26). When it came
to physics for Rachel, Samantha, and most other participants, personal identity stood little chance of rooting itself in recognition as a physics person. Referring to taking home her mid-70% grades in physics, Rachel said, “I wasn’t getting a round of applause at home…so not high on the recognition scale.”

Today, as university students, participants still feel that they are subject to others’ expectations. Marie and Jodi, who are currently studying chemical engineering and astronomy, respectively, struggle with barriers to their recognition as women in STEM fields. Marie explained that “it’s the questioning of why you’re in it that gets me the most, because when it’s a guy, [people assume] they’re in it because they’re interested in it. But when it’s a girl, it’s intellect, or hard work, or dedication…No, I just find it really interesting” (3-25-16). Jodi also has a sense of the barrier to her recognition as a physicist. She explained, “When I tell people I’m a physics student, I really have to convince them. It’s like, ‘Really? You seem so normal.’ Thanks?” (3-25-3).

The limited degree to which the participants in this study have felt recognized as real physics students or as “physics people” portrays an image of just how large this barrier to females in physics can be. The lack of feeling or being credited with recognition as a person of whatever one’s passion or interest or skill may be impedes that person’s belief that success is possible. The following steps are recommended to build feelings of recognition in young women as physics people:

1. Embrace and encourage the multi-dimensionality of students (e.g., intelligent, social)
2. Avoid putting students in potentially embarrassing situations
3. Do not segregate students based on their physics ability (verbally or physically)
4. Do not glorify physics and physics students above other subjects and students
5. Praise students’ efforts, not their intelligence or grades
6. Allow students to determine expectations for themselves
7. Give judgment-free recognition to young women as physics people

Physics identity, referring to one’s feeling that one is a ‘physics person’ needs to be supported in young women in physics education. If all four components of physics identity (interest, competence, performance, recognition) are fostered in students, they contribute to a strong physics identity. If one or more of the components of physics identity are not supported, or if they are all unsupported, then the lack of feeling like a physics person becomes a major barrier to young women establishing an identity in physics.

**Gender-dependent Influences**

With the aim of this research being to understand young women’s experiences in high school physics, gender was an important component to explore. Throughout the four focus group meetings, the women discussed many aspects of their experiences in high school physics that they felt were related to their gender. As a result, experiences, issues, or observations related to gender are mentioned throughout most chapters of this thesis. This chapter specifically addresses the theme of gender-dependent influences on young women’s experience of high school physics. For most participants, their gender was felt to be an influential aspect of their experience in high school physics. However, some participants felt that gender was not overtly related to that experience. Gender-related topics discussed included the school experience of learning physics as a young woman.
and personal and cultural ideas of ‘womanness.’ The finding from these discussions is that observations and feelings related to gender-dependent influences in the experience of high school physics are indeed influential for young women. Often, the gender-dependent influences in high school physics are unfavourable for young women and pose barriers to their success and continuation in physics education.

In Grade 11 physics, some participants found that there was a gender imbalance in terms of the number of girls and boys in the class. Most participants only found the imbalance noticeable in Grade 12, when there were fewer girls than boys in the class. Carmen explained, “There was quite a gender imbalance…I knew going in that I would be one of the few female students” (1-1-9). Amy said that among her girl friends, she “was the only one that took physics. It was really not that popular” (1-9-47). The most common class composition among the participants’ Grade 12 physics classes was “almost all guys with just a few girls” (1-10-4).

Most found that they were “less intimidated” working with girls in their physics class and “more intimidated” working with the boys. In discussing these feelings, the participants indicated that there was a difference between the girls in the class and the boys and the behaviour that each gender demonstrated in class. Participants reported that the boys in their class were “not necessarily better [at physics], but they [were] more confident and sure of themselves” (3-24-12). Jodi recalls finding that “guys [were] a lot more confident with their answers” (3-24-10). Marie agreed with this, but also suggested that the boys were “a lot more careless” (3-24-11). Most participants agreed that they
themselves exhibited perfectionist behaviour or felt fixated on understanding and doing well in physics; however, the participants “didn’t get that impression from the guys,” that they were exhibiting perfectionism. Paula explained, “All the guys in my class were like, ‘Oh whatever, I didn’t do that well’” (4-10-24). The perceived difference in behaviours of girls and boys in physics is noteworthy because the participants, based on their experiences, could identify how they saw girls to be struggling in physics where the boys were perceivably not struggling. The participants’ discussions of personal and cultural ideas of being a girl or woman help us to understand why experiences for girls and boys might differ.

The discussion on ideas of womanness began with the exploration of what it meant to the participants to be a young woman in high school. They explained how some girls, regardless of their true character, acted “flirty” and “dumb” to avoid seeming “smart,” and at the risk of not “being seen as attractive.” The participants spoke about this behaviour unfavourably, but still understood why some girls might behave in a way that discredits their intelligence. Marie explained that “as a woman, you don’t want to be just smart. You want to be all of these other things, too. Especially at that age, where you care about the other gender and you care what other people think in general” (4-4-16). Marie’s words are rich in the way that they represent a common struggle for young women in high school to be recognized as “smart” and “attractive” simultaneously, as the multi-dimensional women that they are. Paula commented on her feelings of the conflict she personally experienced with her intelligence and likability as a young woman.
Because I felt intelligent and because I did well, it almost took away from the idea of me being able to be a feminine figure at the same time… In high school, you want guys to like you or you want girls to like you depending on your sexual preferences, but you want people to like you and I never felt like people liked me because I was smart and because I felt like I was an insufferable know-it-all…It was a very prominent feeling. No one liked me because I was smart and that made me feel like I was less of a girl almost, which is a weird feeling to have (4-4-35).

The incompatibility between young women’s diverse traits can be considered a byproduct of the cultural expectations for girls and women. In other words, it can be said that women are culturally evaluated firstly for potential feminineness and attractiveness and secondly for ambitiousness, athleticism, or other stereotypically non-feminine characteristics. Intelligence, as participants identified, was a characteristic they felt they were secondarily valued for, or sometimes not valued at all for, as in Paula’s experience. Exuding confidence in intelligence, as participants found, had an amplified effect on boys’ perceptions of girls. Marie explained, “If you exude confidence or intellect, it makes them a little nervous” (4-1-47). Participants generally agreed that there could be personal benefits to using confidence to make the boys a little nervous.

As a result of the gendered expectations that exist in high school for students, some of the participants felt that they needed to behave in a friendly, outgoing manner to be considered likable young women. Marie explained that, “being a woman and being a smart woman, you cannot be closed off. You need to be friendly or [else] people will not listen to you” (4-5-31). The need to behave a certain way in order to fit the gendered idea of a young woman perpetuated each participant’s identity as a young woman differently. Some participants dressed differently with the desire of being attractive, and others
avoided the expectation to be feminine because of their strong connection to school and learning.

The perceptions that the participants have today about what it means to be a woman are different than the perceptions they had in high school, a development which the participants view as positive. Most participants’ personal identities are rooted first in their unique characteristics and interests. However, some heavily gendered expectations and images of women still exist in the context of their lives as university students. For example, Paula aspires to be a medical practitioner and struggles with the cultural ideas of women in medicine. She explained, “It’s still a perception that because I am a woman I have less ability to do it. If I do it, I’m going to be a gynecologist or a dermatologist or a family practitioner or pediatrician; I’m not going to be into hard-core neurosurgery” (4-5-37). Unfortunately, the participants feel that they experience barriers in multiple contexts throughout their lives as a result of their gender.

In the context of physics education or academia, some participants were found to have experienced gender-dependent barriers. Jodi explained how it is “interesting because if you talk about being a girl interested in physics, people are so shocked…It’s a little bit more complicated than a guy being like ‘oh yeah, I’m interested in physics’” (3-24-36). Participants attribute the conflict between the association of physics and women to the “social perception” of each. Leah explained how others’ expectations and reactions to women in physics are often made obvious: “Praising differently or responding differently…It’s that difference between what you’re expecting that person to be doing,
because that just shows how they may be stereotyping. And not even implicitly, not even realizing what they’re doing” (3-25-29). Participants explained that the cultural norms of gender affect any and all gender identifications when two gendered ideas, of women and physics, for example, seem incompatible. Participants found questions such as these to be a representation of the social challenges, or barriers, to women who associate with physics: “Why are you into that?” “Why would you like that?” and “How did you get there?” (3-25-37).

It is important to note that this research does not assume that all individuals who are biologically female identify as a woman. However, in the context of the participants’ focus group discussions, the phrases gender, being a woman, and being female were almost always used synonymously. Samantha commented on being female and said that her being a female did not affect her experience in high school physics: “I can’t really overtly think about something that I felt really held me back because I was female or of something that helped me move forwards because I was female” (4-1-36). Rachel explained a similar feeling about her gender: “I really don’t think that my gender was related to my physics experience” (4-1-26). Despite these feelings, she still wondered if “somehow, very unconsciously” her gender was related to her experience of barriers in high school physics. Jodi’s insight on gender in physics depicts how issues of gender in physics are often very difficult to notice: “[The] difference of gender that I have experienced is really, really subtle” (3-23-22). Many barriers specific to young women in physics were difficult to discern by participants, such as those within pedagogy, the
social perception of physics, and issues related to physics identity. All participants felt that their gender was related to their experience of barriers in physics to differing degrees, whether it was an overt barrier rooted in gender, or a barrier related to gender so subtle that it was hardly noticeable until later physics education. All participants, however, agreed that the relationship among all students in a physics class “should be a team” relationship, a dynamic based on “appreciating others’ skills,” which “could be so beneficial” for all students who ultimately share one goal of learning physics.

**Making Meaning of the High School Physics Experience**

This research sought to explore the experiences of barriers for young women in high school physics education and to understand the meaning that young women attribute to experiencing those barriers. Throughout the focus group discussions the participants shared powerful experiences of barriers. The barriers they experienced came in many forms, were often deeply impactful for participants, and were largely related to the culture of physics in various settings, such as the school and classroom. For some participants, the barriers they experienced in high school physics ultimately meant that they would not choose to continue studying physics. These barriers have been explored in previous chapters, such as those relating to negative or gendered perceptions of physics, components of physics identity, or reactions to pedagogy, among others. When participants were asked what their general experience of high school physics meant to them, most, if not all, of their responses communicated an obvious positive tone. The meanings of the experiences of participants were expressed largely in the form of lessons
learned or insightful takeaways that participants would value later in life. Perhaps amazingly, and despite the challenges and barriers faced in their high school physics education, the participants generally viewed their experiences of high school physics as highly meaningful and personally profound. Generally, physics taught participants the value of hard work, how to persevere through challenging academic experiences, and the message that learning is a process that is ongoing. Figure 7, below, contains three clusters of quotations that are examples of the meanings that three participants attributed to their experiences in high school physics.

**Paula**

[Physics] was actually extremely meaningful because it taught me a lot of things about myself…about the way that I need to work to succeed…it showed me that if you actually work hard at something and don’t give up…you can do well at it (4-8-43).

It showed me that sometimes you have to work hard and it’s okay if you have to work hard. It also taught me a lot about how to cope with not doing well in something…In high school I had a very strong perception of myself needing to be as perfect as possible (4-9-10).
When I got out of physics, I don’t know what my mark was, but what I got out of it was so much more valuable than my mark (4-9-46).

The journey is more important than the destination…I think that is something that I learned in physics because I learned so much about my inquisitive nature and how hard I can work when I really need to (4-10-5).

I learned…the importance of not just marks, but a hard working nature…resilience. The idea of failure and picking yourself back up and doing better on the next one (4-10-46).

You need to realize that you’re going to make mistakes and you’re not going to do amazingly on everything (4-11-43).

Anything is possible…Right now I’m designing a manufacturing plant, which is like insane (4-20-48).

I was going to be O.K., and it wasn't the end of the world (4-10-12).

What that class really showed me, and I feel like what I’ve taken with me for today, is this idea that the sun’s going to come up tomorrow (4-21-32).

*Figure 7.* Sample quotations from three participants on the discussion about what meanings they attribute to their experiences in high school physics.
The positive meanings that the participants as young women gleaned from their experiences in physics education can be considered an encouragement for the physics education research community. Based on the findings of this research, the idea that young women find constructive value in their often biased and inequitable experiences in physics education draws attention to the strong degree of resilience and perseverance that many young women possess. The meanings that participants were found to attribute to their high school physics experiences emphasize three important ideas for the physics education community to consider: the experience of barriers in high school physics education cannot be mistaken for its impact on young women; young women can be said to find value and meaning for their lives through experiencing physics education; and with fewer or no barriers to young women in high school physics, there is considerably larger potential for physics education to positively influence young women’s meaning-making about their experience in physics, particularly at times closer to when they make choices about physics education and careers.
Chapter 8

Conclusion

This chapter concludes the thesis by outlining the major findings of this research and situating these findings in the context of relevant literature. This chapter also draws attention to recommendations for physics teachers, to the physics education research community, and to future work in this field. Lastly, the limitations of this study are considered.

In exploring nine women’s experiences in high school physics, there was no mistaking the presence of barriers to the young women in their high school physics education. Some of the barriers were experienced by all participants, while other barriers were experienced by only some of the participants. The shared experience of high school physics education was revealed to be both a richly challenging experience and a rewarding experience. In other words, participants experienced many barriers to their success and continuation of physics learning, but they all identified positive meaningful insights gained from their experiences. For most participants, lessons learned or lasting impressions from the high school physics experience included realizing the value of hard work, learning how to persevere through challenging academic experiences, and understanding that learning is an ongoing process.

The influence of barriers to young women in high school physics was often too great for them to continue in physics education or pursue physics career; few participants continued their elective physics education past high school, and even fewer
continued past the introductory university year. While there are myriad reasons the participants initially decided to take physics, and just as many considerations they took into account when deciding whether to continue studying physics, this research identified a number of significant barriers to the participants in their educational experiences in physics at the high school level. The entirety of the barriers discussed here summarizes the shared experience of barriers in high school physics education as discussed by participants. The major themes, or areas in which participants experienced barriers, that were identified through this research were broadly relating to: perceiving the high school physics experience, experiencing high school physics education, and identity and gender in the high school physics experience.

The barriers to young women in physics begin in early life and early education. This finding is widely accepted in physics education literature on the underrepresentation of women in physics, as it is believed that the underrepresentation is related to educational experiences spanning from kindergarten to Grade 12 (Maltese & Tai, 2011; Sadler, Sonnert, Hazari, & Tai, 2012; Tai, Lui, Maltese, & Fan, 2006). A general lack of experiences or encounters with physics phenomena, and subsequent low physics-related knowledge and learning skills, can leave young women unprepared for high school physics education. This argument supports the findings of other studies that have identified limited prior physics experience for females (Bhanot & Jovanovic, 2009; Chambers & Andre, 1996; Jones, Howe, & Rua, 2000). These findings represent one major belief in physics education literature that girls and boys are socialized differently,
both within and outside the education system (Hazari & Potvin, 2005). Specifically, it was found that throughout early education and socialization, young women generally acquire a negative perception of physics, perceive boy physics students as having an affinity for physics, and approach the subject with many misconceptions, particularly about its gendered nature as a male-dominated subject and field. Similar to findings of previous research, such perceptions posing as barriers to girls are identified as gender stereotypes (Barman, 1997; Deemer, Thoman, Chase, & Smith, 2014; Steele, James, & Barnett, 2002; Yanowitz, 2004) and the cultural bias of physics (Hazari & Potvin, 2005). As a result of such perceptions, young women can feel at odds with studying physics before they consider electing it as a course in high school or actually learn any physics concepts. For those young women who do elect physics, some factors that influence their decision can include a general interest in science, the appeal of physics (e.g., fun labs), preparation for future education, lack of alternative course options, or other influences such as parental and school encouragement to take physics. A lack of some of these factors in decision-making, such as encouragement, can be considered a hindrance to young women electing to study physics; a finding supported by other research (Alexakos & Antoine, 2003; Jones & Wheatley, 1990; Taber, 1992). Gender is another factor young women consider and gender can be a barrier to electing to study physics; young women can perceive physics as useful for their male peers’ futures but not their own, based on the gendered image of physics as a masculine subject and field. The understanding of gender as a barrier to young women in physics extends other research findings that
document the gendered images of physics learners and career options (Makarova, 2015; Yoder & Schleicher, 1996).

Within Grade 11 and Grade 12 physics education, traditional pedagogies are less favourable than progressive pedagogies to young women learning physics. Young women generally associate what the participants referred to as “bad” teachers with traditional pedagogy and “good” teachers with progressive pedagogy. The bad teachers simply fail to meet students’ needs, that is, they fail to connect students’ learning needs with their teaching practices. Bad teachers or traditional pedagogy can pose barriers to all students learning physics, and particularly to young women because of the gendered nature of many physics teacher’s pedagogies and personal characteristics. In a classroom setting, students learn what the ideal image of a physics student is; however, when teachers expressly favour male students or high-achieving students and treat male and female students differently, young women can feel excluded from what they observe to be the image of a physics student. Young women in high school physics classes have specific needs for successful physics learning that require support from teachers. The participants recommended that physics teachers consider young women’s specific needs as students that are related to conceptual understanding, critical thinking, problem solving, support for learning, and the relevance of physics. The recommendations made to teachers in this research echo and extend those made in other literature, such as those intended to increase young women’s increase interest and self-concept in physics (Häussler & Hoffmann, 2002). When young women are supported in their learning, their
perceptions of and identification with physics are more likely to be positive and sustained.

Utilizing the concept of physics identity as a lens through which the experience of barriers in physics education can be understood has proven to be productive for two major reasons. First, through the data collected in this research, the influence of barriers to young women in physics education can be said to have been substantial and impactful to the participants. It has been found that, as young women in high school physics, participants experienced barriers to their identity in physics; namely, to their feelings of interest in physics, their beliefs in themselves as a competent physics student, their beliefs in themselves as students able to perform well in physics, and their feelings of recognition as female physics students. Second, exploring the lived experience of high school physics through the lens of physics identity has been productive because it can be suggested that if all four components of young women’s physics identity (interest, competence, performance, recognition) are not supported, the lack of feeling like a physics person can become such a major barrier to young women that they have little to no chance of rooting their identity in physics. To young women, the experience of barriers in high school physics, particularly to their identification as a physics person, often results in no further election of physics education and no career in physics. This research suggests four sets of recommendations for physics teachers to support the four components of young women’s physics identity in high school physics education. These findings are supported by recent literature that asserts the need to support young women’s
physics identity, particularly young women’s feelings of recognition, and the teacher’s essential role in this (Hazari, Brewe, Goertzen, & Hodapp, 2017).

Conceptualizing this research through social cognitive career theory (SCCT) supported the research purpose of understanding young women’s experiences of barriers in high school physics. Since SCCT considers contextual barriers as inhibitors of self-efficacy and goals, SCCT offered a framework for understanding the connection between young women’s experiences and the associated meanings. Through the use of physics identity as the conceptual lens through which the influence of contextual barriers can be understood, the findings of this research are consistent with SCCT’s assertion that learning experiences in high school physics moderate the development of young women’s physics identity (Hazari, Sonnert, Sadler, & Shanahan, 2010).

In addition to understanding the barriers that young women face to their identification with physics, their reactions to pedagogy, and other aspects of their physics experience, the concept of gender and its role in the context of the experience was explored. Physics is a popular subject among young men, but is not as popular among young women, and the experiences of physics for young women and young men were found to be different: girls were found to be struggling in physics where the boys were perceivably not struggling. Cultural expectations and similar personal beliefs about being a woman create barriers to young women. For example, young women can feel that it is impossible to possess traits such as intelligence and femininity simultaneously without one trait or the other being compromised. In the case of women and physics, the cruxes of
each as they are culturally known are in conflict with one another, as evidenced by the experiences of gender-dependent barriers by the participants of this study. This research suggests that such findings serve as a reminder to the physics education community that cultural and gendered ideas perpetuate young women’s lived experiences in high school physics.

In seeking to understand the experience of barriers in high school physics for young women in Ontario, this research explored nine women’s lived experiences. The women showed deep wisdom while sharing and discussing their experiences in high school physics; the power of their stories, emotions and voices was palpable. By offering their voices to research, they have provided the physics education research community with rich insight into ways that they experienced barriers in high school physics classes. In such experiences, barriers specific to young women in physics influenced them. The barriers existing in physics education are experienced by young women through their perceptions of what physics is and who can study it, in academic and career decision-making processes, in interactions with physics teachers, and in identifying as a physics person.

**Implications for Practice, Research, and Future Work**

The findings of this study address the gender gap in physics education research by providing student voices and an understanding of the barriers experienced by young women in physics education. These insights contribute to our overall understanding of why young women reject physics or, in other words, why the pipeline that supplies the
physics field with women is most “leaky” during the period immediately after high school. The experiences, voices, and emotions of the participants can help practitioners and researchers alike understand young women’s experiences of cultural, pedagogic, academic and other barriers in high school physics. This research contributes an understanding of how barriers influence young women, specifically in terms of the meanings that young women attribute to experiencing barriers in their high school physics experience. For these reasons, there are implications for practice, research, and future work from this research.

Throughout the chapters of this thesis, lists of recommendations for physics teachers have been developed to support young women’s learning in physics. For example, there are four suggested lists that suggest practical steps that are recommended for teachers to take in nurturing and sustaining young women’s physics identity: their interest, beliefs of competence, beliefs of performance, and feelings of recognition in physics. The recommendations are intended to mitigate barriers to young women succeeding in learning and continuing with physics education and to support all physics learners. For teacher educators, it is recommended that they incorporate equitable physics education as a topic of instruction and discussion with pre-service teachers. From this research, young women’s needs for successful physics learning or examples of barrier-producing pedagogy can be used as guides for discussion. For educators other than teachers and teacher educators, such as parents, guardians, program leaders, and community members, it is recommended that they acquaint themselves with the often
hidden cultural barriers of physics to young women and act against these. For example, encourage girls’ early experiences with physics phenomena, demystify and explore physics with young people, or correct physics misconceptions both about actual physics concepts and social stereotypes.

For physics education researchers and other researchers, it is recommended that they use the findings of this study to foster positive changes for women in physics. Whether through replication of research, further exploration, collaboration with other physics education researchers, or dissemination of ideas, researchers hold a critical role in understanding educational issues and suggesting sound recommendations for improvement. Specifically, it is recommended that researchers hear the voices of students, feel the emotions of young women who are experiencing barriers in their physics education, and credit their stories of lived experience with value and influence. In the broad context of improving education through research, looking to and listening to students can provide the truest answers to our research questions, if only we listen and attempt to understand.

The scope of this research included nine individuals who were involved in discussing the shared experience of barriers in high school physics for young women. During the focus group meetings that participants attended, the discussions were rich and there was scarcely a moment of silence. The participants remarked how they looked forward to the meetings because they enjoyed discussing their experiences together and the topic of high school physics. As extensions of this research, women’s experience of
barriers might be explored at another educational level, such as the post-secondary level, or specific aspects of the experience might be explored, such as those related to teachers and pedagogy in physics education. Based on the participants’ discussions in this research, it was apparent that their male peers were a key aspect of their experience; exploring boys’ experiences, stories, and emotions about high school physics would also be valuable. Another potentially valuable avenue to explore would be the broader cultural influences on young women’s ideas of physics, on the education system, and educational culture. One suggested avenue might be to explore the experiences of young women who never elected physics, but did elect to study other science disciplines.

**Limitations**

Despite attempts to decrease the limitations of this study, there are some limitations that remain. As in any phenomenological research that adopts a degree of interpretation, researcher subjectivity is inevitable and poses risks that the researcher’s biases will be introduced. Both before and during the research process, careful consideration was given to the researcher’s position in relation to the study. The researcher’s position proved to be an important role in understanding young women’s experience of barriers in high school physics. High school physics was not an experience had by the researcher, which helped in avoiding bias rooted in personal experiences. However, the researcher having personal interest in understanding and improving the experience for young women was also helpful in attributing value to all participants’ contributions and in gathering meaning from the participants’ experiences. Member
checking was completed at three stages during the research process to ensure that data processing and analysis were as accurate as possible. Participants were sent documents to make changes and approve, first following transcription, again after participant stories were written, and finally after the themes were written on. All participant requests for changes and clarifications were accommodated.

The sample size of this study—nine participants in total—does not lead to findings that are generalizable to a larger population. In other words, all young women’s experiences of high school physics in Ontario, or in Canada, cannot be said to include similar barriers. The women who participated in this study went to high school in regions mostly located in southern and central Ontario, but also in eastern and western Ontario and in the near north. One participant attended high school in New Brunswick and the data she contributed were not seen as different from the data provided by other participants and thus were not excluded from the analysis. Although not generalizable, the findings of this study offer a good understanding of the barriers that young women in Ontario experience in high school physics.

The participants who were recruited for this study may pose a limitation in terms of the demographic they represent. First, the participants were all attending post-secondary education, which may indicate an advantageous socioeconomic background or personal characteristics, such as heightened academic interest and ambition. When discussing participants’ experiences in education, these factors may be considered inevitable limitations. Future studies may look to explore a variety of high school
students’ experiences at the same time that they are living the experience in order to better combat these potentially limiting factors. Second, this study only explored the experiences of barriers in high school physics for young women, and therefore made suggestions to mitigate barriers to young women’s success and continuation in physics education. The lack of understanding of boys’ experiences could be considered a limitation to this study, as it is true that young men should also be supported in physics education. However, this does not negate the issue of few young women continuing in physics education beyond high school or this study’s recommendations to support these individuals. Given that this research ultimately aims to present an image of equitable education, the recommendations made here can be considered beneficial for all students learning physics.

The methods of this qualitative phenomenological study were designed to gain an understanding of the experience of barriers in high school physics for young women. Focus groups as a data collection method allowed participants to construct an understanding of the shared experience based on their own memories of stories and emotions. It could be considered a limitation to the depth of understanding of the lived experience, given that there were nine participants. Another potential limitation of focus groups is the risk of memories being exaggerated or suppressed in a group setting. Despite these potential limitations, the participants were regularly encouraged to suggest different perspectives and new ideas about experiences during focus group meetings. The differing perspectives introduced during focus groups created a rich discussion that
revealed many detailed aspects of the lived experience. Being in a group setting, the participants were also able to ask each other questions for clarification or better understanding, which in turn served to validate the understanding of the shared experiences. The participants were also offered a follow-up interview after the focus group meetings; this provided an opportunity for participants to voice their individual experiences and share anything they did not have the opportunity to contribute in the focus group meetings. The interviews also served to combat the final, obvious limitation to the study, which was its short duration. Interviews allowed more time for participants to explore and discuss their experiences in a one-on-one environment.
References


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Appendix A GREB Clearance Letter

October 05, 2016

Ms. Lindsay Mainhood, Master’s Student, Faculty of Education, Queen's University, Duncan McArthur Hall, 511 Union Street, Kingston, ON, K7M 5R7

GREB Ref #: GEDUC-826-16; TRAQ # 6019192
Title: "GEDUC-826-16 Physics Education: Understanding the Barriers for Young Women in Ontario"

Dear Ms. Mainhood:

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled "GEDUC-826-16 Physics Education: Understanding the Barriers for Young Women in Ontario" for ethical compliance with the Tri-Council Guidelines (TCPS 2 (2014)) and Queen's ethics policies. In accordance with the Tri-Council Guidelines (Article 6.14) and Standard Operating Procedures (405.001), your project has been cleared for one year. You are reminded of your obligation to submit an annual renewal form prior to the annual renewal due date (access this form at http://www.queensu.ca/traq/signon.html; click on "Events"; under "Create New Event" click on "General Research Ethics Board Annual Renewal/Closure Form for Cleared Studies"). Please note that when your research project is completed, you need to submit an Annual Renewal/Closure Form in Romeo/traq indicating that the project is 'completed' so that the file can be closed. This should be submitted at the time of completion; there is no need to wait until the annual renewal due date.

You are reminded of your obligation to advise the GREB of any adverse event(s) that occur during this one year period (access this form at http://www.queensu.ca/traq/signon.html; click on "Events"; under "Create New Event" click on "General Research Ethics Board Adverse Event Form"). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example, you must report changes to the level of risk, applicant characteristics, and implementation of new procedures. To submit an amendment form, access the application by at http://www.queensu.ca/traq/signon.html; click on "Events"; under "Create New Event" click on "General Research Ethics Board Request for the Amendment of Approved Studies". Once submitted, these changes will automatically be sent to the Ethics Coordinator, Ms. Gail Irving, at the Office of Research Services for further review and clearance by the GREB or GREB Chair.
On behalf of the General Research Ethics Board, I wish you continued success in your research.

Sincerely,

John Freeman, Ph.D. Chair General Research Ethics Board

c: Dr. Tom Russell, Supervisor Dr. Richard Reeve, Chair, Unit REB Ms. Erin Wicklam, Dept. Admin.
Appendix B Letter of Information and Consent Form

Letter of Information

PHYSICS EDUCATION: UNDERSTANDING THE BARRIERS FOR YOUNG WOMEN IN ONTARIO

This research is being conducted by Lindsay Mainhood under the supervision of Dr. Tom Russell, in the Faculty of Education at Queen’s University in Kingston, Ontario. This study has been granted clearance by the General Research Ethics Board according to Canadian research ethics principles (http://www.ethics.gc.ca/default.aspx) and Queen’s University policies (http://www.queensu.ca/urs/research-ethics).

What is this study about? The purpose of this research is to explore the experiences of Ontario female high school students in order to gain an understanding of the barriers they have encountered in their physics education and the meanings they associate with their experiences. This research topic is of importance because (ongoing) female underrepresentation in physics is not fully understood, and is believed to relate to female’s educational experiences.

What is involved to participate in this study? The study will require 4 focus group meetings, each up to 2 hours in length. The study also includes 1 follow-up interview of about 1 hour in length. The meetings will occur at Queen’s University in Duncan McArthur Hall. In total, participating in this study will require 5 hours minimum, up to a maximum of 9 hours depending on the duration of focus groups. Participation will occur over 1 to 2 months. The focus of the focus group meetings and interviews will be on your experiences in high school physics education. You will be provided with questions to be asked in the focus groups or interviews prior to the meeting time. Your contribution will be recorded via audio recording device. There are no known physical, economic, or social risks associated with this study. Psychological risks are minimal in this study; these may include evocation of certain emotions based on personal experiences. The benefits to this study for participants are a sense of contribution to positive change through research, an opportunity for their voices to be valued in an academic and research context, and a sense of community gained through focus group meetings. The benefit to this study for the research community is filling a gap in literature: understanding the experiences of females in physics education from those individuals' perspectives. The benefit to this study for society at large exists because the knowledge gained through this study will help improve physics education to more equitably support young women in their high school physics education and beyond.

Is participation voluntary? Yes. You should not feel obliged to answer any questions that you find objectionable or that make you feel uncomfortable. You may choose to withdraw from the study at any time during the study with no effect on your standing in school. If you wish to withdraw, contact Lindsay Mainhood at lindsay.mainhood@queensu.ca. If you withdraw, you may request removal of all or part of your data from the study and this request will be granted up to the time of any publication of results of the study.
What will happen to your responses? Your responses will be kept confidential. Only Lindsay Mainhood and Dr. Tom Russell will have access to this information. Your anonymity will be maintained to the extent possible. The focus group and interview recordings will be transcribed; however, none of the data will contain your name or the identity of your place of study. To protect your identity a pseudonym will replace your name on all data files and in any dissemination of findings. Results from this study may be published in professional journals or presented at scientific conferences, but any such presentations will maintain individual confidentiality. In accordance with the General Research Ethics Board Standard Operating Procedures, data will be securely/password protected for a minimum of five years or beyond. If data are used for secondary analysis they will contain no identifying information. You are entitled to a copy of the findings, if you are interested. If you would like a copy of the findings, please contact: Lindsay Mainhood at lindsay.mainhood@queensu.ca

Will you be compensated for your participation? No. You will not receive compensation for participation.

What if you have concerns? Any questions about study participation may be directed to Lindsay Mainhood at lindsay.mainhood@queensu.ca or Dr. Tom Russell at tom.russell@queensu.ca or 613-533-3024. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at chair.GREB@queensu.ca or 613-533-6081.

Thank you for your interest in participating in this research study.

Consent Form

PHYSICS EDUCATION: UNDERSTANDING THE BARRIERS FOR YOUNG WOMEN IN ONTARIO

Name (please print clearly): _______________________________________

1. I have read the Letter of Information and have had any questions answered to my satisfaction.

2. I understand that I will be participating in the study called Physics Education: Understanding the Barriers for Young Women in Ontario. I understand that this means that I will be asked to participate in focus group meetings and interviews where my voice will be audio recorded for data collection purposes.

3. I understand that my participation in this study is voluntary and I may withdraw at any time. I understand that every effort will be made to maintain the confidentiality of the data now and in the future. Only researchers affiliated with this study will have access to my data. The data may also be published in professional journals or presented at scientific conferences, but any such presentations will be of general findings and will never breach individual confidentiality. I understand that I am entitled to a copy of the findings, if I am interested.
4. I am aware that if I have any questions, concerns, or complaints, I may contact Lindsay Mainhood at lindsay.mainhood@queensu.ca or Dr. Tom Russell at tom.russell@queensu.ca or 613-533-3024. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at chair.GREB@queensu.ca or 613-533-6081.

I have read the above statements and freely consent to participate in this research.

Please sign one copy of this Consent Form and return to Lindsay Mainhood. Retain the second copy for your records.

Signature: _____________________________________
Date: ______________________________

Optional Consent: Please sign any or all of the 3 options in Section A below, according to your preferences.

Section A

I agree to allow Lindsay Mainhood to use the audio of our session for one or more of the following purposes:

1) Publication in a Journal  Signature: ______________________________

2) Demonstration to Students  Signature: ______________________________

3) Demonstration at a Conference  Signature: ______________________________

Date: ______________________________

I understand that my name will not be associated with any publication or demonstration.

Please provide your email address below if you wish to receive a copy of the results of this study:

Email: _____________________________________
Appendix C Confidentiality Agreement

Physics Education: Understanding the Barriers for Young Women in Ontario

Lindsay Mainhood, Faculty of Education
Queen’s University at Kingston
Kingston, Ontario K7L 3N6
September 7th, 2016

I have read and retained the Letter of Information concerning the above referenced research project being conducted by Lindsay Mainhood, Queen’s University. In my role as a participant for the researcher, I understand the nature of the study and requirements for confidentiality. I have had all of my questions concerning the nature of the study and my role as a participant answered to my satisfaction.

A. Maintaining Confidentiality

I agree not to reveal in any way to any person other than the researcher any information (i.e., name, email address, or phone number) collected from participants.

B. Identification and Signature Indicating Agreement

Name: ______________________________________________

Email: ______________________________________________

Telephone: __________________________________________

Mailing Address: _____________________________________________________

Signature: _________________________________________________________

Should you require further information please feel free to contact Lindsay Mainhood, at the Faculty of Education, Queen’s University, Kingston, Ontario K7L 3N6, or by email lindsay.mainhood@queensu.ca, or by phone 519 803 8663.

For questions, concerns or complaints about the research ethics of this study, contact either the Principal Investigator, or the Chair of the General Research Ethics Board, telephone 1-844-535-2988, email: chair.GREB@queensu.ca.
Appendix D Participant Recruitment Script

Email Recruitment Script

*LOI will be attached in email with the following message

Subject: Research participation: Females and physics

Are you a female who took physics in high school and would be willing to discuss your experience with a few others?

A researcher at Queen’s Faculty of Education is conducting a research study on the topic of female underrepresentation in physics, and is looking for study participants. If you took a physics course in high school in Ontario and would be willing to discuss your experiences, please consider contributing to research on women in physics. You would participate in 4 small focus group meetings with students like yourself, and you would also have the option to participate in one follow-up interview. In total, participating in this study would require a minimum of 5 hours and up to a maximum of 9 hours of your time (depending on the length of focus group meetings) over the period of 1 to 2 months.

If you are interested in being a participant in this study, or have any questions about the study, please contact the principal investigator, Lindsay Mainhood, by email at lindsay.mainhood@queensu.ca. You can also find additional information about the study attached to this email.

Thank you for your time. Your possible interest in participating in this study is greatly appreciated.

Sincerely,

Lindsay Mainhood

lindsay.mainhood@queensu.ca
Appendix E Focus Group and Interview Protocols

Focus Group Protocol

Participant names:

Date: ________________________________
Time: ________________________________
Location: ________________________________
Additional contact information: ________________________________

Introductory Elements (5 minutes)
• Explain what is being studied and why.
• Explain the format and rules of the focus group and the approximate duration.
• Provide a statement that will alleviate any concerns of confidentiality. This statement would include both confidentiality within the university and in published results.
• Introduce myself and provide a brief biography.
• Ask the participants if they have any questions prior to beginning the focus group session. Remind participants that they should not feel obligated to answer any questions that make them feel uncomfortable.

Planned Questions (60 or more minutes)

1. When everyone is comfortable, please introduce yourselves briefly and include a sentence or two about where you are now in your education journey.

2. What do you think your perceptions of physics, as a field of science, were when you were in high school before you enrolled in physics?

3. Why did you decide to take physics? What are the factors that you feel influenced you to take physics in high school?

4. What is the nature of some of your memories from high school physics (i.e., do you remember it fondly or not?)? Based on your memories, how do you remember feeling most of the time while in your physics class?

5. Describe a time in high school physics when you felt like you wanted to study physics more (i.e., wanted to continue).

6. Describe a time in high school physics when you felt like you wanted to study physics less (i.e., wanted to discontinue).

7. Give an example of how your perceptions of physics changed since taking physics in high school.
8. In what ways, if at all, do you think your experiences in high school physics influenced your decision-making process about future education or career options?

9. In what ways, if at all, do you think your high school physics education met your needs as a student in terms of your learning needs, or other needs?

10. Can you think of any features of your high school physics course(s) that could be seen as barriers to further study of physics by female students?

11. What specific experiences do you still remember today from high school physics?

Concluding Elements (5 minutes)
- Thank the participants for their time and efforts.
- Answer any questions participants may have.
- Reassure confidentiality and secure processing and storage of data.
- Request permission to follow-up either in-person, by email, or through a phone call regarding data that may seem unclear during transcription or analysis.
- Remind participants of the next scheduled focus group meeting or begin interview scheduling if timing is appropriate.

Interview Protocol

Participant name: _____________________________
Date: ________________________________
Time: ________________________________
Location: ______________________________
Additional contact information: ______________________________

Introductory Elements (5 minutes)
- Explain the format and operation of the interview and the approximate duration.
- Provide a statement that will alleviate any concerns of confidentiality. This statement would include both confidentiality within the university and in published results.
- Ask the participant if they have any questions prior to beginning the interview session. Remind participant that they should not feel obligated to answer any questions that make them feel uncomfortable.

Planned Questions (50 minutes)

*Unplanned questions are expected to be asked and depend on the participant’s responses.

1. What further comments do you have about the question: “In what ways, if at all, do you think your experiences in high school physics influenced your decision-making process about future education or career options?”
2. What were the most interesting issues that were discussed in the focus group? Do you have any further comments about those issues?

3. Were there issues of importance to you that were not discussed in the focus group that we can explore now?

Concluding Elements (5 minutes)
- Thank the participant for their time and efforts.
- Answer any questions the participant may have.
- Reassure confidentiality and secure processing and storage of data.
- Request permission to follow-up either in-person, by email, or through a phone call regarding data that may seem unclear during transcription or analysis.
Appendix F Sample Transcript

Focus Group Meeting #3 Transcript, Pages 1–5

FG 3, Saturday, November 26\textsuperscript{th}, 2016, 2:30 - 4:30

Int. [Introduction and administrative items]. What was your day day-to-day physics class like?

J For me I had a lot of…sometimes it was lectures and the teacher would explain concepts on the board. We had a lot of open work periods to work on your problems and discuss with each other. I remember it was a mixture of both and I feel like it was a lot of working together working through problems.

R I feel like when we were working through problems we would have had lecture style classes often. She would work on the board and do an example problem or put up an overhead and show us an example problem or something like that. I think most of the times when we were actually working together was pretty much when we were doing labs. When we would do a lab we would usually do it in a group or a pair and that’s when we would work together. I don’t remember doing too much work together time apart from the labs, but maybe that’s something I’m just not remembering.

P My high school had a mandatory lab fee that you had to give if you were doing any of the science classes. We had a pretty experimentally-based physics class, so we did a lot of different things in the class; we had ripple tanks, so we looked at waves through those. We usually would start a unit and we would do homework take-up at the beginning of the class and then we would have open discussions about whatever the topics were. We would do problems on the board and he would walk us through how to do them. We had time where we would work in groups but it was a lot of groups as a whole class doing problems together. It was always teaching through example, never just conceptual. It was always example-based.

L I remember at the start of every unit, my teacher would show these weird videos and I remember thinking they were really weirdly funny and he would introduce the units with them. The everyday class was usually using a whiteboard and SmartBoard and discussing the concept. It wasn’t only problem-based, we would either get handouts that we had to fill in and copy down parts that he would write down on the board or he would tell us about different concepts and there would be different examples. I don’t remember so much time working on problems alone in class or in a group but more so working through them as a class and writing them down as examples on these handouts that we had. Taking notes on lined paper and stuff like that. We had the occasional lab; I don’t remember anything too interesting. We went into the hall, and this is pretty much the only lab that I remember, it was about waves and we were moving it back and forth or whatever, I don’t remember what they’re called, translational waves. Oh, and taking up homework problems.

M I remember we did the exact same lab and I think ours was a slinky and you would try to change the [inaudible] and see how very…we did it in the hallway and everyone was walking by thinking physics is so cool it was almost advertising as much as it was learning, take this class.
I remember having a lot of labs in the hallway.

We did a lot of labs using some software on the computer, I think it was just a detector over time I think you could see the graphs. I’m not exactly sure what we were measuring. We did labs and those were nice because they were lab stations at the back of the class with the chairs in the middle where everyone was sitting down. A lot of lectures. A lot of problem sets. And then we did a lot of problem sets we do the problems that every unit and I just remember it being so time-consuming. It was a lot more work than other courses.

We had a lot of textbook problems instead of problem sets, and she would assign them from the textbook. I’m just remembering now that that’s how we could do ours. When you mentioned about having videos I just remembered that she was sometimes show us animated videos. To introduce or show a concept, like what is work or what’s power or something like that, just little animated videos. You also mentioned the layout of your classroom, we also had desks near the front of the classroom and at the back we would have lab benches where we would do most of our labs. I remember when we would do a unit test we had to spread out throughout the room so some people were at the benches in the back and I would always get so keyed up to do the test so I would always like to stand at the lab bench to write the test rather than sit because I just felt like I was too jittery and nervous. I remember my teacher being like sit down, sit down, but I would say miss I can’t, I have to stand here. It definitely helped me to stand for some reason I feel like I could shift my weight and it just helped me focus rather than being sitting down, I lost my focus that way.

It’s funny that you mention textbooks because we didn’t have any at all in high school. Our teacher had then and if we wanted to look at them we could but nothing that we did was ever based out of a textbook at all.

I feel like we had textbook practice problems. I feel like every day we would have assigned problems and I don’t think we would ever take them up but I remember a lot of that. I don’t really remember any labs at all. I remember my teacher drawing stuff on the board and working through problems together as a whole class, not as little groups. I’m pretty sure he, I remember videos as well, we had a SmartBoard and he just left showing videos to explain everything. When I think about high school physics all I think about is textbook practice problems.

We had a lot of textbook practice problems as well and I remember, I can almost see it, writing down homework page this and this. One other thing that I thought, we didn’t do it very often, but sometimes we would get into groups and I don’t remember exactly what the question or problem was that we were working on, but our teacher would give four roles, and I don’t remember what they were but I remember that my role was the skeptic. Each person had a different purpose or main role in the group when you were working on some sort of problem. I was the skeptic so I was supposed to be like wait, do you think, or are we really going about this the right way or maybe we should think about this for this too. I don’t remember why I remember that.

It’s really cool though. Having a skeptic I think it’s a really good perspective.

And I was good at that role! I can’t tell you where to go and I don’t know what to do right but I can tell you what you’re doing wrong.

That’s good too though having that experience validates what you do know, better than focusing on something that you’re struggling with.
Lo. For me, I remember doing a lot of labs. But kind of different labs like that one I was talking about the other day on momentum. I remember we did this lab that I really, really enjoyed in Grade 11. We put a ball on the ramp and through some investigation we found what the velocity was coming off of the bottom, but then knowing that we had to go to the top of the stairs in our school and guess—we had to try to get the ball into a tin can. That was our project and I remember doing that and it was a week long exploration thing and I loved it because it introduced so many parts, and I’m going to sound like a physics teacher, but it introduces air and air is a big part of physics. You know, you’re calculating stuff and I thought it was so exciting and so different from normally just sitting in the classroom and not really doing much. That’s definitely something that I really enjoyed. In Grade 12 we did do that month-long lab and I was kind of sick of it at the end but it was definitely helpful getting that much time to work on it. I remember one time we were looking at an interference pattern with light and I remember the light shifting and I asked why is the light shifting. I was so confused about why the light was moving. My physics teacher said well there’s the road there are cars on the road and the cars could be shaking the building, or us moving, or anything can change the way it is shifting. That even introduces air into the problem as well and I just liked that there was an answer to everything that we did in physics, but that’s not always the case. Definitely in that class, the teacher giving suggestions as to why physics is not perfect. I do remember doing a lot of notes as well but I feel like we were kind of more geared towards the investigation side of physics.

S My experience kind of echoes what [Amy] said. I think it started off with going over homework questions from the textbook of course. I think just listening to everyone’s experiences, I feel like I have identified one difference from physics 11 and 12 even though it was the same teacher. We had a lot of videos in physics 11, and I forget what it’s called now, the phenomenon, there was this bridge that was flapping around. It was kind of like oscillating. This was real, and it was a bridge, and I thought it was so cool. He kind of lured us in with the videos and then we did problems on the topic with a paper and pencil. But I don’t remember that in physics 12, he didn’t show any videos anymore and it wasn’t very interesting.

R Maybe it didn’t have to be a video but maybe just that hook component that would make you find something interesting.

S I think that’s a big difference. Labs. I don’t remember doing very many labs. I did physics in New Brunswick so maybe that’s the difference because I know a lot of you did the same labs, but if we did, I obviously wasn’t very interested. There was no designated lab time in physics.

P Thinking about it now there were a lot of videos in Grade 11 and 12 and the idea of that hook to get us into it... My physics teacher probably should have [inaudible] as a motivational speaker because probably once a month he would try to bring everything into context and tell us how you could apply this to everyday life. I distinctly remember him talking about velocity and driving and how fast you are moving in a car in terms of how many lengths of the classroom you would be moving every second. Say 60 m/s then you’re doing this many classroom lengths per second and he would equate it to how many kilometers and he was trying to make a point of driving safely. He always try to put it into real world context for us, as well as saying you can do it and I know it’s hard and you’re struggling now but you can do it it’s going to be fine, it’s going to be great.
It’s interesting what you just said about driving safely, which makes me think of one time the teacher explained why there are speed limits and I thought that’s fascinating. I’ve always wondered how they determine speed limits and it has to do with friction and the curve angle and he said no matter how icy the off-ramp is and if you’re traveling at this distance you’re not going to make it. I thought that is fascinating, now I know that speed limits are legitimate.

That concept is kind of funny, it’s going backwards a little bit if that’s okay. I very much remember being a little kid in the car and asking my dad when we are getting home and he would always tell me half an hour even if we were a few minutes away or an hour away and I was like dad you need to tell me when we are getting home. I learned that the interchange numbers on the highway correspond to a kilometer marker and then I snuck my head over and read my dad’s speedometer and calculated the time. It took me so long, I was 10 or 11. I was sitting there and I was trying to do it because he wouldn’t give me the answer or the easy way out kind of thing. Still to this day I know my exit is 392. I think that’s important, not giving someone the easy way out, making them work for it kind of thing. Because then you’re more interested in it. I didn’t think of it when I was little, it was like okay fine, I’ll figure it out on my own kind of thing. And then I knew exactly what time we would get home so I would win. Going back to videos, we did a lot of investigative videos in high school and I still watch them: minute physics and Veritasium. Minute physics was cool because it was all animated and there was just a voice over in the background and it would teach you about concepts but it would use it to answer questions. I remember one, if it was raining outside should you run should you walk? It was looking at how the water was coming down and if you ran...

I remember I read a book about that when I was a kid and that was one of the questions in it.

It’s cool because it teaches you about the answers to those little questions that your parents don’t tell you what the answer is, or in my case they don’t tell you, but it’s cool because then you understand the physics concepts behind them and then you can actually answer them yourself. I think those videos sparked my interest a lot.

What you were saying, [Louise], about the investigation kind of thing, we had this one project where you had to build this car. It had to be made with Popsicle sticks and CDs. You were in the group of three or four and I remember being in a group with two other girls in my class. I think it was a little bit less intimidating working with two of the other girls in my class. I feel like I would have felt more intimidated if I was working in a group with some of the boys. I had this impression of some of them being kind of, already coming in knowing these things. Like I said earlier, a number of them were part of the physics club so they did know more and this was something that really interested them so I really enjoyed that time working with my two female friends from class. I do remember it being very stressful though because I think we only had three tries, we set a ramp-up in the hallway and everyone would get a chance to roll the car down the ramp and I think it was the best of your three tries and it was really stressful because you needed to make the car not just good for one round, it needs to be consistent and you want to be confident that when you put it on the ramp for the test it would go pretty far. I don’t remember how far ours went or how far anyone else’s went but I did enjoy the actual building of the car. It was still a little bit tricky for me to wrap my head around how we actually fix the car, or change the car to make it do what we want.
Thinking back to a lot of the physics experiments that we did other than triple tanks, we built a motor and we also did the egg drop on top of the roof of the high school. I remember nobody really thought about the physics concepts we were making sure our egg didn’t break. It was kind of like what can we do and a lot of people just padded it as much as possible rather than thinking of how to reduce drag or something like that. It was interesting how sometimes it would be for the physics class but people wouldn’t necessarily think about physics in terms of the technicalities of physics to actually answer the problems. I remember being extremely stressed out about the motor because it was like if you didn’t get that thing to work, if you didn’t get the perfect angle for…

Because then it was obvious that yours didn’t work in front of everyone because always we tested it in front of the whole class.

We had a really cool project that I will always remember, it was a potato cannon. It was to reinforce the concept of projectile motion and I always thought projectile motion was so interesting and back in the history of it. We were given potatoes and we had to go, we weren’t given any materials, so we went to Home Depot and we bought PVC pipe and you bought everything that you needed to make it. We were all in Grade 11 going to Home Depot, we just got our G2 licenses, and it was a really exciting open-ended problem. But then in the end it wasn’t, your mark wasn’t based on how close you got to the target or anything it was just sort of like a fun project. It turned into a day of us going to the park and shooting potatoes into the… It’s kind of funny when you look back on it. It’s good because it was the investigative and looking at the air because you would shoot once and it would go here and you’d shoot there and he would come around ask us to think about okay why did that happen, can you answer the question why did that happen? That’s where your marks came from, not the accuracy, which was nice I think.

That’s cool because I’m thinking of that car thing that we had to make, the mousetrap car. We had to make it go as close to 10m as possible and I was not appreciating any of what it was about I was just stressing so much about satisfying this requirement to make it go closest to 10m as it could. I feel like that’s a better way to do it because it doesn’t really matter as much, maybe… If you have to make materials to build it or whatever.

It’s more appreciating your understanding of what you learned. There was one, I don’t remember anything about what the lab was about. How fast sound travels was our concept. We would have a unit and then a problem set and then a lab to reinforce what we learned in the unit. You can see certain things sticking in your head more, like what we did with sound I couldn’t even tell you.

Actually now that I’m thinking about it we had one lab on sound, we had to find the resonant frequency. We had some kind of column where you could change the length and at some length it would be louder something. I guess we did do a couple of labs they just don’t really stick out because I wouldn’t have been very… they just would be little small things like that they wouldn’t even take up the whole lecture I don’t think.

I think what’s really interesting is if I think back to elementary school, that’s when I did things like the egg drop from the top of the school, or the paper airplane thing where you changed different things about the plane. I literally did not think about those things as physics until right now. In elementary school you do all these creative types of projects and it’s a lot more common and then in high school, science happens, and someone said, or at least I did not even have a designated lab session and we would now. It’s awesome, some people seem to have teachers that emphasize the lab or the application component.
more but I guess because there isn’t that structured time built-in and it’s not as creative anymore, it’s kind of up to the teacher’s discretion if that’s something they want to emphasize or not. The creativity component. And the application component and the investigation component. Then you get to first year and you have a lot of labs again in a designated time, which was interesting, but the problem with how that was set up is that it doesn’t even necessarily correspond that well to what you’re learning in lectures. It’s a different TA, it’s someone different, and it’s not aligned, and you’re like what does this have to do with anything? I definitely think that the application piece is, if it’s done right to emphasize the right parts of it, could be used as something that could stimulate a lot of interest in high school.

R I find it interesting that you brought up the creativity component. It reminded me how we did our labs. Everyone got a duotang and you had to keep your labs in there and you had to write your table of contents and it all had to be very specific about how you did it and so it didn’t seem very creative. I don’t remember it being very creative at all. Yes, there were some trial and error and you got to do some different things, like we did a pendulum lab and we did the slinky lab and you measured or calculated something. I think we also did one for optics; we had a candle and you could hold it a certain distance away and you could see where the shadow was and how big it was and that kind of stuff. I remember different labs but I remember it was very to the point and facts based and I don’t remember there being any kind of creative component to that other than that you got to experience the lab, hands-on. I do remember some of them where they made it more visual but it wasn’t necessarily creative.