EXPLORING ONTARIO GRADE TEN STUDENTS’ DECISIONS TO SELECT OR REJECT SCHOOL PHYSICS

by

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A thesis submitted in conformity with the requirements for the degree of Master of Arts Graduate Department of Curriculum, Teaching, and Learning Ontario Institute for Studies in Education University of Toronto

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Abstract

Declining science enrolment, with the greatest decline in physics, is well documented and has generated concern surrounding students’ future abilities to function in an increasingly scientific and technology-focused society. In an attempt to understand why students select or reject physics, a multiphase qualitative phenomenological study was designed, with the following questions: (a) Why do students select or reject physics courses? (b) What role does physics identity play in student course selection? (c) What other factors, extrinsic or intrinsic, affect their choices to pursue physics? Questionnaire, interview, focus group and student drawing data indicate that students select senior level physics when it is required for further studies in university, but they reject physics when it is not required based on their belief that physics is a difficult math-reliant subject, they do not identify with physics, and they are unsure about what physics is and what they would learn in a physics course. Recommendations include teaching physics in a context that aligns with students’ interests, and teaching physics to promote a positive physics student identity.
Dedications

This thesis is dedicated to my parents, Arthur and Yvonne. Your insight and patience over hours of conversations regarding my research and its progress is more appreciated than I can put into words. You have provided a safe, quiet place to think, work and write while supplying me with an endless supply of tea and cookies. Thank you.

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To my children, Eryn, Gwynith, and Riley, who have been patiently waiting to spend some more time with their mom; I love you and I am looking forward to playing with you more.
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To Clare Brett, thank you for the exceptional support during the data collection, analysis, and final phase of this study. Your support, guidance, questions and comments have inspired me to think more about this project and where it can lead after its completion.

To Patrick Finnessy, thank you for shaping my understanding of ethics and qualitative studies. You have made me aware of the utmost importance of the ethical considerations of research. To Eunice Jang, thank you for your insights on my initial conception of this study. You have helped me to understand how to layer a study to provide a richer understanding of the data.

Finally, to my friends, the teachers and the students who supported and participated in this study; thank you for your interest in my research and your thoughtful contributions to this work. It is for you that this study has been conducted as I have worked to understand how to support you through physics education.
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1. Introduction

1.1 Purpose of the study

In 2003-2004, the Ontario Ministry of Education reported that close to one third of students were dropping out of school before completing their high school diploma (Ontario Ministry of Education, 2011a). This sparked great concern as the Canadian Council in Learning reported costs associated with dropping out of high school including: income loss, increased social assistance costs, increased health care costs due to decreased health, and an observed high percentage of prison inmates that had dropped out of school (Ontario Ministry of Education, 2011a). In an effort to improve graduation rates, the Ministry worked towards creating additional opportunities for students to complete the course requirements for graduation with an Ontario Secondary School Diploma (OSSD). The requirements to graduate from secondary school include, in addition to completing optional and core compulsory courses, the completion of one additional credit in each of Group 1, Group 2, and Group 3 where each group emphasizes different learning skills (Ontario Ministry of Education, 2011b). Group 1 focuses on communication skills (senior social science), Group 2 focuses on performance and application (arts, physical education or business), and Group 3 focuses on problem solving and inquiry (technology or senior sciences). It is the change in Group 3 that initially sparked this study.

Group 3 originally included only science and technology education. Although science and technology are often considered to be the same, they differ in that science seeks to understand the “basic and fundamental nature of reality,” whereas technology seeks to solve problems of a particular need (McComas, 2004, p. 26). Both, however, focus on problem solving and often overlap in practice. Since 2003, the Ontario Ministry of Education has altered Group 3 to include cooperative education, and more recently (2010) French as a second language (Ontario Ministry of Education, 2011b). These additions provide opportunities for students to opt out of further studies in science and technology at the senior level.
Declining science enrolment, with the greatest decline in physics, is well documented and has generated concern surrounding students’ future abilities to function in an increasingly scientific and technology-focused society (Kessels, Rau & Hannover, 2006; Owen, Dickson, Stanisstreet, & Boyes, 2008; Sjøberg & Schreiner, 2010; Smithers & Robinson, 1996). One of the goals of science education is the development of scientific literacy, both in skills and attitudes (Pedretti & Little, 2008; Wellington, 2001). Those that are scientifically illiterate are often disempowered as compared to their literate counterparts. Scientifically literate citizens are considered to be able to make sound decisions regarding science and technology in their lives (Hodson, 1994, 1998), as well as contribute to their country’s competitiveness in the global market (Busch, 2005; Jenkins, 1999; Qualter, 1993; Wellington, 2001). Physics education makes a special contribution to scientific literacy as it shapes problem-solving skills in ways that other sciences do not (Krusberg, 2007). To better understand the factors that are influencing students as they make decisions surrounding physics education this study asked: why do students select or reject physics, how does physics identity shapes those decisions, and what other motivations influence students’ decisions.

Krusberg (2007) describes three ways that physics education contributes to problem solving skills: the expansion of students’ knowledge bases; the development of strategies for problem analysis and qualitative reasoning prior to mathematical applications; the employment of meta-cognitive activities (such as planning solutions and evaluating outcomes). The expansion of students’ science knowledge base through formal education can help to demystify science and deepen their understanding of other sciences. The mystification some students feel about science is partially attributed to the generation of intuitive explanations of their interactions with the physical world, or what diSessa calls phenomenological primitives (p-prims) (Sherin, 2006). While some of these p-prims may be correct, others contain misconceptions (Krusberg, 2007; Norvilitis, Reid & Norvilitis, 2002). When erroneous p-prims are not addressed through a formal physics education these misconceptions may lead to the
perception that science is both mysterious and challenging, as students cannot explain experiences inconsistent with their p-prims (Sherin, 2006).

Physics education is deeply intertwined with the other sciences, so much so, that it can enhance and deepen students’ understandings of topics in biology and chemistry (Bybee & Gardner, 2006). This belief is the premise upon which the “Physics First” Movement in the United States (a movement that places a physics curriculum at the beginning of secondary school education with “Capstone Biology”) is based (Bybee & Gardner, 2006). Consider for example, in biology we are taught \textit{sharks are well adapted to their environment}. If limited to a descriptive understanding we might say that sharks are big, fast and can find prey over far distances and this makes them well adapted to being predators. If we add an understanding of physics we realize that the shape and texture of their bodies decrease hydrodynamic drag, and that sharks are able to detect the electric fields of their prey using an electroreceptor. The biological understanding combined with physics understandings may now inform design technology for watercraft or swimsuits, or influence our own vacation plans (as sharks may attack motors on boats as they misinterpret the electric fields as potential food). Physics has lead to advances in many other fields (such as molecular biology) through its development of techniques and tools (Brooks, 1968). Physics informs all scientific disciplines and therefore a rudimentary understanding of physics is important. While physics education can expand students’ knowledge necessary for understanding the context of a problem, the strategies and qualitative reasoning that is emphasized in physics education also adds to students’ problem-solving ability and scientific literacy.

Skilled physics problem solvers are taught to solve problems by spending time identifying assumptions, extracting information, applying background knowledge, and monitoring their problem solving process through checking, setting and updating goals related to the solution (Anderson, 2005; Taraban, Craig & Anderson, 2011). While this process is clearly linked to classroom studies in physics, problem-solving skills are necessary to navigate in both our personal and professional lives. Anderson, Goddard and Powell (2009; 2011) found students who are better able to orient a problem are less
anxious and depressed; Jablokow, Jablokow and Seasock (2010) found in business that effective problem solvers on a team can lead to a more efficient use of resources, a necessity as the problem definition stage (exploring a changing context, understanding relationships and variables) can consume up to two-thirds of the project’s budget before even determining if a project is workable. Problem solving is not relegated to physics, but is instead a skill that is transferable to arenas outside of science.

I believe it is important to have scientifically literate citizens, both in science and non-science related careers. When we consider the contribution physics education can make to scientific literacy, those who have additional exposure to physics may be better equipped to make meaningful decisions about science and technology. This could include being critical about solutions presented by the media, or making personal decisions of action with respect to science and technology. It is the connection between scientific literacy and physics education that has informed the questions of this study. I suggest that the decline in school physics enrolment may have a lasting impact beyond the science classroom, hence my interest in pursuing questions pertaining to grade 10 students and their decisions about selecting or rejecting school physics.

1.2 Statement of the research problem

The overarching research question of this thesis is: what factors influence a student’s decision to study physics in grade eleven? An underlying assumption in this study is that Ontario grade ten students’ views and perceptions of physics influence their senior level course selection. Using a phenomenological approach, I focused on the reasons grade 10 students provided for making course selections surrounding grade eleven physics. To this end, the following research sub-questions guided my work:

1. Why do students select or reject physics courses?
2. What role does physics identity play in student course selection?
3. What other factors, extrinsic or intrinsic, affect their choices to pursue physics?
1.3 Significance of the study

The data I collected from student focus groups, questionnaires, and semi-structured interviews provided insight into the reasons why students selected (or rejected) school physics. Insights and findings from this work contribute to how, as educators, may better position and explain physics courses to high school students. I selected a phenomenological approach as I anticipated that students’ views of physics and their physics identities have influenced their selection (or non-selection) of physics, and phenomenology puts participants’ own interpretations and voice at the centre of the research process.

At present, schools schedule more sections in their timetables of biology and chemistry than physics as the majority of students who do select science from Group 3 select these sciences over physics. As an example, one participating public school board of this study provided that in 2012, 47.6% of students select biology, 39.1% select chemistry, and 29.4% select physics (the specific number of students not taking any science was unavailable). A better understanding of the factors that influence students during the course selection process may better enable teachers and guidance counselors to support students through the process. Also, a revelation of students’ attitudes and perceptions of physics and school physics may help curriculum developers design courses that can cultivate positive scientific attitudes and skills, as well as a more positive physics identity.

This project focused particularly on the reasons informing course selection of physics-related courses. There have been many studies that have looked into the phenomenon of students’ predominantly selecting biology or chemistry over physics, but the literature is limited with respect to the factors informing these decisions in relation to identity. A better understanding of students’ attitudes towards physics can be beneficial for physics curriculum developers and physics teacher practitioners as studies in physics are often viewed as subject matter gatekeepers for careers in science and engineering (Udo, Ramsey, Reynolds-Alpert, & Mallow, 2001). If the insights gleaned into students’ attitudes and physics identities could lead to changes that would increase student interest and
willingness to enrol in physics, more opportunities may present themselves for students to pursue science and science related careers, as well as provide more opportunities to develop their problem-solving skills and overall scientific literacy.

1.4 Background

In Ontario, the courses students select to study in grade eleven and twelve are considered to be senior level. There are numerous science courses available after grade ten (this study will focus on biology, chemistry and physics), however they are offered in different years (see Figure 1: Prerequisite Chart for Science, Grade 9-12) (Ontario Ministry of Education, 2008b, p.13). In Ontario, grades nine and ten are broken into two types, academic and applied. A school board called may offer a third type (Locally Developed Compulsory Credit Course, LDCC) that leads to workplace preparation courses and is beyond the scope of this study. Academic and applied courses differ in that “academic courses focus on theory and abstract problems, and applied courses work on practical and concrete examples” (Ontario Ministry of Education, 2008b, p. 13). The pathways available to students after the successful completion of these courses differ, with academic students able to pursue studies in university, college, or workplace destination courses, and applied students able to pursue studies in college or workplace destination courses, only. There is a notable difference in the offerings for students after the completion of the grade ten courses. The grade ten academic students may select biology, chemistry or physics (university level), all of which are offered in grade eleven. Each of these courses also leads into a second senior course offered in grade twelve. This differs from the options available for grade ten applied science students who are offered only one senior level course in biology, chemistry or physics. The biology course (college) is offered in grade eleven, and chemistry and physics courses (college) are offered as grade twelve courses. From my own experience, applied grade ten students are often surprised that they are allowed to select chemistry or physics in their grade eleven year to fulfill their diploma requirements even though these courses are listed as grade twelve courses.
1.5 Background of the researcher

I began working as a secondary school science, biology and physics teacher in 1997 with the Toronto District School Board (TDSB), and I hold an Honour Specialist: Physics (which means I have
completed a minimum of nine physics courses from a university). After completing a literature review for this proposal I find that the choices I have made with respect to my own education are congruent with findings from studies in the field. I selected my upper year courses for academic reasons, which centered on my interest in the subject matter (Babad, 2001). I am interested in physics particularly as presented in a biological context, which is evident from my completion of an honours undergraduate degree in Biophysics. This preference may reflect the findings of Osborne and Dillon (2008) who suggest that females express interest in physics when it is presented in a human context.

As a teacher, I enjoy teaching senior physics to students and I work hard to make connections between theory and practice explicit for my students. I enjoy the evaluation of “truth claims” and (what I see are) the logical steps of problem solving (McComas, 2004). The students I have in my physics classes are diverse in their backgrounds and interests and I teach males and females in varying proportions (sometimes more male, sometimes more female). That said a physics class feels different from a biology class or a general science class. As I am the common factor in the classes I teach, I have noticed (anecdotally) that the students seem to inherently bring something different to their physics class versus the other sciences. Hence, part of my interest in conducting this study was to unpack this “difference.”

My previous research interests explored factors that lead to success as secondary school students made the transition to post secondary studies in science. To this end, in 2007 I conducted interviews with college and university first year science professors to understand what they feel are the characteristics of successful first year students, and what present first year students lack as measured against those characteristics. In an extension of that project, in 2007 and 2008 I administered surveys to first year students who were two months into a science or engineering program, to determine why they enrolled in particular programs. This work has informed the design and impetus for this study.
2. Literature Review

2.1 Overview and organization of the literature review

In order to situate my findings in the existing literature I drew upon past studies investigating the reasons secondary school students select (or reject) school physics. Since this study is focused on fifteen and sixteen year old (year ten) students who are about to make decisions regarding their physics education, the articles that report on information for this group dominate this chapter. I have divided the literature into the following sections: Students, Science and Scientific Literacy; Students and Science Identity; Students and Physics Identity; and finally Potential Career that may influence student course selection.

2.2 Students, science and scientific literacy

McComas (2004) describes science as developing a “basic understanding of the fundamental nature of reality” (p. 26). We develop our own understanding of the physical world through our experiences and develop our own explanations or p-prims. These p-prims are most similar to mini-theories (Osborne, 1984) where students’ explanations are context specific and limited in their application, and they may (but not necessarily) include alternative frameworks, naïve ideas and misconceptions (Blosser, 1987; diSessa, 1993; Jones, Collis & Watson, 1993). Once a student has adapted a p-prim into their working knowledge of the world, it is not isolated but becomes integrated into an elaborate web of explanations as it provides the foundation for understanding future experiences (Jones, Collis & Watson, 1993). As an example, consider that a car is turning left, and a passenger sitting inside the car appears to move toward the car’s right side. A student could form a p-prim that there is a force that pushes the passenger towards the car’s right side. Once this p-prim is formed a student could apply this belief to a ball released out of the turning car’s window. The p-prim of the existence of a centrifugal force would lead the student to believe that the ball would move away from the car (perpendicular to the car’s path). If the student were to release the ball, however, they would see that the ball instead moves parallel to and in the direction of the car’s direction of motion at the instant
of release; an anomaly of the student’s p-prim (which, in this example includes a misconception). The collections of p-prims students hold shape their ability to understand scientific concepts, and subsequently will shape their attitudes towards science (Fischbein, 1987; Seligin, 2012). In this example, the behaviour of the ball cannot be explained by the student’s p-prim, which may lead to the student’s frustration and their sense that science is mystifying.

Einstein is alleged to have said that through trial and error “a physicist learns half his or her physics by the age of three” (Osborne, 1984, p. 505). While a physicist may not have learned exactly half of physics by three, p-prims do begin to form at very young ages from everyday experience and observation, perceptual thinking, textbooks, and prior educational experiences (Kwen, 2005; Sherin, 2006). Osborne and Dillon (2008) report that by the time students are 14 they have formed an interest and level of engagement in science (and technology) with the majority of 15-year-old students having generally positive attitudes towards both science and technology (Kahle & Lakes, 1983; Sjøberg & Schreiner, 2010). These positive attitudes are not globally consistent. The Relevance of Science Education (ROSE) Project (2010) surveyed 15-year-old students from across 34 participating countries and found that students from countries that have higher scores on the Programme for International Student Assessment (PISA), Trends in International Mathematics and Science Study (TIMSS), and the Human Development Index (HDI), have lower scores and less positive attitudes towards science and technology than students from lower scoring countries (Sjøberg & Schreiner, 2010). Students from those countries with higher scores on PISA, TIMSS and HDI were also found to show more scepticism.

1 To un-learn p-prims, strategies are suggested that include: creating situations to evaluate that phenomenon from which the p-prim has originated, discussing or drawing the p-prims, fostering a non-evaluative environment in which to discuss the p-prims, debating and discussing the merits of competing frameworks, and assisting students to reorganize their cognitive structure to accommodate the scientifically acceptable alternative (Gilbert & Watts, 1983; Mintzes, 1984; Reiner, Slotta, Chi & Resnick, 2000).

2 Technology differs from science in that technology involves innovations that apply science to solve problems or that facilitate further exploration, such as the microscope or oscilloscope (McComas, 2004). The ROSE project however does not make that distinction within the statements that students are asked to respond.
about the positive effects of science and technology on their daily lives, and more scepticism that the positives effects of science and technology will outweigh the potential negatives. Although Canada is not a participating country in the ROSE (2010) project, by comparing Canada’s scores on the PISA, TIMSS, and the HDI with other participating countries, it is possible that because Canada scores high in all of these assessments that Canadian students may also hold similar attitudes to other high ranking countries (see Table 1: Comparison of Canada scores on PISA (PISA 2009 key findings, 2009), TIMSS (Trends in International Mathematics and Science Study: Average science scores of 8th-grade students, by education system, 2011) and HDI (United Nations Development Programme, 2011) to the highest and lowest ranked countries).

Table 1: Comparison of Canada scores on PISA (PISA 2009 key findings, 2009), TIMSS (Trends in International Mathematics and Science Study: Average science scores of 8th-grade students, by education system, 2011) and HDI (United Nations Development Programme, 2011) to the highest and lowest ranked countries.

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<tbody>
<tr>
<td>Number of Countries Ranked, N</td>
<td>187</td>
<td>501</td>
<td>42 + 14 Benchmarking education systems</td>
</tr>
<tr>
<td>Mean, x</td>
<td>0.682</td>
<td>65</td>
<td>500</td>
</tr>
<tr>
<td>Canada (rank)</td>
<td>0.908 (rank 6)</td>
<td>529 (rank 6)</td>
<td>512 (Ontario, rank 18)</td>
</tr>
<tr>
<td>Highest score (country)</td>
<td>0.943 (Norway)</td>
<td>556 (Shanghai-China)</td>
<td>613 (Korea)</td>
</tr>
<tr>
<td>Lowest score (country)</td>
<td>0.286 (Democratic Republic of the Congo)</td>
<td>314 (Kyrgyzstan)</td>
<td>331 (Ghana)</td>
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What is troubling is that although there is a generally positive attitude towards science amongst students, science education (that is, the science taught in school) is viewed far less favourably. The ROSE Project (2010) found that the majority of 15-year-old students prefer other subjects to science, and that students find science school work “boring” or “difficult” (Riley & Docking, 2004, p. 171; Seligin, 2012; Sjøberg & Schreiner, 2010). Many national and provincial school science programs insist on mandatory science education for students to the end of year 10, after which time students who have successfully completed the mandated number of science courses for their diploma can opt out of science education. National statistics from around the globe show that once students are liberated from mandatory science enrolment, many opt out of engaging in more science courses. For example, Trumper (2006) reports a decline in Israeli students in science from 50 percent registering in senior
science in the 1980s to just 25 percent in the early 2000s. Wellington (2001) found that in England and Wales, students enlisting in A-level sciences dropped from 37 percent in 1981 to 16 percent in 1993. The same trend of declining enrolment in the sciences is reported in Canada (De Brouker, Bordt, Read, Harris & Zhang, 2001). While there has been much documentation about the global decline in sciences as a whole, within those trends the enrolment in physics continues to be below both chemistry and biology. In the UK, A-level physics enrolment has declined by 7%, and the number for physics graduates has declined in the United States by 9% from 1996 to 2001, in France by 37% since 1995, and in Germany by 50% since 1993 (OECD, 2005; Owen et al., 2008).

The declining enrolment in science education by secondary school students is a national and international phenomenon that affects society in a number of ways as science education is designed to “select and educate future scientists; prepare students to be responsible citizens; to respond to economic needs, social crises and problems of degradation” (Hodson, 1998, p. 1); and, develop an attitude that places science in students’ current and future lives (Ainley & Ainley, 2011). Tobias (1993) highlights the consequences of students not pursuing science education in the United States in the following way:

Whether you accept the shortfall or not, whether your focus is on scientific literacy or the scientific professionals, we have a national problem I would define as: not enough ... citizens studying not enough science. Related to this are the twin problems of a decline in the numbers of ... students ... willing to make science a career; and not enough professionals in fields other than science having enough science at their disposal to make good judgments as to the allocation of resources for the firm and for the nation (p. 297).

Although twenty years have passed since Tobias’ observations, the sentiments still hold true today. The declining enrolment in the sciences is a concern because a fundamental goal of science education is to generate scientifically literate citizens (both those who will and who will not pursue science careers) who can evaluate, discuss, and make informed decisions about science and technology issues (OECD, 2009; Ontario ministry of education, 2008b).

The declining enrolment of students in senior sciences has already affected the demand for scientists and researchers in Europe. Osborne and Dillon (2008) report “Europe has 5.7 researchers per
1000 workforce and cannot fill their current demand domestically for researchers and must hire foreign researchers (considering that Japan and the United States report 9.14 and 8.08 researchers per 1000 workforce, respectively)” (p. 14). Science is thought to be valuable as it develops “the intellectual skills that serve to fortify the human capital of all students and the productivity of the nation” (de Hart, 1998, p. 334 as cited in Cleaves, 2005, p. 482). If student enrolment continues to decline in the sciences there will be fewer scientists and engineers to work in academia, government, or industry, subsequently impacting the nation (European Commission, 2004). If one accepts that only a small percentage of a nation’s population enter a science-related career, we still need to consider the impact of declining enrolment in science on the non-science career students.

In addition to the economic argument, there is a strong citizenship argument for trying to keep students enrolled or interested in science. Tobias (1993) and Hodson (1998) suggest one of the purposes of science education is to educate students to be scientifically literate enough to ”make evidence-based conclusions to make decisions” (OECD, 2009). With only a small proportion of students going on to pursue a career in science, science education needs to provide the tools for those entering non-science careers to understand and interact with the scientific and technology-focused society that surrounds them in an informed, ethical, and compassionate way. One way to do this is for science education to teach students about the basic concepts of science and include the core ideas of the nature of science (NOS). McComas (2004) outlines these ideas calling NOS “the sum total of ‘the rules of the game’ leading to knowledge production and the evaluation of truth claims in the natural sciences” (p. 25 - 27).

The core ideas about NOS include:

- science demands and relies on empirical evidence
- knowledge production in science includes many common features and shared habits of mind
- scientific knowledge is tentative but durable
- laws and theories are related but distinct kinds of scientific knowledge
- science is a highly creative endeavor
- science has a subjective element
- there are historical, cultural, and social influences on science
- science and technology impact each other, but are not the same
- science and its methods cannot answer all questions
By including NOS in science education, students develop scientific literacy while they learn how to be critical, curious and creative through applying their scientific knowledge, skills and attitudes to their everyday world experiences (McComas, 2004). Tobias’ (1993) inclusion that students need to “have enough of a science background to make good judgments” is critical (p. 297). Hodson (1998) emphasizes this point when he says that science education should “respond to ... social crises and problems of degradation” (p.1). As an example, Lee and Roth (2003) discuss the use of science, in conjunction with other discourses, in addressing a community based social crisis in a case study on the Henderson Creek Project. In this case, the stream had been impacted by industrial discharge to the point that the system was no longer a viable resource for food and water. Through initiatives by the local community (including: First Nations leaders, home owners, schoolteachers, scientists, politicians, a coordinator, and others), the local community educated themselves about science related to that system to the point where they could make meaningful, informed changes in their actions. Lee and Roth (2003) highlight that “[u]nderstanding of scientifically articulated issues and problems is portrayed as a springboard to a moral commitment” (pp. 415-416). In this case, science education was used to foster “socially and morally responsible citizens” rather than producing scientists (p. 417).

It is not scientific knowledge alone that makes one scientifically literate, it is also the emphasis on critical thinking (CT) as it incorporates, “rational, logical, reflective, and evaluative thinking towards decision making” (Ben-Chaim, Ron & Zoller, 2000, p. 149). Krusberg (2007) argues that these skills are more heavily emphasized in physics than in other sciences. Solid literacy skills lead to increased career opportunities, beyond those confined to science, engineering and technology (Ainley & Ainley, 2011). Students who are scientifically literate and pursue a non-science career (or are scientifically literate in a science career) are better equipped to consider claims of truth, recognize bias, and consider the impact of actions as they critically evaluate and respond to scientific and technology-based issues. These abilities increase when students enrol in school science (Ben-Chaim et al., 2000).
With declining enrolment in science, and a divide between students’ attitudes towards science and technology, it is important to consider the purposes of science education. To this end, the view of scientific literacy from Hodson (1994) is most helpful. He describes scientific literacy as including: learning science, learning about science, and doing science. Learning science refers to obtaining and understanding conceptual knowledge; learning about science includes appreciating science’s development and history, plus understanding the relationship amongst science, technology, society and environment (STSE); doing science entails developing the skills and expertise necessary to engage in science (Hodson, 1998). By including each of these components into our science lessons it may be possible to create an environment where students feel engaged with science to the point that it becomes a subject that they want to take, and perhaps discover a career they would like to investigate. In the next section I will explore how student identity and science identity influence a student’s science course selection.

2.3 Students and science identity

According to Pike and Dunne (2011) identity (made up of one’s genetics, institutional position, peers and dialogues) is a dynamic social construct that shapes how one perceives and is perceived, and identity continually evolves through both deliberate and unintentional actions. For students, subject choices shape their identity, and in return student identity will shape their course selection since school subjects also have their own identity (or subculture) based on the subject’s image and the prototype of the subject (that is, the “characteristics that identify students who have a preference for that school subject” (Kessels, 2005, p. 310)).

When a student selects a course, they become a part of the community that is identified with that course; they become a member of that subject’s subculture where a subculture is defined by its values, beliefs, expectations and conventions (Aikenhead, 1996). Course selections by students are then an incredibly important part of a student’s journey as they “determine the nature of a student’s school experience in both intellectual and social domains” (Babad, 2001, p. 469), as the student inherits that
subject’s identity with its “issues connected to participation, non-participation, inclusion and exclusion” (Wenger, 1998, p. 145). This is complicated for students as they belong to multiple subcultures (family, peer groups, classrooms and school) (Aikenhead, 1996). By belonging to a community, non-conformist actions can lead to friction (or even ejection) within the community, and belonging to one community can mean exclusion by another (Wenger, 1998). For some students, this friction can act as a deterrent from trying something that is incongruent with their other subcultures’ identities. “Border crossing” is one way to understand how students make choices about school subjects. The process of “border crossing” involves crossing the border between two subcultures. Students cross subculture borders throughout their day and when the subcultures share similar attributes the transition from one subculture into the other is more easily accomplished than when the subcultures’ attributes are divergent (Aikenhead, 1996).

When the student’s subcultures’ (such as peer, family or media) values diverge from a school science subject subculture, students may face a negative recognition for pursuing studies in science, or “border crossing” from their social subculture into a science subculture (Aikenhead, 1996). It is important then for students to have a clear vision of the values they hold and the values held by school subcultures.

In the public school board Ayalon and Yogev (1997) report, “science is considered a high status course and that only the more able students and those students that belong to more prestigious social groups will take them” (p. 349). When asked, prototypic science students perceive themselves as more task-centred, tough-minded, more interested in ideas than people, tending toward being loners, and communicating better through diagrams than through words as compared to non-science students (Woolnough, Guo, Leite, de Almeida, Ryu, Wang & Young, 1997). Lee (1998) also found significant differences in the perceptions, and self-perceptions, of science students from other same sex students. They report science students to be more slow/quiet, more likely to seek general truths, more systematic, and to be significantly more logical. Science students also were found to share some characteristics
(usually identified with boys) such as: “individualistic, hard, not emotional, and want to work with things” (Lee, 1998, p. 209). Students who choose to study science are showing that they belong to a science community, with all its privileges and limitations that are afforded by the community’s characteristics and identity.

In this study, I use the science identity conceptual framework of Hazari, Sonnert, Sadler and Shanahan (2010) to explore and help elucidate why grade ten Ontario students choose to select (or reject) physics. Hazari et al.’s (2010) four domains (recognition, performance, competence and interest) provide the theoretical context for understanding the reasons students elect (or reject) school physics.

2.3.1 Recognition. Hazari et al. (2010) explains that the recognition of a student’s ability in science shapes the student’s self-perception of their ability. This recognition is complicated for students as the recognition may come from family, teachers and peers. Cleaves (2005) highlights the influence of relationships with significant adults as one of the factors that shape this identity development, and parental expectations and recognition are found to be important influences for students.

Within her study Cleaves (2005) describes that students were guided towards some subjects that parents felt were “solid” or “fundamental” (identified as mathematics or physics) while some students were guided away from other courses that their parents deemed “fluffy.” These “parental messages” about the worthiness of some subjects over others became part of the student’s self-recognition and as such, are likely to influence students’ course selections in post-secondary education (Hazari et al., 2010, p. 979).

Teachers can also contribute to student identity by recognizing and encouraging students explicitly, or in more subtle ways by matching the delivery of the curriculum to student worldviews through the selection of specific labs of interest or by guiding class discussions in specific directions.
(Hazari et al., 2010). Even though students may become disinterested in science education earlier in their academic career, a teacher who recognizes them as “science able” in secondary school can sometimes re-engage those students with science education to the point that they will further their studies in science (Hazari et al., 2010).

**2.3.2 Performance.** The performance of a student is connected to the student’s belief that they will be able to perform a specific task (Hazari et al, 2010). Performance in science courses, as measured by students’ grade point average (GPA), correlate positively with student’s positive science identity (Hazari et al., 2010). Gardner and Tamir (1989) found that students with past success in science are more likely to enrol in senior science. Similarly, Ost (2010) found that the higher a student’s GPA (from an American “elite” university) the more likely they are to major in that discipline. However, Ost (2010) also found that an increase in a student’s non-science course GPAs decreased their persistence to stay in either the physical or life sciences.

What is ironic is that the results from the TIMSS (1999) found that students with the highest average student achievement had the least positive attitude towards science (Osborne & Dillon, 2008). This suggests that students may still select science courses during course selection if they believe they will perform well on science tasks without actually enjoying the subject.

**2.3.3. Competence.** Hazari et al. (2010) define competence as the “belief in the ability to understand [science] content” (p. 982). Sadly, science anxiety begins as early as grade three or nine years of age (Kahle & Lakes, 1983; Udo et al., 2001), and those students who have high non-science anxiety and/or are female tend to have higher science anxiety (Udo et al., 2001). If students already have a well-established level of anxiety towards science, this may influence both their academic self-concept and their projected careers (Cleaves, 2005). The result is that their academic self-concept (which Stokking (2000) found more consequential for females than males) may influence students’

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3 It is important to note that teacher influence is found to be more influential for students at low SES schools than high SES schools (Nye, Konstantopoulos & Hedges, 2004). This point is significant regarding the participants of this study, however the analysis is beyond the scope of this study.
academic achievement in science together with their selection of post-compulsory science courses (Cleaves, 2005; Norvilitis, Reid & Norvilitis, 2002; Trumper, 2006). Cleaves (2005) also found that even when students scored well on the General Certificate of Secondary Education (GCSE) in science, students still thought they did not have the competence to pursue studies in science.

To compound this issue, science is perpetually advertised as a difficult subject, something that not everyone can do. Since 1942, American high school seniors have competed in a Science Talent Search by completing a two-and-a-half hour science aptitude test. This test, made up of questions that ask about specific scientific terms, math, and specialized knowledge is advertised as a search for students who have the potential to be future scientists (Simons, 1957). While rich in its detail, science through this lens appears to be based on the memorization of facts rather than the application of knowledge. This lens shows science to be the opposite of the preference of those students studied by Woolnough et al. (1997) who universally declared they preferred learning to do science (Hodson, 1998) rather than only learning science facts.

**2.3.4 Interest.** Interest can be classified as momentary, situational, or personal (Ainley & Ainley, 2011). It is personal interest (“personal orientation... to engage with a particular domain” (Ainley & Ainley, 2011, p. 53)) that Hazari et al. (2010) report as a key factor in whether or not a student will continue to study science or will influence subsequent career choices.

It is believed that students’ attitudes towards science will influence their choice to participate in science activities throughout their lives. Those students who are actively engaged in extra- and co-curricular scientific activities have positive attitudes about science and will be more likely to be engaged with science (in some capacity) throughout their lives (Ainley & Ainley, 2011). This is congruent with Woolnough et al. (1997) who found that students who take science have scientific hobbies, and enjoy science and technology competitions. Student interest in science is also found to vary based on gender and age. The majority of those students that express an interest in science are interested in biological sciences, but the specific topic in biology changes as students mature (Baram-
Tsabari & Yarden, 2007; Gardner & Tamir, 1989). As well, boys are found to have more interest in a wider scope of physical science topics than girls, while girls are interested in physics when presented in “human content” (Hazari et al., 2010; Osborne & Dillon, 2008; Qualter, 1993). What is interesting is that the content of the science courses required to enter a specified career is not as important to the future or potential scientists as the teaching in the science department, the amount of self-expression allowed in science lessons, the likely salaries in science and engineering jobs, and finally, their personal scientific hobbies (Hazari et al., 2010; Woolnough et al., 1997).

Of those students that do have an interest in science some consider becoming a scientist. 4 To become a scientist, a student needs to take more science courses, a choice that is influenced by how much their own science identity is aligned with their perception of a scientist identity (Lee, 1998). Lee (1998) argues that to engage in science, math, or engineering (SME) career paths, a student’s science identity must be aligned with a scientist identity. Consider the portrayal of science and scientists in popular culture and media - the scientist is usually male, very smart and somewhat on the periphery of society. If these identities conflict, Lee posits that a student’s interest in SME will change and ultimately will reject subjects that they find incongruent (Aikenhead, 1996; Cleaves, 2005; Dellar, 1994; Lee, 1998; Leonardi, Syngollitou & Kiosseoglou, 1998).

Although some students’ feel that the time commitment to become a scientist is daunting and that a scientist’s lifestyle is undesirable (Bozak & Perez, 1994), “[i]f students can see themselves in a career, then the likelihood of these students pursuing an educational program to prepare for that career is increased” (Finson, 2002, p. 338). A similar result is found in Ainley and Ainley (2011) where students enjoyed science when it was linked to their future science goals. Our understanding of whether considerations about career plans are governing grade ten high school students’ course selection is limited. For example, Babad (2001) found that first year university students were more likely to select a

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4 Even as the recognition and interest domains need to be aligned with a student’s science identity, I will continue the consolidation of literature about careers in both the interest domain and potential careers.
course that matched their timetable and workload needs, as well as instructor’s humour, rather than how a course matched their long term goals.

In the next section I have organized the literature using the physics identity framework of Hazari et al. (2010) to consider specifically physics identity and how it influences students selection (or rejection) of physics education.

2.4 Students and physics identity

The term physics is used by students to mean a “physics course of study, the science of physics, or the physics that describes nature” (Adams, Perkins, Podolefsky, Dubson, Finkelstein & Wieman, 2006, p. 2). Throughout the literature a distinction between these interpretations is not always readily made so it is not always clear in what context physics is being discussed. Similarly, I found that students in this study also used the term physics to mean different things.

When students select or reject physics courses (as with any subject), they alter their identity in terms of recognition and interest, and they potentially expand their experiences to add to performance and competence. Hughes (2001) explains:

Students take up scientist identities through expressing interest in studying scientific disciplines, and/or aims to pursue a science or technology related career. Conversely, rejection of a scientist identity might be expressed through dislike of science or dropping out of a science course. ... Other subjectivities apart from gender, arising through discourses and practices of class, academic achievement and ethnicity, interact with scientist subjectivities so that there are numerous possibilities for rejecting or accepting science (pp. 278-279).

General physics ability has been linked to variables including: academic variables, creativity and scholastic self-competence, instruction and exposure, and intellectual curiosity (Norvilitis, Reid & Norvilitis, 2002). When specifically considering physics identity (with respect to the participants in this study who have completed grade ten science in Ontario), these variables again correspond to the recognition, performance, competence and interest domains in the framework of Hazari et al. (2010). It is important to note the Ontario context: students in grade 10 have not experienced a full stand-alone course in physics (since this happens in the senior grades), and so this may affect their understanding
and views about physics. Although physics strands exist within the grade nine (the characteristics of electricity, or electrical applications, plus Earth and Space Science: the study of the universe, or space exploration) and grade ten (light and geometric optics, or light and applications of optics) curricula, students may not always be able to differentiate one science strand from another. The consequence is that their current performance in physics may not be able to be isolated from the junior science courses.

2.4.1 Recognition. According to Hazari et al (2010) recognition as part of physics identity is about the student being recognized by others (parents, teachers and/or others) as being a capable physics student. A student’s physics identity overlaps with both their personal identity (individual characteristics) and their social identity (group characteristics assigned to a member of that group) (Hazari et al., 2010). As such, the decision a student makes about becoming a physics student usually aligns with their other identities.

There is an abundance of research about the discrepancy between male and female enrolment and pursuit of careers in the physical sciences. It therefore becomes possible to place this study within the context of how student physics identity overlaps with social identity (Kessels et al, 2006; Koul, Lerdpornkulrat & Chantara, 2011; Lacklard & DeLisi, 2001). For example, Kessels et al. (2006) found that students hold a common belief that physics is non-female. As students are developing their overall identity, the perception that those students who like physics are “less attractive, less socially competent, more isolated and more arrogant (but also more intelligent and industrious) than targets preferring [English]” (Kessels et al., 2006, p. 775) may deter students from opting to choose physics if they are unsure of their own identity or feel their identity would be negatively impacted by this physicist identity. In addition, Hughes (2001) reports that although the physical sciences are viewed as more masculine than biological science, the male student who selects physics is not seen as more masculine so there is no gain in perceived masculinity for a male who selects physics (Kessels et al., 2006).

2.4.2 Performance. A student’s belief that they will be able to perform a physics task is influenced by their performance in both physics and mathematics, as students believe that physics is
more reliant on understanding and logic than biology that is perceived to be more memory focused (James, 2007). Norvilitis et al. (2002) conducted a study of 112 college undergraduates and found that students’ scores on a physics quiz were positively correlated to their physics grade in high school \( r = .38, p < .01 \) and to the number of math courses they had taken \( r = .24, p < .05 \). Tai, Liu, Maltese and Fan (2006) tracked grade eight students over twelve years and found that it was more likely for a student to earn their expected degree in physical sciences or engineering if they were high math achievers in grade eight. However, Tai et al. (2006) point out that even average math achievers in grade eight are more likely to earn a degree in physical science or engineering if that is what they are interested in pursuing than those students who do not express an interest in physical science and engineering.

2.4.3 Competence. Physics is perceived to be more difficult than other subjects and so students have lower expectations of success (a diminished physics competence domain) (Kessels et al., 2006). For example, James (2007) found that students rejected physics because they thought they were not good at physics or that physics was too hard. Considering that competence, as defined by Hazari et al. (2010) includes the “student’s belief in their ability to understand the subject’s content” (p. 982), when a student earns a lower grade this correlates with a lower comprehension of that subject, feeding their belief that they do not have the ability to understand the subject (Kessels et al., 2006). An additional risk for the student is that earning lower grades, or even failure in a subject, is it may be viewed by their peers and family as the student lacking intelligence (Kessels et al., 2006). This risk also acts as a deterrent to enrol in physics (Kessels et al., 2006).

2.4.4 Interest. Hazari et al. (2010) describe interest within physics identity as the “desire/curiosity to think about and understand physics” (p. 982). Physics is very much about understanding how things work, laws that can be applied to multiple disciplines and enhance one’s understanding of those. Even though students may find physics class to be “horrible”, “difficult”, and “unpleasant” they may also find it worth studying as physics explains “how everything works”
Having a basic curiosity about the physical world is essential for success in physics. Norvilitis et al. (2002) found that college students who have a natural curiosity and think it is important to understand how things work perform better in physics than those that do not.

How interest influences students as they make the decision about whether or not to study physics is complicated. Physics is viewed as a subject that can lead to professional status and so students may take physics because it makes sense to their future goals, not because they necessarily enjoy the subject (Hughes, 2001; Stokking, 2000). Stokking (2000) found that the greatest predictor of whether or not students would choose to study physics was future relevance (education and professions) and that “background, gender, textbooks and advice were not important” (p. 1273). This is supported by Cleaves (2005) who reports that students select physics do so if their intended career path directs them to do so. Conversely, Adams et al. (2006) found using the Colorado Learning Attitudes about Science Survey (CLASS), that the greatest predictor of whether a student will become a physics major is their personal interest. While students may take physics because they hold a general interest or that it makes sense for their future career plan, the reasons why students do not take physics may also connect to interest.

If physics is not a prescribed part of a student’s future, then other factors related to recognition, performance, or competence may be more significant in deterring students from signing up for physics. James (2007) found that the most frequent reasons students would not select physics was because they were not interested, thought it was boring or disliked physics as a school subject. What may contribute to students’ dislike of physics is that physics is viewed as a subject that converges on a single answer. Kessels et al. (2006) found that students think physics is absolute, what Hughes (2001) refers to as the “ideal model for positivist science” (p. 287). Many students do not understand the Nature of Science (NOS), or perhaps have not been exposed to these perspectives, which teach that science is influenced by history, culture and society, and that science is tentative, changing, and creative (McComas, 2004). When students hold the perception that physics is absolute it may act as a deterrent to those students
who do not already have a predisposition towards finding a “right” answer (Adams et al., 2006; McComas, 2004). These students may be more drawn to classes that they perceive provides them with a breadth of opportunities to express themselves, opportunities that for these students, do not seem to exist in physics class (Kessels et al., 2006).

It may be argued that the line between issues of identities and issues of interest are blurred when interest refers to a student’s interest in entering a specific field for their career. However, when the career is not specifically in science, considerations of a potential career that requires studies in physics lies beyond the framework of Hazari et al. (2010). In the next section I treat potential career as a separate factor that may influence students’ course selections.

2.5 Potential Career

A student’s interest in a future career can influence their course selections in ways that move beyond the identity framework of Hazari et al. (2010). Monk (2008) suggests that physics, unless leading into a career as a physicist, is slowly becoming a passport course, required for entrance to programs but one that has little relevance to the program once admitted. James (2007) found such a situation in his study of students in an International Baccalaureate Programme (IB). Even while interest and enjoyment (interest domain), and ability (competence) were included as reasons that students do select courses, students in the higher levels (HL) indicated that university and career requirements were far more influential than standard level (SL) choices (James, 2007). When students did not require a specific science for the university or career requirements, James (2007) found that students made their science selections based on interest and their self-perceived competence in that subject. Physics courses have become gatekeepers for careers that students think they would like to hold, and as such, students do not consider their own interest, competence, recognition or performance in that subject as relevant factors in their choice; they simply see the courses as necessary for their career goals.
2.6 Summary

In trying to understand why students accept or reject physics courses I have drawn on a number of key areas in the research literature; scientific literacy, science identity, physics identity, and systemic factors that impact students’ course selections. Each of these plays a part in students’ perceptions and choices they make. I draw heavily on the physics identity work by Hazari et al. (2010) as a useful framework for understanding students’ physics identity, which includes four domains: recognition, performance, competence, and interest. It is hoped that this study will add to our knowledge about the role physics identity and other factors play in student physics course selection and that this knowledge will help educators to provide physics education that inspires, engages and best addresses students’ needs and interests.
3. Methodology

3.1 Research questions

The overarching research question of this thesis is: *what factors influence a student’s decision to study physics in grade eleven?* To answer this question, the following list of sub-questions were used to guide this study:

1. Why do students select or reject physics courses?
2. What role does physics identity play in student course selection?
3. What other factors, extrinsic or intrinsic, affect their choices to pursue physics?

The remaining sections of this chapter outline this study’s methodology and methods; explain the study’s context and participants; describe the data analysis strategies; and provide detailed ethical considerations for implementing this study.

3.2 Methodology

This study is a multiphase qualitative phenomenological study that looked into the attitudes, views and experiences of two groups of students: those who have elected to and those who have opted not to study physics in grade eleven (see *Figure 2: Multiphase design and considerations for Reasons why Ontario grade 10 students select (or reject) physics*). To triangulate the data, student drawings, past achievement data, enrolment data, focus groups and interviews were combined to provide detailed data for analysis of the essence of their shared experience (Creswell & Clark, 2007).
3.3 Methods

I used primarily a purposeful sampling strategy (snowball sampling technique, Patton, 2002) and data was collected from August 2012 to October 2012 based on student contact and availability. Students came from various backgrounds and multiple school Boards, and students’ differences did not interfere with the ability to gather data to address the guiding questions of this study.

I used several methods to gather data to analyze for this project. These methods include questionnaires, student drawings, semi-structured interviews, focus groups, and enrolment data. Unfortunately, not all the participants participated in each phase of the study due to access and availability. I recognize this as a limitation to the study, but is a consequence of the sampling strategy that was implemented. However, most participants in the semi-structured interviews or the focus group also completed a questionnaire and this provided additional information about performance in science, as well as information about the courses they selected to study in grade eleven.

Each method of data collection was used as it lent itself to gathering specific types of data as related to the research questions of this study or to triangulate the students’ response data. A summary appears in Table 2: Summary of questions addressed by each mode of data collection.
Table 2: Summary of questions addressed by each mode of data collection

<table>
<thead>
<tr>
<th>Question</th>
<th>Questionnaire</th>
<th>Semi-structured Interviews</th>
<th>Focus Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why do students select or reject physics courses?</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Why other factors, extrinsic or intrinsic, affect their choices to pursue physics?</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

The timeline for the completion of data collection is shown in Table 3: Data collection timeline and sample numbers. The “redo(s)” indicated in the table refer to questionnaires that were done by the same participant at a later time to ensure instrument reliability. The later use of convenience sampling through a teacher-contact yielded a large number of questionnaire responses and a single focus group in October 2012.

Table 3: Data collection timeline and sample numbers

<table>
<thead>
<tr>
<th></th>
<th>Questionnaire</th>
<th>Interview</th>
<th>Focus Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Selected</td>
<td>Did not</td>
<td>Selected</td>
</tr>
<tr>
<td></td>
<td>physics</td>
<td>select</td>
<td>Physics</td>
</tr>
<tr>
<td>August</td>
<td>8</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>September (before school begins)</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>September (after school begins)</td>
<td>5 (plus 1 redo)</td>
<td>2 (plus 4 redos)</td>
<td>2</td>
</tr>
<tr>
<td>October</td>
<td>37</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>50 (plus 1 redo)</td>
<td>20 (plus 4 redos)</td>
<td>4</td>
</tr>
</tbody>
</table>

One school’s data was unable to be used to determine the presence of a correlation between students’ marks and their course selection because the vast majority of the students from that school who completed the questionnaire were selected from a physics class.

3.3.1 Questionnaire. The questionnaire enabled the researcher to collect information about students’ performance, recognition, and their interests as connected to physics identity. The questionnaire is based on the ROSE Project (2010) questionnaire, Section F: My Science Classes with
“physics” replacing “science”. Questions include context information, 16 closed questions using a four point Likert scale anchored by disagree and agree, and based on the ROSE Project (2010) questionnaire, Section F: My Science Classes with “physics” replacing “science”, as well as an open-ended question that asks students to write about what they would do if they were a researcher (see Appendix B). The questionnaire was administered using Survey Wizard, a web application for producing online surveys (55 questionnaires), and using pencil and paper format (25 questionnaires). Students were asked to include their school assigned email address on the parental consent form (see Appendix A). Students who exclusively opted to complete the questionnaire online had their email address added to a survey group in Survey Wizard and they were sent an invitation and the link to the survey to complete the questionnaire online. All students who selected this option completed the online survey.

All students who participated in the focus groups and semi-structured interviews were asked to also participate in the Online survey and were required to complete a Consent Form and an Assent Form for the Online Survey. Seven interviewees and five focus group participants completed the questionnaire in addition to either the interview or focus group. There were no negative consequences for the remaining four students who opted not participate in the questionnaire.

3.3.2 Student drawings. To glean a better understanding of students’ perceptions of science, scientists, and what scientists do, researchers in the past have used students’ drawings of scientists on blank pieces of paper in addition to interviews and questionnaires. The rationale for using drawings stems from Chambers’ Draw-A-Scientist-Test (DAST) established in 1983 that allowed the collection of information from children who may not have had the skills to write or verbalize their perceptions of science and scientists through more traditional methods of collecting data (Finson, 2002). Since its inception, the DAST has been used for students from kindergarten through college to provide initial data about student perceptions of scientists, science, and careers in science, and to supplement and stimulate interview data (Finson, 2002). The wording to instruct students was carefully considered to
instruct students to draw a “scientist” and a “physicist” so as to not influence what they drew, but rather to guide them to accurately include in their drawings what they think rather than what they may think the researcher wants to see (would they draw an Einsteinesque scientist because they really believe that is what a scientist is/does or do they think that is the “right” answer?) (Finson, 2002). The drawings were used to explore specifically students’ perceptions of physicists, and how those perceptions may have influenced the individual student’s career interests. The locations were specifically selected to be as neutral as possible in order to minimize any external influences that could affect students’ drawings.

3.3.3 Semi-structured interviews. The interviews addressed all three questions, and specifically looked into physics identity domains of recognition, competence, and interest that influenced course selections. It was important to include a semi-structured interview to provide an opportunity to gather rich unique perspectives from the subjects, to enrich data, and to uncover both intrinsic and extrinsic factors that influenced students’ course selection decisions. The interview focused on students’ particular views and attitudes about physics, school physics, the curriculum and its delivery, and their perceived competence in physics and math (see Appendix B). Since there are many factors that may have influenced their course selection decisions it was better to conduct these questions with an interviewer and without the presence of student’s peers, as it allowed students to share information about their own science identity without the potential influence of their peers (Bernard, Killworth, Kronenfeld & Sailer, 1984). While cognizant of possible response effects of the respondents to the interviewer’s gender, race or socio-economic class, attempts were made to ensure that participants were engaged and respected throughout the interview (Bernard et al., 1984).

Students were recruited to participate in the semi-structured interviews until a total of eight students were interviewed. To recruit students the principal researcher’s contact information via the Consent Form and Assent Forms was distributed through friends and acquaintances of the principal researcher (see Appendix A). Those students who were interested in participating contacted the principal researcher, and were only allowed to participate if they had returned the Semi-structured
interview Consent and Assent Forms. At no time was potential participant contact information accepted by the principal researcher unless those forms were completed.

The interviews were conducted either face-to-face (four) or remotely using a Google Doc (three) or email (one). The face-to-face interviews ran between fifteen and twenty minutes, while the remote interviews took between 20 minutes to two hours. The interviews conducted from remote locations instantly provided a transcript; for those interviews conducted face-to-face they were audio recorded and from those recordings a verbatim transcript was produced. All identifiers were changed to preserve the anonymity of the respondents. Seven of the eight interviewees were also asked to either draw (face-to-face) or describe (remote) a physicist. All of the drawings were scanned and identifiers were removed to maintain the anonymity of the students.

In general, the interviews began with a dialogue about the activities that were taking place at the time course selections were occurring. This “anchoring” technique for the reference period when students made their course selections were used based on Smith (2002) who indicated that respondents have a better recall of things that are linked with significant life events. As course selections happened at the change of semester (January and February) for most students, talking about student activities that occurred in the school at that time helped them to recall factors that may have influenced their course selection.

3.3.4 Focus groups. The focus groups explored students’ answers that pertain to the reasons they selected or rejected physics, physics identity (recognition, competence in science and math, performance, interest), and other factors may have influenced their course selections. The guiding questions for the focus group were constructed using some of the same themes used in the existing survey from the ROSE project (Sjøberg & Schreiner, 2010) with respect to content and context. The focus group discussion was conducted with carefully selected questions that were intended to be non-

---

5 Using this technique has also been shown to improve internal consistency of respondent reports about events (Schaeffer & Presser, 2003).
leading and inclusive with enough breadth to allow the respondents to bring in their own experiences without reducing their responses to “yes” or “no” (see Appendix B). However, as this study was looking for the emic perspective of the students, the discussions were guided minimally.

To select the students the principal researcher discussed the study with friends and acquaintances making enquiries into whether they knew anyone that matched the inclusion criteria. The principal researcher’s contact information (email address) was provided in addition to the Consent and Assent Forms to be given to potential participants (see Appendix A). The acquaintances coordinated with the primary researcher once they had found a group of interested students with respect to the time and location of the focus group. The students arrived to participate in the focus group with their signed Consent and Assent Forms. At no time was potential participant contact information passed to the principal researcher without their completed Consent and Assent forms. While considerations were made about the composition of the focus group to encourage open dialogue among students, the snowball approach used to locate participants resulted in two groups of academic students: one was a group of friends, the second a group constructed by a contact teacher.

The result was two forty-minute four-person focus groups that were conducted face-to-face and were audio recorded at science neutral locations (one at a community centre and the other in a library conference room at the students’ school). I also made notes during the sessions. Students took turns speaking and when they began speaking they said their name to help with the transcription. I produced verbatim transcripts from each focus group’s recording and changed the identifiers to maintain the anonymity of the respondents.

Similar to the interviews, anchoring techniques were used to help students recall factors that may have influenced their choices. I found this technique to be not as crucial as students were able to recall information from their shared experiences as they attended the same schools and essentially could fill-in-the-blanks for one another.
Based on information gathered in the semi-structured interviews, drawings of both a generic scientist and a physicist were requested of the participants in order to better understand the perceptions students’ hold of each. The drawings were scanned and identifiers were removed to maintain the anonymity of the students. Whether or not the students’ drawings were influenced by the presence of their peers is unclear, but some students did look at one another and each other’s drawings during the time allotted. Students were asked share their drawings with others during the focus group after the drawings were completed.

3.3.5 School data. Trumper (2006) found that physics experiences the fewest number of student enrolments in the senior sciences. Applications for external research were sent to those six school boards identified by student participants’ school information to request school board enrolment data to better understand how the participating students of this study may represent the students at the board level. In total, one public school board and Independent School A agreed to provide their data for this study. This data was analyzed using descriptive statistics for a single school board (2011-2012) and Independent School A (2012-2013 school year).

3.4 Context of study

This study explored the reasons that Ontario grade ten students select (or reject) school physics by conducting the research within the Greater Toronto Area (GTA). The GTA is made up of the City of Toronto plus four regional municipalities (including: Durham, Halton, Peel and York) and boasts a population of just over six million residents (about half of the population of all of Ontario) with just under 230 thousand students enrolled full time in secondary school (Dufferin-Peel Catholic District School Board, 2011; Halton District School Board, 2012; Toronto Catholic District School Board, 2012; Toronto District School Board, 2007; York Catholic District School Board, 2010; York Region District School Board, 2011). The GTA is a unique context, due to its size, catchment area and diverse student population. In addition the study includes a modest number of participants. As such, the findings from this study are not generalizable to the Ontario student population.
3.5 Participants

For all of the phases of data collection, students were selected based on their successful completion of grade ten science (either applied, or academic). Students enrolled in locally developed courses that lead into environmental science or general science (not biology, chemistry nor physics), were excluded from the study. Participants that met the inclusion criteria were purposefully selected using a snowball approach (Patton, 2002), which resulted in students participating from multiple schools and school boards that cover a broad range of SES backgrounds and the Education Quality and Accountability Office (EQAO) Grade 9 Assessment of Mathematics results. To compare the responses of the students, the 2011 Fraser Report (Cowley, Easton, & Thomas, 2011) was used to provide contextual information about the students’ schools; in particular, parental average income (as this connects to SES profile of the school), and EQAO results (as this links to student math competency). Twenty-eight different schools (plus three home schooled students) are represented in the data, therefore teacher effects (such as the avoidance or preferential selection based on who teaches physics) are reduced with the exception of the focus groups (each focus group was comprised of students that attended the same school).

Teacher effects are not limited to just “liking” or “disliking” a teacher. The literature indicates that teacher effects are found to be greater in schools that have low SES profiles (Nye et al., 2004). As SES is based on income, education, and occupation, it is expected that schools located within an affluent community will more likely have students with a high SES profile than schools located in poorer communities. For this study, according to the Fraser Report (2011) the student participants attended schools whose parents average income ranged between $45,200 to $232,000 (Cowley et al., 2011). Data was not collected about each individual student’s SES background so it is not possible to tell which students would have parents with corresponding parent incomes. Some of the schools have a specialized program that allows (or even draws) students from other districts to attend (such as a
Specialist High School Major (SHSM) or a gifted program). In this case, the student body SES profile would be harder to predict since students come from both the surrounding community and out of area. If the respondents were from the same SES background then their reasons for selecting a course could be unique to that SES profile and may hold a particular bias, similar to that found by Sjøberg and Schreiner (2010).

The EQAO results are used as an indicator of the mathematics ability of students. Although study is not looking specifically at math, mathematical skill is necessary for success in physics (O’Halloran & Russell, 1980). Having schools with comparable EQAO scores may have reduced the difference in the influence of the student identity competence domain, however, due to the sampling technique used, a range of EQAO scores for schools has been included in this study (Hazari et al., 2010). By referencing the Fraser Report (2011) students attended schools with EQAO scores that ranged from 2.5 to 3.3 (Cowley et al., 2011). Based on the data collected and the focus of this study, it is beyond the scope of this study to explore a correlation between math competency and physics competency.

As compensation, students were presented with a certificate of appreciation for volunteering their time towards this research. At the conclusion of the study executive summaries were shared with the participating school board and Independent School.

3.6 Data analysis

This section contains specific information about how various instruments and data sources were analyzed to answer the research questions. Below, is an overview of the research questions and the data collection and analysis methods used (see Table 4: Research questions and data collection and analysis methods overview). Prior to analysis, student data for this study was scrutinized against the inclusion criteria (completed grade ten academic or applied science in Ontario, consent and assent forms completed). The data linked to those students who did not match the inclusion criteria was subsequently removed.
### Table 4: Research questions and data collection and analysis methods overview table

<table>
<thead>
<tr>
<th>Phase</th>
<th>Research Questions</th>
<th>Data Collection</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>➢ What role does physics identity play in student course selection? (performance, interest)</td>
<td>➢ Questionnaire to inquire factors underlying students’ choices and the relationship between course selection and achievement</td>
<td>➢ descriptive statistics (level of agreement with statements)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>➢ inferential statistics (correlation between marks and course selection; correlation between marks and level of statement agreement)</td>
</tr>
<tr>
<td>2</td>
<td>➢ Why do students select or reject physics?</td>
<td>➢ individual semi-structured interviews (qualitative data to further explore why and why not physics)</td>
<td>➢ verbatim transcript, open coding, thematic analysis</td>
</tr>
<tr>
<td></td>
<td>➢ What role does physics identity play in student course selection? (recognition)</td>
<td>➢ Student drawings about scientists and physicists</td>
<td></td>
</tr>
<tr>
<td></td>
<td>➢ What other factors, extrinsic or intrinsic, affect student choice to pursue physics?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>➢ Why do students select or reject physics?</td>
<td>➢ Focus groups</td>
<td>➢ verbatim transcript, open coding, thematic analysis</td>
</tr>
<tr>
<td></td>
<td>➢ What role does physics identity play in student course selection?</td>
<td>➢ Student drawings about scientists and physicists</td>
<td>➢ thematic analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➢ Enrolment documentation</td>
<td>➢ descriptive analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>➢ thematic analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>➢ descriptive statistics (percentage of students opting out of physics)</td>
</tr>
</tbody>
</table>

#### 3.6.1 Questionnaire instrument analysis.** Once data was collected, the questionnaire was analyzed for its internal validity, factor analysis, and test-retest reliability using SPSS (Mac OSX V21.0.0). To determine the internal validity of the instrument, the coefficient alpha, $\alpha$, was calculated using the equation:

\[
\alpha = \frac{k}{k - 1} \times \left(1 - \frac{\sum s_i^2}{s_T^2}\right)
\]

where, $k$ is the number of items, $s_i^2$ is the variance of the individual item within the construct, and $s_T^2$ is the total variance of the sum of the items.

The correlation between statements was calculated, as well as Kaiser-Meyer-Olkin statistic, and Bartlett’s test of Sphericity. Based on those results I performed a factor analysis to determine the
number of dimensions with Eigenvalues above 1. The results were then considered and implications were identified.

To determine the test-retest reliability the intraclass correlation coefficient (ICC) using a two factor mixed effects model was calculated. The correlation coefficients were also calculated to look for differences in the overall results if either the students’ first or second responses were used.

3.6.2 Analyzing focus groups and interview data. Verbatim transcripts produced from the interviews and focus groups were thematically analyzed. Emergent themes were compared with the domains from the physics identity framework of Hazari et al. (2010), including: recognition, competence and interest. How performance in science influenced student course selection decisions was extracted primarily from the questionnaire data using inferential statistics calculated from the correlation between students’ marks in grade ten science and their other responses and ranking on the questionnaire.

3.6.2.1 Recognition and interest. Recognition and interest are also connected to the student drawings as recognition includes self-image and possible selves, while interest includes career goals (Hazari et al., 2010). To code the drawings I used the images, categories and guidelines included with the Draw-A-Scientist-Test Checklist (DAST-C) that is a validated instrument for assessing trends across grades, student age, gender and racial groups (Finson, Beaver & Cramond, 1995; Finson, 2002). The images and categories included on the DAST-C include: images (lab coat, eyeglasses, facial hair growth, symbols of research, symbols of knowledge, technology, relevant captions) and alternative images (gender, Caucasian, danger, light bulbs, stereotypes, secrecy, location, age, open comments) (Finson et al., 1995). From the gathered data, descriptive statistics was used to look at the percent of drawings that include common perceptions and attitudes students hold about physicists by looking at traits unique to students’ drawings of physicists.

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6 Permission to use the DAST-C for not for profit purpose was granted from Kevin Finson (personal communication, September 28, 2012).
Data on interest was also collected through the questionnaire, where students responded to the open-ended statement in the format “I would like to... because...”:

Assume that you are grown up and work as a scientist. You are free to do research that you find important and interesting. Write some sentences about what you would like to do as a researcher and why.

A thematic analysis of student responses revealed themes that were grouped into subcategories of the super order categories identified by Baram-Tsabari and Yarden (2005).

3.6.2.2 Performance. Inferential statistics were used to look at the correlation between student’s performance in science and the science courses students selected to study in grade 11, as well as the correlation between student’s performance and their attitude towards the utility of studying physics. Only 56 of the 63 questionnaires were used as one student did not want to report his/her mark, and six students indicated they could not recall their mark. Students may believe there is a correlation between past achievement and course selection and thus such a relationship may or may not be found (Gardner & Tamir, 1989). To assess if there is a correlation between students’ performance in science and the courses students selected for grade eleven, the correlation coefficient, r, was calculated using the following equation:

\[
r = \frac{n \left( \sum xy \right) - \left( \sum x \right) \left( \sum y \right)}{\sqrt{\left[ n \sum x^2 - \left( \sum x \right)^2 \right] \left[ n \sum y^2 - \left( \sum y \right)^2 \right]}}
\]

where \( n \) is the number of students, \( x \) is the self-reported mark of the student, and \( y \) is the course combination. Additional analysis was conducted on the results to explore the possible correlations between student’s performance in science and the combinations (or absence) of science courses they selected in study in grade eleven. There are other combinations students could have selected in science, but I only considered the prominent three (biology, chemistry and physics).
To determine if there is a correlation between a student’s mark with their level of agreement with each statement, the correlation coefficient, r, was calculated using the following equation:

\[
  r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{n \sum x^2 - (\sum x)^2} \cdot n \sum y^2 - (\sum y)^2}
\]

where \( n \) is the number of students, \( x \) is the self-reported mark of the student, \( y \) is the statement rating (that is, the student’s level of agreement).

### 3.7 Ethical considerations

An ethical review for this study was submitted to the University of Toronto Social Sciences and Humanities Research Ethics Board REB. The study was granted approval on June 28, 2012 (protocol reference #27710).

Snowball sampling was the source of recruiting participants and so the socioeconomic or socio-cultural background of the participants was unknown. The result was that the participants were between 14-16 years of age, from across eight school boards, including, twenty-eight public, Catholic, and Independent Schools, and three home-schooled students. The group vulnerability is low to medium based on the phase of the study (the focus group will have the greatest risk to participants as their participation is not anonymous in front of their peers). The research risk was low as participants were involved in a focus group, a questionnaire, and/or individual interviews, and the research topic is transparent. Parental permission was required for participation in this study. If parental permission was not granted then those students without permission were selected out of the study.

Student anonymity has been maintained throughout this study; the primary researcher only knows their identities. The exception to this is the Focus Group where anonymity could not be ensured, since students were participating with others who may choose to discuss the content of the discussions outside of the Focus Group. Students have been referred to by a pseudonym in any reports when students needed to be named to aid the reports readability. School data has also been kept confidential.
All records were kept in a locked filing cabinet for the duration of the study and will be destroyed five years after the study is completed. Audio recordings were erased after they were transcribed.

The next chapter will explicitly detail the participants’ profiles and findings from the data collected in order to answer the research questions of this study.
4. Findings and Discussion

4.1 Overview of this chapter

This chapter discusses the data collected from students who successfully completed grade ten science in either the academic or applied strand. Questionnaires, semi-structured interviews, and focus groups (each of four participants) were analyzed in relation to the research questions:

1. Why do students select or reject physics courses?
2. What role does physics identity play in student course selection?
3. What other factors, extrinsic or intrinsic, affect their choices to pursue physics?

This chapter is divided into two parts: participant profiles, followed by the discussion of the results in connection to the above listed research questions. All of the respondents were assured that their identities would be kept confidential. To this end all identifiers were either changed or removed from responses in questionnaires, transcripts and drawings, as well as all subsequent writings in connection to this study.

4.2 Participant profiles and context

The respondents spanned eight different school boards from within the Greater Toronto Area (GTA), including four public school boards (fifteen schools plus three home schooled), three Catholic school boards (six schools), and six Independent School boards (seven schools). Seventy-eight students: twenty-three female and fifty-five male students, all of who had completed grade ten science, participated in this study. Two of the participants completed grade ten science at an applied level and the remaining students completed grade ten science at the academic level. Also, two students had completed grade ten science in July 2012 and were entering their second year in September 2012; the remaining seventy-six students were entering or in their third year (or equivalent) of secondary school.

Eleven students were excluded entirely from this study and their data was removed as five did not return parental consent forms, and six did not attend grade ten in Ontario. Of the remaining students (N=67), sixty-three completed questionnaires. Five of these students completed the questionnaire a
second time (referred to as ‘redo’) for test-retest reliability purposes of the instrument (fifteen students who initially completed the questionnaire by pencil and paper were invited to redo the questionnaires online, students were sent reminders one week later, five students completed the questionnaires). This leaves sixty-three questionnaires linked to unique respondents that were included for the analysis of this study.

The remaining student participation within each phase is summarized in Table 5: Summary of final student participation. As different groupings of students participated in each phase of this study, I will describe the profiles (including their course selections and self-reported marks) of each phase separately.

<table>
<thead>
<tr>
<th>Table 5: Summary of final student participation (N=67).</th>
<th>Number of participants who completed the questionnaire</th>
<th>Number of participants who did not complete the questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaire only</td>
<td>51 (plus 5 questionnaire redo’s)</td>
<td></td>
</tr>
<tr>
<td>Questionnaire and interview</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Interview only</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Questionnaire and focus group</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Focus group only</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Total Participants</strong></td>
<td><strong>63 (plus 5 redo)</strong></td>
<td></td>
</tr>
</tbody>
</table>

4.2.1 Course selections and marks of questionnaire respondents. The sixty-three students that completed questionnaires came from eight different school boards within the GTA, including four public school boards (fifteen schools), three Catholic school boards (six schools), and six Independent School boards (seven schools). The students predominantly completed grade ten science in the academic stream (61 of 63 responses) with only two respondents in the applied stream.

It is important to note that the data collected from Independent School A is different in terms of course selection and marks reported as compared to those randomly selected respondents from the Catholic and public school boards. My contact teacher within Independent School A conveniently sampled students by asking his class of physics students to complete the questionnaire (forty-seven were asked and thirty-eight complied) as well as four students to participate in the focus group who
were all necessarily not taking physics. In comparing the courses selected by the randomly selected group and the course enrolment from the conveniently sampled students, there is a difference in the percentages of students that pursue each subject. As shown in Chart 3: Comparison of courses selected by Independent School A (series 1) and convenient sample (series 2), the convenient sample shows that the physics selections (SPH3U) make up 85% of the science courses selected with the fewest selections in biology (92% chemistry selections, SCH3U; 30% biology selections, SBI3U), which differs from the enrolment at the school, where the chemistry classes (68%) have the most enrolments, followed by physics (46%) and biology (36%). Course code explanations can be found in Table 6: Ministry descriptions of course codes.

Table 6: Ministry descriptions of course codes

<table>
<thead>
<tr>
<th>Course code</th>
<th>Description</th>
<th>Course code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBI-</td>
<td>Biology</td>
<td>SBI3C</td>
<td>Biology, grade 11, college preparation</td>
</tr>
<tr>
<td>SCH-</td>
<td>Chemistry</td>
<td>SCH3U</td>
<td>Biology, grade 11, university preparation</td>
</tr>
<tr>
<td>SPH-</td>
<td>Physics</td>
<td>SCH3U</td>
<td>Chemistry, grade 11, university preparation</td>
</tr>
<tr>
<td>SVN-</td>
<td>Environmental science</td>
<td>SCH4C</td>
<td>Chemistry, grade 12, college preparation</td>
</tr>
<tr>
<td>-C</td>
<td>College preparation</td>
<td>SPH3U</td>
<td>Physics, grade 11, university preparation</td>
</tr>
<tr>
<td>-E</td>
<td>Workplace preparation</td>
<td>SVN3E</td>
<td>Environmental science, grade 11, workplace preparation</td>
</tr>
<tr>
<td>-M</td>
<td>University/college preparation</td>
<td>SVN3M</td>
<td>Environmental science, grade 11, university/college preparation</td>
</tr>
<tr>
<td>-U</td>
<td>University preparation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These numbers differ significantly from the randomly selected sample where I found that the greatest number of selections were in biology (35%) and the fewest selections of physics (30% chemistry and 24% physics) (see Chart 4: Comparison of courses selected by participating public school board (series 1) and randomly sampled student (series 2). Comparing the random sample to one of the school
boards I found that the selections from the sample of students who participated within this study vary from the profile of course selections from the school board.

Also, the self-reported grades are higher for Independent School A than for the random sample with twenty-eight respondents (88% of those reporting a mark) reporting marks over 80% as compared to the random sample of seventeen respondents (59% of those reporting mark) reporting marks over 80%.

These differences are shown in Chart 5: Self-reported marks of respondents from Independent School A and Chart 6: Self-reported marks of respondents from random sample.
4.2.2 Course selections and marks of interview respondents. A total of eight students (six female and two male) participated in the semi-structured interviews. The respondents for the interviews came from three public school boards (five respondents attend a public school and one is homeschooled) and two Catholic district school boards (two respondents) from the GTA. All of the respondents completed grade ten science at the academic level. A summary of the science courses students elected to study in grade eleven is included in Table 7: Summary of self-reported grade ten marks and course selections for interviewees, along with their self-reported grade ten science mark.

<table>
<thead>
<tr>
<th>Respondent</th>
<th>Science Courses Chosen for Grade 11</th>
<th>Mark in Grade 10 Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adam</td>
<td>SCH3U, SPH3U</td>
<td>80-89%</td>
</tr>
<tr>
<td>Beverly</td>
<td>SBI3U, SCH3U, SVN3M, SPH3U</td>
<td>60-69%</td>
</tr>
<tr>
<td>D’Arcy</td>
<td>SBI3U</td>
<td>Does not remember</td>
</tr>
<tr>
<td>Erin</td>
<td>SBI3U, SCH3U</td>
<td>80-89%</td>
</tr>
<tr>
<td>Eunice</td>
<td>SBI3U</td>
<td>70-79%</td>
</tr>
<tr>
<td>Grace</td>
<td>None (intends SBI3U summer school 2013)</td>
<td>70-79%</td>
</tr>
<tr>
<td>Terry</td>
<td>SPH3U (others not reported)</td>
<td>Not reported</td>
</tr>
<tr>
<td>Zelda</td>
<td>SBI3U, SCH3U, SPH3U</td>
<td>80-89%</td>
</tr>
</tbody>
</table>

Six of the eight students reported that they had selected biology. I failed to ask Terry which courses he elected to take in addition to grade eleven physics (university preparation), but I would assume as he told me he intends on entering a career in the Health Sciences he is also going to take SBI3U. If this were the case, then instead of 75% of students selecting biology, it would be 87.5% that have selected grade eleven biology (university preparation). Four of the respondents selected grade eleven chemistry (university preparation) and four of the respondents selected grade eleven physics (university preparation). In the case of a student selecting a single science, the student chose biology.

4.2.3 Course selections of focus group respondents. Eight students (2 female, 6 male) in total participated in the focus groups. In the first focus group the four students attended the same semestered public school and had all selected to study physics in grade eleven. Two of them had completed the second week in their first semester physics course, and the other two respondents will begin their studies in physics in second semester. All of these students had started their third year of high school.
In the second focus group the four students attended the same non-semestered Independent School and none of them had selected to study grade eleven physics. Two of the students were in their second year of high school but were selected to participate by their teacher as they had completed grade ten science in the previous summer. Both of these students intended to take physics in their third year. The other two students were in their third year of secondary school. All of the students in the second group had elected to study chemistry and three of them had also selected biology.

4.2.4 Summary of course selections for participants. If you consider all the students included in this study across the data sources, their course selection looks like this (see Table 8: Overview of participants’ course selections):

<table>
<thead>
<tr>
<th>Course Selections</th>
<th>Biology (SB13C)</th>
<th>Biology (SB13U)</th>
<th>Chemistry (SCH3U)</th>
<th>Chemistry (SCH4C)</th>
<th>Environmental Science (SVN3M)</th>
<th>Science (SNC4M)</th>
<th>Physics (SPH3U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of course selections made by participants</td>
<td>2</td>
<td>35</td>
<td>52</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>47</td>
</tr>
<tr>
<td>Percent of participants</td>
<td>3 %</td>
<td>53 %</td>
<td>79 %</td>
<td>2 %</td>
<td>4 %</td>
<td>2 %</td>
<td>71 %</td>
</tr>
</tbody>
</table>

The remainder of this chapter discusses the findings with respect to instrument analysis and the guiding questions of this study.

4.3 Findings

I have divided this section into two: the first section discusses the results of the statistical analysis of the questionnaire as an instrument; the second section discusses the findings in relation to the guiding questions of this study.

4.3.1 Questionnaire instrument analysis results. To ensure the questionnaire is a valid instrument, test-retest reliability, internal validity, and factor analysis was performed using the results from the surveys. The questionnaire is found to be both reliable and internally valid (\( \alpha = 0.89 \)). The factor analysis showed that while the overall instrument can be used to explore a single main construct (student attitudes towards the relevance of physics education), it could be further divided into four
individual constructs (career, curiosity, and two undefined). These results are discussed in detail in the following three sub-sections.

4.3.1.1 Test-retest reliability. While fourteen of the sixteen statements showed changes in student rankings, most were only the strength of their either agreement or disagreement. However, five of the statements showed that students had changed their position of agreement: either from agreement to disagreement, or vice-versa (see Table 9: Statements that show a change in position of agreement).

<table>
<thead>
<tr>
<th>Table 9: Statements that show a change in position of agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1: “School physics is a difficult subject.”</td>
</tr>
<tr>
<td>3: “School physics is rather interesting for me to learn.”</td>
</tr>
<tr>
<td>9: “School physics has made me more critical and sceptical.”</td>
</tr>
<tr>
<td>11: “School physics has increased my appreciation of nature.”</td>
</tr>
<tr>
<td>13: “School physics has taught me how to take better care of my health.”</td>
</tr>
<tr>
<td>16: “I would like to get a job in technology.”</td>
</tr>
</tbody>
</table>

*Rankings: 1 disagree; 2 somewhat disagree; 3 somewhat agree; 4 agree

Of the five statements that showed a change in students’ positions of agreement, statement eleven seemed to be most problematic. The analysis of Statement 11, “School physics has increased my appreciation of nature,” using SPSS (Mac OS X V21.0.0) for ICC returned an error that indicated that it “violates the reliability model assumptions”. These findings combined suggest that statement eleven needs to be re-written and piloted in order to better measure its intended construct.

With the exception of statement eleven, no significant differences were found between the initial completions of the questionnaire with the second completions by the five students (see Table 18: Test-retest reliability results from SPSS (Mac OS X V21.0.0) for ICC, Appendix C). This indicates that the instrument is reliable. I also compared the correlation coefficients for the students’ first and second answers and found no significant differences. Therefore, I have used the students’ second responses for the rest of the analysis as their conditions may have changed since first answering the questionnaire.
4.3.1.2 Internal validity. The questionnaire was found to have internal validity (α = 0.89) for the sixteen items with a total variance of 92.22 (see Table 10: Variance and Cronbach’s alpha for relevance of physics education). This is interpreted to mean that the instrument is internally valid.

Table 10: Variance and Cronbach’s alpha for relevance of physics education

<table>
<thead>
<tr>
<th>Construct (k)</th>
<th>Item (s_i^2)</th>
<th>Variance for sum of items, (s_T^2)</th>
<th>Coefficient alpha, (\alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevance of physics education (16)</td>
<td>“School physics is a difficult subject.” (0.82)</td>
<td>92.22</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>“School physics is interesting.” (0.73)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“I like school physics better than most other subjects.” (0.99)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“School physics is rather interesting for me to learn.” (0.97)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“I think everybody should learn physics at school.” (0.96)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“I would like to have as much physics as possible at school.” (0.96)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“School physics has made me more critical and sceptical.” (0.92)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“School physics has increased my curiosity about things we cannot yet explain.” (0.68)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“School physics has opened my eyes to new and exciting jobs.” (1.09)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“I think that the physics I learn at school will improve my career choices.” (1.07)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“The things that I learn in physics at school will be helpful in my everyday life.” (0.94)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“School physics has shown me the importance of physics for our way of living.” (0.81)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“School physics has taught me how to take better care of my health.” (0.84)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“School physics has increased my appreciation of nature.” (1.09)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“I would like to become a physicist.” (0.65)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>“I would like to get a job in technology.” (1.32)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3.1.3 Factor analysis. I found that all of the statements correlate well (the determinant is 5.607 x 10^-5), but statements 6 (“I think everybody should learn physics at school”) and 13 (“School physics has taught me how to take better care of my health”) were flagged as potentially problematic (correlation coefficients are above 0.05). A factor analysis (KMO=.812; Bartlett’s test of Sphericity was significant) revealed four dimensions with Eigenvalues above 1. However, the last dimensions included statements 6 and 13 (Eigenvalues 1.104) (see Table 11: Statement groupings as determined by SPSS (Mac OSX V21.0.0) Factor Analysis). In analyzing the statements connected with the identified dimensions, the first two dimensions could be categorized as career (first) and curiosity (second), while the connections between the statements for the last two dimensions is unclear. As the internal consistency is considered acceptable for the instrument as a whole I have considered that the instrument
does measure a single factor that addresses the construct of students’ attitudes towards the relevance of physics education.

<table>
<thead>
<tr>
<th>Factor (Eigenvalue)</th>
<th>Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (6.846) Career</td>
<td>“School physics is rather interesting for me to learn.”</td>
</tr>
<tr>
<td></td>
<td>“School physics has opened my eyes to new and exciting jobs.”</td>
</tr>
<tr>
<td></td>
<td>“I like school physics better than most other subjects.”</td>
</tr>
<tr>
<td></td>
<td>“I think that the physics I learn at school will improve my career choices.”</td>
</tr>
<tr>
<td></td>
<td>“School physics has made me more critical and sceptical.”</td>
</tr>
<tr>
<td></td>
<td>“I would like to become a physicist.”</td>
</tr>
<tr>
<td></td>
<td>“I would like to have as much physics as possible at school.”</td>
</tr>
<tr>
<td></td>
<td>“I would like to get a job in technology.”</td>
</tr>
<tr>
<td>2 (1.672) Interest</td>
<td>“School physics is interesting.”</td>
</tr>
<tr>
<td></td>
<td>“School physics has increased my curiosity about things we cannot yet explain.”</td>
</tr>
<tr>
<td></td>
<td>“School physics has increased my appreciation of nature.”</td>
</tr>
<tr>
<td></td>
<td>“School physics has shown me the importance of physics for our way of living.”</td>
</tr>
<tr>
<td>3 (1.195) Unknown</td>
<td>“School physics is a difficult subject.”</td>
</tr>
<tr>
<td></td>
<td>“The things that I learn in physics at school will be helpful in my everyday life.”</td>
</tr>
<tr>
<td>4 (1.104) Unknown</td>
<td>“I think everybody should learn physics at school.” (statement 6)</td>
</tr>
<tr>
<td></td>
<td>“School physics has taught me how to take better care of my health.” (statement 13)</td>
</tr>
</tbody>
</table>

4.3.2 The research questions. I draw upon both qualitative and quantitative data collected, and subsequent analyses, to address the sub-questions of this study:

1. Why do students select or reject physics courses?
2. What role does physics identity play in student course selection?
3. What other factors, extrinsic or intrinsic, affect their choices to pursue physics?

4.3.2.1 Why do students select or reject physics courses? I was able to delve deeper into the factors that directly impacted student’s course selection choices through interviews with sixteen students (eight interviewees and eight focus group participants). When asked directly why students did (not) choose to study physics, fifteen of the sixteen students (eight interviewees and seven focus group participants) stated their reasons. The ten students who chose physics stated that they did so either because it was a requirement for the post secondary program they wanted to pursue (six), they held an interest in physics (four), or that physics is easy because it is absolute (one).

The six students that opted not to study physics explained that they heard physics is difficult since it uses mathematical formulas (three), they did not know what physics was (two), physics was not a requirement for university (one), or they did not want their average to drop (one).
I really had no idea what a physicist was at all (Kristen, interview, September 15, 2012)

I think... ‘cause I don’t know exactly what physics is. From what I did take in a physics unit we did in my science class it involves math... I think that is why for me it would be harder because math is hard for me (D’Arcy, interview, September 2, 2012).

I think the reason why [I didn’t pick physics] is because I heard it is similar to chemistry, kind of, with all the formulas. And I do not like chemistry, so, and physics is not where I’m going so I don’t want to waste my time doing it when really I’m not going to use it (Eunice, interview, September 8, 2012).

I have a pretty limited understanding of physics is... I sort of thought, at least, that it was sort of [the] study of force and energy and data, also (Pedro, interview, October 18, 2012).

In each focus group, one respondent drew about physics rather than depicting a physicist because they knew that physics had to do with forces or motion but felt unable to draw the person who would study those types of phenomena (see Figures 7 & 8: DAST Physicist by Kristen (left) and Pedro (right)).

When comparing the answers given from the two groups (those taking physics and those that are not) university admissions is a common theme. Students explained that ease or difficulty translated into the ability to receive a good mark, and those students that were asked all wanted to keep their options open to attend a university. Specifically, seven students expressed that university requirements influenced their decisions (six are taking physics because it is a requirement for a program they want to study, and one is not taking physics because it is not needed for their intended program of study), and
five students referred to their need to maintain a higher average (one chose physics because he thinks it will be easy, and four avoided physics because they think it will be hard). Xi-Wang explains this:

Physics is always been perceived as a difficult subject, which is why I haven’t taken it... I mean physics is definitely a tough course. I’ve seen a lot of smart kids do very poorly in physics, so, it kind of pushes you away [from] it... someone who goes from nineties to seventies [is poorly] (interview, October 18, 2012).

For students, studying physics and physics as a branch of science are also two different things. Beverly made this interesting distinction when explaining why she chose to study physics:

One of the reasons [I chose physics] is because I really love science. I really enjoy physics. I wouldn’t say I really like physics, or would enjoy doing it in class, but what I want to do is to investigate physics; learn more. Because, I was really interested in the convex mirrors and since they are giving us a course in physics in grade eleven I really want to take it (interview, August 17, 2012).

Here, Beverly tells me she wants to know more about physics but does not really want to study it in school. This is congruent with the ROSE Project (2010) findings that students have positive attitudes towards science but are less enthusiastic about school science.

**4.3.2.2 What role does physics identity play in student course selection?** Recall that the framework of science identity by Hazari et al. (2010) is broken into four domains: recognition, performance, competence, and interest. By applying this framework specifically to physics and using those domains as prefigured categories to code the transcripts from the interviews and focus groups, I found that students indicated they experienced influences from all of these domains to varying degrees. Subsequent readings of the transcripts revealed emergent subcategories. The final categories and subcategories are summarized in the Table 12: Summary of coding categories and sub categories.

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognition</td>
<td>Parental expectations, self image and possible selves</td>
</tr>
<tr>
<td>Performance</td>
<td>Performance</td>
</tr>
<tr>
<td>Competence</td>
<td>Math-type, science-type</td>
</tr>
<tr>
<td>Interest</td>
<td>Career, physics as absolute, interest</td>
</tr>
<tr>
<td>Other extrinsic or intrinsic factors</td>
<td>University, the unknown, classes with friends</td>
</tr>
</tbody>
</table>
The next four subsections look specifically at how the domains of physics identity influenced students as they made their course selections.

4.3.2.2.1 Recognition. Hazari et al. (2010) describe how recognition for a student, which may come from family, teachers, and peers, can shape a student’s self-perception of their ability in science. Applying this specifically to physics education, I asked students about parental expectations and recognition, peer influences, and to a lesser degree teacher influences. There was some evidence of parental expectations that may have influenced students’ course selections as the strand (college, university, mixed or open) they selected but not the type of course. The drawings students produced of physicists cross referenced to their ratings of statements on the questionnaire about becoming a physicist or working with technology indicated that their view of what they think it means to be a physicist is incongruent with their own self-image and so acts as a deterrent to selecting physics (Aikenhead, 1996; Cleaves, 2005; Dellar, 1994; Leonardi et al., 1998). The next two sub sections discuss these findings in detail.

4.3.2.2.1.1 Parental Expectations. Cleaves (2005) notes that parents (in particular mothers) held the most influential position with students, and student course selection. Guidance counselors at students’ home schools were reported, for the most part, to be information dispensers about the mechanics of course selection (whether it be online or filling out paperwork) rather than playing an integral part of goal setting or outlining course pathways to meet the requirements for future careers. When asked about conversations students had with their parents, students made it clear that their parents were significant sounding boards for their decisions rather than decision makers. The general message was that the students were supported, perhaps even guided by their parents, but were ultimately allowed to select the courses they wished without parental interference.

[My parents] let me do [my] own thing. They said, “it’s your career, so you can choose whatever you want” (Terry, interview, September 9, 2012).
The nature of “guiding” seemed to depend on the parents’ professions. Of the eight students interviewed, three have parents who are teachers, and two of these students expressed the greatest involvement of their parents with respect to the course selection process.

[My mother] helped me decide for some courses, giving me pointers and tips on what would be useful courses for me and I would try to steer towards those courses (Adam, interview, August 11, 2012).

[Speaking to a guidance counselor at my father’s school] was helpful because it opened my eyes to many new different job opportunities and informed me on what courses I would need to take and the marks I would need to get (Zelda, interview, September 7, 2012).

Those students who did not have a teacher-parent still maintained that their parents were involved. The nature of this involvement varied. For example, Beverly indicated that she “didn’t want [her parents] to think too much about [her] educational plan” (interview, August 17, 2012); Grace explained that her parents did not influence her decisions at all, while other respondents spoke with one parent more than the other. Students did report that their parents held either neutral or positive attitudes towards science in general and none reported that their parent(s)/guardian(s) held a negative attitude towards science.

Whether or not this translated into an expectation that the students should take science is unclear. Only one student vocalized that her mother thought that taking a science when science is no longer mandatory to graduate was a good idea even though science may not be in her future career plans.

So [my mom] said to choose whatever you’re interested in. Said to choose a science because they don’t... science isn’t mandatory anymore. But she thought it was a good idea (D’Arcy, interview, September 2, 2012).

This recommendation was made even though D’Arcy revealed that she had difficulties in science last year and had required a tutor. Later, when asked how she felt about her course selections D’Arcy revealed she felt nervous about taking a university level science as “biology sounds pretty hard” (interview, September 2, 2012). For D’Arcy, I interpret her following her parental recognition as a more significant influence in course selections than competence.
Amongst all of the student descriptions there is an absence of parental expectations for the students to take physics over any of the other sciences. While parents did not express negative attitudes towards science, Ida revealed that her parents thought that physics was challenging.

Well, my parents have always given me the impression that physics is very hard for most people. Especially... it’s one of those things where (well I get them)... but, it’s one of the things that if you don’t understand it quickly, or if you just don’t understand, it’s hard to make yourself understand it, that’s all (interview, September 15, 2012).

Even though Ida selected to study physics, because she believes it is “life knowledge,” she already feels that physics is a subject that will be difficult, a belief, which she identifies as stemming from her parents.

My analyses suggests that parental recognition is an important factor in student course selections as it pertains to pursuing a path to university (students reported that their parents recognized them as university bound students), but not specifically towards a specific career (the students did not tell me about their parents recognizing them as good at science or physics). With respect to physics, it is inconclusive whether or not parental recognition would influence a student’s decision to select it for further studies.

4.3.2.2.1.2 Self image and possible selves. Students are more likely to select subjects that they can associate with their self-image and their possible selves (Aikenhead, 1996; Cleaves, 2005; Dellar, 1994; Leonardi et al., 1998). When asked if students would like to become a physicist on the questionnaire, students disagreed (1.63 +/- 0.81) with the statement “I would like to become a physicist.” Out of sixty-three respondents on the questionnaire only one student selected Agree (and this student explained that he considered physics to be a back-up plan to his present career choice), nine students Somewhat Agree, and the remaining fifty-three students either Somewhat Disagreed or Disagreed (84%).

Students also revealed in the interviews and focus groups their own classification of types of students; some students are science types and some are not. Eunice made the distinction between
herself and her friend and competencies in science. She describes her friend as more “science-minded” while she herself has difficulty thinking in terms of formulas. After completing her own drawing of a physicist I asked her how her drawing would be different for other types of scientists. She tells me a biologist would be more “artsy” - more like her. This is significant as Eunice has selected to study biology rather than physics as biology is more interesting to her, aligns more with the image she has of herself as artsy, and she thought she would be more successful in biology than physics. Her representation and modification of the scientist drawings echoes Leonardi et al. (1998) findings that students link positive possible selves to personal control and success. Similarly, Pedro’s self-image has turned him towards sciences other than physics.

I didn’t study physics because it is not my strong suit. I am better inclined towards the art side of the spectrum, but because of my desire to keep my options opened I have taken what I feel (based on other peoples opinions, and my own personality) are the easier sciences, and the sciences [that] better suit my strengths. These choices are biology and chemistry (interview, October 24, 2012).

Here, Pedro explains that course subjects are part of a spectrum, with art lying in one part separated seemingly by a great distance from physics.

To further explore this concept I asked students in the interviews to draw what they think a physicist would look like, and to explore possible connections to self or self-image. In general, the participants seemed unsure about how a physicist would appear.

I don’t think it would be any different, maybe the outfit a bit. Maybe they don’t even wear lab jackets at all. Because I’ve never seen a physicist person (Beverly, interview, August 17, 2012).

I’m not exactly sure. Wasn’t Einstein a physicist? (Erin, interview, September 2, 2012).

Those are chemicals or whatever they would be working with. That’s what I would picture. I’m not exactly sure what a physicist is (D’Arcy, interview, September 2, 2012).

After the initial results from the interviews, to clarify whether students made distinctions between physicists and scientists I asked the focus group participants to draw first a scientist (see
While students laughed at the images that came to mind, recognizing that there would not be a single type of person that would be a scientist or physicist, many used descriptors like “typical” or “scientist-looking” to help express the image that came to their mind.

What comes to mind is the typical physicist - a man in a white lab coat with crazy hair, but realistically I know that is false (Zelda, interview, September 7, 2012).

I think of a scientist-looking person... And whenever I think of a physicist I think of a person like that. A person with curly, kind of messy hair and glasses, and a scientist’s outfit on (Eunice, interview, September 8, 2012).

I used the Draw-A-Scientist-Test-Checklist (DAST-C) (Finson et al., 1995) and analyzed the drawings looking for (stereotypical) image characteristics. Findings are presented in Table 13:

Summary of themes from descriptions and drawings of scientists and physicists.
Table 13: Summary of themes from descriptions and drawings of scientists and physicists.

<table>
<thead>
<tr>
<th>Image characteristics</th>
<th>Generic Scientist (all)</th>
<th>Physicist (all)</th>
<th>Generic Scientist (Focus Group)</th>
<th>Physicist (Focus Group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab coat</td>
<td>9 (100%)</td>
<td>7 (47%)</td>
<td>8 (100%)</td>
<td>2 (25%)</td>
</tr>
<tr>
<td>Eyeglasses</td>
<td>7 (78%)</td>
<td>6 (40%)</td>
<td>7 (88%)</td>
<td>3 (38%)</td>
</tr>
<tr>
<td>Facial Hair</td>
<td>0 (0%)</td>
<td>2 (13%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Symbols of research</td>
<td>6 (67%)</td>
<td>9 (60%)</td>
<td>6 (75%)</td>
<td>6 (75%)</td>
</tr>
<tr>
<td>Symbols of knowledge</td>
<td>4 (44%)</td>
<td>6 (40%)</td>
<td>4 (50%)</td>
<td>5 (62%)</td>
</tr>
<tr>
<td>Technology</td>
<td>0 (0%)</td>
<td>5 (33%)</td>
<td>0 (0%)</td>
<td>5 (62%)</td>
</tr>
<tr>
<td>Relevant captions</td>
<td>0 (0%)</td>
<td>4 (27%)</td>
<td>0 (0%)</td>
<td>2 (25%)</td>
</tr>
<tr>
<td>Male</td>
<td>9 (100%)</td>
<td>11 (73%)</td>
<td>8 (100%)</td>
<td>6 (75%)</td>
</tr>
<tr>
<td>Caucasian</td>
<td>9 (100%)</td>
<td>13 (87%)</td>
<td>8 (100%)</td>
<td>6 (75%)</td>
</tr>
<tr>
<td>Indications of danger</td>
<td>4 (44%)</td>
<td>4 (27%)</td>
<td>4 (50%)</td>
<td>3 (38%)</td>
</tr>
<tr>
<td>Presence of light bulbs</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Mythic Stereotypes</td>
<td>2 (22%)</td>
<td>2 (13%)</td>
<td>2 (25%)</td>
<td>1 (12%)</td>
</tr>
<tr>
<td>Indications of secrecy</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Scientist doing work indoors</td>
<td>7 (78%)</td>
<td>6 (40%)</td>
<td>7 (88%)</td>
<td>4 (50%)</td>
</tr>
<tr>
<td>Middle aged or elderly scientist</td>
<td>6 (67%)</td>
<td>7 (47%)</td>
<td>6 (75%)</td>
<td>4 (50%)</td>
</tr>
<tr>
<td>Open comments - big/crazed hair</td>
<td>6 (67%)</td>
<td>7 (47%)</td>
<td>6 (75%)</td>
<td>1 (12%)</td>
</tr>
<tr>
<td>Open comments - math</td>
<td>0 (0%)</td>
<td>5 (33%)</td>
<td>0 (0%)</td>
<td>5 (62%)</td>
</tr>
</tbody>
</table>

Of the drawings and descriptions that were completed, ten of twelve were clearly male. The remaining two are androgynous, and the descriptions of the drawings given by the students use gender-neutral language (see Figures 11 & 12: DAST Physicist by Eunice (left) and D’Arcy (right)). Consistent with Hazari et al. (2010) if the drawings are of men, they are simply depicted as “non-female” but with no obvious indications of being male. In none of the drawings was facial hair included. In the verbal descriptions of physicists given over the Internet, Einstein is used as a descriptor in two. Whether this descriptor included his famous moustache is unclear, as one focus group participant had told me he thought of Einstein but the student had not included any facial hair in his drawing.
In comparing specifically the drawings of physicists and generic scientists, I found that students think physicists are less likely to wear lab coats or have big/crazed hair, however they are more likely to use technology and math (see Figures 13 & 14: DAST Physicists performing calculations Ida (left) and Lance (right)).

From the focus groups (where students were asked to draw first a generic scientist and then a physicist) five of the seven drawings show physicists using technology, whereas none of the generic scientist drawings include technology.
Cause I think physicists use really intense machines... atom destroyer things... atom separators (Ida, interview, September 15, 2012).

The data from the questionnaire sheds light on the significance of linking physics careers to technology. The responses to the statement “I would like to get a job in technology” indicate that twenty-three (34%) whom Somewhat Agree or Agree, while the majority of students were disinclined to want careers in technology field (2.45 +/- 1.15). The majority of students surveyed do not see themselves holding careers in technology, and students connect physics to technology (as shown in their drawings). It is possible that the combination of students’ beliefs that physics is a difficult subject and its reliance on technology turns students away. This incongruence of physics with their possible selves may influence their decision to reject senior physics.

To summarize my analyses, students’ views of a physicist do not match their view of what they see themselves becoming. Students often link physics to technology; neither being a career that these students generally indicate they wanted to pursue. While it may seem counter intuitive that students would not like a career in technology considering the incredible usage of technical gadgets (the Piper-Jaffray DECA Teen Opinion survey revealed that 40% of participating teens in the United States have an iPhone (Rosati, 2012)), this study did not explore what a career in technology meant to these students. This omission creates an interesting opportunity for future study.

4.3.2.2.2 Performance. Unlike the findings of Gardner and Tamir (1989) there was no correlation between the student’s mark and their desire to enrol in senior science (three students indicated they were not going to take any more science courses and all three had marks between 70-79%). This may be because students who enjoy science in general were more likely to have participated in this study. Looking only at the random sample, I did find a mild positive correlation between a student’s mark and their selection to study grade eleven university physics \(r=.263\) (students with higher marks are less likely to agree with the statement “school physics is difficult”, \(r=-.283\), significant at 0.05 level (2-tailed)), and a mild positive correlation between a student’s mark and the number of
science courses the student selected ($r=.215$). These correlations, however, are statistically weak and insignificant.

However, looking at the trends of course selection with respect to performance in grade 10, the data suggests that the higher the mark in grade ten science the more students tended to select physics (60%-69% two students selected physics, 70%-79% one student, 80%-89% six students, and 90%-100% five students). This is not to the exclusion of biology, but often in combination with biology and/or chemistry. More is said about this in the next section.

4.3.2.2.1 Relationship between course selection and self-reported marks. I used descriptive statistics to explore the relationships between the specific science courses students selected and their self-reported grade ten marks. A summary of the courses students selected is found in Table 14: Course selections related to self-reported marks and displayed in Chart 15: Courses selected by marks for all students (note: none of the students selected Earth and Space Science (SES4U); Physics - Grade 12, College (SPH4C); or, Science - Grade 12, Workplace (SNC4E)).

<table>
<thead>
<tr>
<th>Mark</th>
<th>Course</th>
<th>SBI3C</th>
<th>SBI3U</th>
<th>SCH3U</th>
<th>SVN3M</th>
<th>SPH3U</th>
<th>SCH4C</th>
<th>SNC4M</th>
<th>Other</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-69%</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>70-79%</td>
<td>1</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>80-89%</td>
<td>0</td>
<td>10</td>
<td>21</td>
<td>1</td>
<td>20</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>90-100%</td>
<td>0</td>
<td>10</td>
<td>16</td>
<td>0</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Chart 15: Courses selected by marks for all students
In general, the lower the student’s mark the more likely they are to select biology over the physical sciences (chemistry and physics), while those students with higher marks being more likely to select the physical sciences. I found that there was very little variation between which science course a student would select and their mark for students with marks that fall between 60-69% and 70-79%. However, students with marks reported of 80-89% and 90-100% were 1.5 times more likely to select physical sciences (chemistry and physics) at the university level than biological sciences.

When considering combinations of biology, chemistry, and physics (there are other possible combinations but I have only considered the top three based on number of selections) that students could select, those students with marks above 80% never selected grade eleven biology to the exclusion of chemistry or physics (always with one or both), but students did select the physical sciences (chemistry and physics) without selecting biology. These results are summarized in Table 15: Course selection combinations of grade 11 university level biology, chemistry and physics selected by grade ten students.

Table 15: Course combinations of grade 11 university level biology, chemistry and physics selected by students

<table>
<thead>
<tr>
<th>Mark Range</th>
<th>None</th>
<th>SBI3U</th>
<th>SCH3U</th>
<th>SPH3U</th>
<th>SBI3U, SCH3U</th>
<th>SBI3U, SPH3U</th>
<th>SCH3U, SPH3U</th>
<th>SBI3U, SCH3U, SPH3U</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-69%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70-79%</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>80-89%</td>
<td></td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>12</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90-100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

Using inferential statistics, I found a mild positive correlation (r=0.339, significant at 0.05 level (2-tailed)) between the student’s mark and the course combination of the courses selected. This is interpreted to mean that the higher a student’s grade ten science mark the more apt the student is to select courses in physical sciences or combinations of courses that include physical sciences rather than just biology. This result is displayed in Chart 16: Course combinations selected by marks for all students. Removing the data from Independent School A, the trend of students with higher marks taking physics still occurs (r=0.401, significant at 0.05 level (2-tailed)). This can be seen in Chart 17: Courses
selected by marks from random sample, and Chart 18: Course combinations selected by marks from random sample.

Even as students are still largely selecting biology, there is a dramatic increase in enrolment in chemistry and physics with students reporting marks in the range of 80% and above.
4.3.2.2.2 Level of agreement with statements on questionnaire. In general, students agree that although physics is difficult (83%) it will improve their career options (78%) without necessarily becoming a physicist (84%) or working with technology (48%) (see Table 19: Relevance of physics education, Appendix C). Students also agree that physics has inspired interests they can relate to in their own lives. Using inferential statistics, I also found that the higher a student’s mark in grade ten science the less difficult they think school physics will be (mild negative correlation, $r=-.33$) and the more likely the student is to want a job in technology (mild positive correlation, $r=.34$). There are other factors (such as satisficing, providing socially desirable answers, marks in other subjects) that could influence the student’s ranking on a statement, therefore, it should not be interpreted that the grade ten science mark alone would result in specific attitude toward physics education.

When comparing the responses of the randomly selected students with those of the convenient sample, findings suggest that they differ substantially in whether or not a correlation is found between students’ marks and their level of agreement. In the single school sample, nine of the sixteen items found an absence of correlation between student marks and their level of agreement with each statement (see Table 20: Correlation coefficient, $r$, between students’ marks and their questionnaire statement ratings, Appendix C). Notable differences between the two groups were found as summarized in Table 16: Notable correlation differences between samples.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Correlation coefficient, Independent School A, $r_{sa}$</th>
<th>Correlation coefficient, random sample, $r_{rs}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>“School physics is interesting”</td>
<td>-.01</td>
<td>.35</td>
</tr>
<tr>
<td>“School physics has opened my eyes to new and exciting jobs”</td>
<td>-.01</td>
<td>.22</td>
</tr>
<tr>
<td>“School physics has increased my appreciation of nature”</td>
<td>-.01</td>
<td>.20</td>
</tr>
<tr>
<td>“School physics has taught me how to take better care of my health”</td>
<td>.22</td>
<td>-.18</td>
</tr>
</tbody>
</table>

The students from Independent School A have marks that only span three ranges (70-79%, 80-89% and 90-100%), which may account for the absence of correlation between their marks and their level of
agreement with each statement. While the instrument is internally valid \((\alpha = 0.89)\) these differences indicate that the two groups differ in how students’ marks correlate with their perspectives on the relevance of physics education to their careers and physics education’s general utility, but not their level of agreement with the statements.

4.3.2.2.3 Competence. The domain of competence in Hazari et al. (2010) centres around the “student’s belief they can understand the subject’s content” (p. 982). Consider for a moment, a typical school science trajectory. In grade one, students are first exposed to the concept of energy. Throughout elementary school Ontario students learn about simple machines, forms of energy, climate change and other topics. Once they reach secondary school, their science classes are divided into four areas of study, including: Biology, Chemistry, Earth and Space Science, and Physics (it could be argued that students study two units of physics within each of these years as Earth and Space Science is introductory astronomy (celestial objects, space exploration) in grade nine and introductory meteorology (weather, climate change) in grade ten). The physics units include electricity in grade nine and optics in grade ten. Within each of the physics units students continue to develop their understanding of energy (Ontario Ministry of Education, 2008b). Up to this point, the mathematics is limited to the use and manipulation of three variable equations (such as, \(V = IR\) or \(n = \frac{c}{v}\)).

In this study the participants repeatedly talked about their belief that school physics is difficult, and only Terry explicitly said that physics was easy. The students reported thirty times over eight interviews that physics is rumored to be a difficult, math-laden subject in the senior years.

I heard physics is pretty difficult in grade 11... I heard physics is mainly math, which I am not a huge fan of, opposed to biology, which has nothing to do with math, and chemistry, which mainly has to do with multiplication (Zelda, interview, September 7, 2012).

From the drawings of physicists produced by the focus group participants many pictured a physicist using technology for experiments or calculations (62%), and frequently performing
mathematical calculations (62%) (see Figures 19 & 20: DAST Physicists performing calculations Xi-Wang (left) and Nigel (right)).

He is thinking about equations, he is thinking about laws, he is thinking about force movement. It all has to do with physics (Terry, interview, September 9, 2012).

I think that is why, for me, [physics] would be harder because math is hard for me, too. So, I think that is probably the main reasoning saying it is harder for me. There would be one more thing I don’t understand. I already don’t understand science, but then you add math equations on top of it... that makes is worse for me (D’Arcy, interview, September 2, 2012).

And he’s on his desk he’s frustrated. He’s looking at his papers with, like, a chart on it and information. And there’s, like, a whole stack of them. He also has a computer to help him. And he has a garbage can full of wrong results, too (Ida, interview, September 15, 2012).

The difficulty of senior physics courses seems to be amplified by students’ lack of knowledge about physics as a subject. While some students believe that they will just have to “work harder” to be successful (congruent with the findings of Leonardi et al., 1998), others avoid physics at all costs due to its perceived difficulty, reliance on math, and their belief that they will not be able to succeed in the subject. Some students also spoke about the belief that physics is a subject that you either understand or you don’t.

I’m choosing biology because... I’m not really a chemistry/physics kind of person, because, to me, that kind of stuff doesn’t really come easily (Eunice, interview, September 8, 2012).

In any other subject you actually... even if you don’t pay attention in class, you take notes down and just not even understand. But you can go home and actually study it, right? But then, in
terms of physics, you have to actually listen in class, and if you don’t get the materials, and you
don’t find out, then either way, even if you study twelve hours, ten hours, in order of physics
you will still not get it (Nigel, interview, October 18, 2012).

But [physics] is one of those things that if you don’t understand it quickly, or if you just don’t
understand it, it’s hard to make yourself understand it, that’s all (Ida, interview September 15,
2012).

Many students connect this intangible ability to understand physics with a competency in math.

It’s like you can understand the theory but then understanding how the formula backs up the
theory is also really difficult. So, I think that sometimes the concepts can be easy just to say I
understand and take it for what it is and then once you through bit of a formula in there then you
have to understand how they correlate and all that kind of stuff. I think that is what is really hard
about it (Xi-Wang, interview, October 18, 2012).

The focus group respondents shared what they thought their own math competencies were by using a
scale of 1 to 10 (1 is abysmal and 10 is brilliant). Of those selecting physics, they rated their math
competency from 7 to 9 (on a scale from 1 to 10, with one preferring not to respond) and those not
selecting physics ranging from 5 to 8. Using the Fraser Report (2011) I found that the participants’
schools ranged in their EQAO scores from level 2.5 to level 3.3, where level 3 is considered the
provincial average (Cowley et al., 2011). In the case of the focus groups, both schools scored above the
provincial average on the EQAO. The range in self-professed competencies indicates that a school’s
EQAO score is not indicative of a student’s perception of their math competence.

Repeatedly, students expressed that their marks were of concern for their grade eleven year,
even a “driving factor” that would influence their decisions about the courses they would take.

I just need to get good marks. And I just choose my courses according to what will get me A’s,
nineties, eighties, that kind of thing (Terry, interview, September 9, 2012).

So [my parents and I] talked about how it was important that I take certain classes and
remember that grades are very important this year (Zelda, interview, September 7, 2012).

I am taking mixed math so my average does not drop, and I don’t need to take functions to do
what I would like to do in the future (Grace, interview, August 31, 2012).

With the common intent that they will enter into a university program upon completing their secondary
education, students are selecting courses that are requirements for their programs and that will allow
them to get the best combined average to meet university entrance cutoffs. Of the respondents, only one indicated he has selected physics because he finds it easy to understand.

Physics comes easy to me... I’m very equation based; either right or wrong (Terry, interview, September 9, 2012).

Whereas most students expressed a dislike of math and used this as a point of concern about taking physics or as an actual deterrent, Terry embraced physics and predicted his success due to his mastery of mathematical manipulations and his perception that physics has a heavy reliance on formulae.

In summary, competence influenced students’ decisions to select or reject physics. While math was discussed, it was not explicitly connected to a student’s success in physics. Competence was tightly tied to what mark students thought they could achieve in physics, which was preferentially influenced by reports supplied from upper year students over the students’ own experiences. If students thought the mark would be too low to be used for university acceptance then students opted not to take physics unless physics was required for their intended university program. This is congruent with Kessels et al. (2006) who found that students avoid courses in which they think they will not do well.

4.3.2.2.4 Interest. Interest is the final domain in Hazari et al. (2010) science identity model. Interest is complex as it relates to intrinsic interests as well as extrinsic interests, and these interests may not be mutually exclusive. For example, someone may have a general interest in space travel (intrinsic); someone else may have an interest in space travel because it is a requirement of his or her occupation (extrinsic). A data analysis suggests that student course selections are heavily influenced by careers they want to enter, and as a result, the educational requirements to enter those careers. Only a few students stated that their choice to take physics was motivated by curiosity about the subject. Students also seem to share the view that physics’ reliance on math forces it to converge on a single absolute truth; this view acted as both a deterrent and motivation to select grade eleven physics. The following three subsections explore in detail students’ interests in science and physics, their intended careers, and finally the view of physics as a science that is regimented, unvarying, and absolute.
4.3.2.2.4.1 Physics as a subject. Course selection in grade ten is a pivotal point in an Ontario student’s scholastic secondary school career as he/she is allowed six electives, which is more than in previous years (one elective in grade 9 and three electives in grade 10). There is a common theme from participants in this study that they believe that the courses they have elected to study will make school more enjoyable than in previous years. Erin expressed great enthusiasm about her courses:

I’m really excited for this year! Every other year we only got to choose 1 or 2 courses... but this year we basically get to choose the entire thing... that’s really exciting for me! And I’m really happy with the courses I’ve selected. I’m really into science, math, business and the arts... & all my courses relate to one of those so.... Just generally excited for subjects I actually enjoy:) (Erin, interview, September 2, 2012).

Students told me about their interests in “unnecessary” courses, which included: writing, history, music, and law. To explore students’ interests in science, they were asked to respond to the statement:

Assume that you are grown up and work as a scientist. You are free to do research that you find important and interesting. Write some sentences about what you would like to do as a researcher and why.

Sixty-three students responded to the statement and I produced a word cloud of the students’ responses and found that it prominently displayed the words “space,” “cancer,” and “cure” (see Figure 21: Word cloud of student’s responses when asked to pursue scientific research).
Thematic coding of the responses revealed seventy-nine subcategories that were grouped into categories identified by Baram-Tsabari and Yarden (2005), including: astrophysics, Earth science, human biology, physics, technology, zoology and other (see Table 17: Example of student responses for each category). Predominantly students expressed an interest in human biology (30.4%) followed by astrophysics (22.8%), with the least interest in physics (2.5%) (if one considers astrophysics and physics together, this makes 25.3% of the codes).

**Table 17: Examples of student responses for each category.**

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub category</th>
<th>Example</th>
<th>Percent responses</th>
</tr>
</thead>
</table>
| Astrophysics | astrobiology (3), astronomy (3), gravity (1), space missions (2), universe (6), other (3) | “I would like to research about outer space because I would like know if there is life in outer space.”
“I would like to research how physics on Earth is different from physics from SPACE, because space has always fascinated me and I would like to see the differences/similarities between them.” | 22.8%             |
| Earth Science| energy (2), environment (3), marine environment (2), origin (2)               | “I would like to research the possibility of turning salt water into normal drinking water because with the world being one 30 percent drinking water and the other 70 percent being salt water, humans will run out one day. To find a way to make salt water not only drinkable but also safe is very critical and important for man itself to live.” | 11.4%             |
| Human biology| behaviour and neurobiology (2), genetics and reproduction (3), kinesthetic (1), nutrition (1), sickness and medicine (17) | “I would like to research human behaviour in stressful situations because it interests me and the information found during the process would be helpful in helping people cope in high-stress situations.”
“I would like to research in the field of medicine in paediatric plastic surgery. I would like to discover more ways how to perform surgery on children who have suffered serious burns and serious injuries and to help these children recover faster so they could get back to doing what they love because I, myself had to undergo surgery and it took me quite a few weeks to recover from my surgery.” | 30.4%             |
| Physics      | quantum physics (1), velocity (1)                                             | “I would like to do research about efficient ways for one to calculate and expand on topics related to velocity. The reason for this is because not only would this substantially give an advantage to the daily lives of our human civilization in terms of technology and efficiency; however, a possibility for me to discover more and expand on these topics.” | 2.5%              |
| Technology   | computers & the Internet (2), energy (3), engineering (6), robotics (1), time travel (1) | “I would like to research more about efficiency in jets because I find it interesting and would love to help build a fighter jet as an Aerospace Engineer.”
“Time Machine because I fail at most of things in life, and going back will allow me to do everything perfectly.” | 16.4%             |
| Zoology      | behaviour & neurobiology (2), other (2), veterinarian (1)                    | “I would like to be a veterinarian because I love animals and I think I would really enjoy working with them and getting to learn more about them. I would like to be a marine biologist because I love the ocean and marine animals, and I think I’d enjoy working with them and learning both about the animals and the ocean where they live.” | 6.3%              |
| Other        | architect (2), aviation (1), economics (1), sports (1), God (3)              | “Zoology, to show God’s power and glory and that he created all.”                                                                                                                                   | 10.1%             |
Even with a relatively high interest in physics, when asked what physics is about, students gave a variety of answers bounded by the physics units studied in grades nine and ten (they did not include topics studied in Earth and Space Science, nor experiences beyond the classroom) (see *Figure 22: Word cloud of students’ perceptions of physics*).

*Figure 22: Word cloud of students’ perceptions of physics.*

In Figure 22 we see space reduced in the background, with math (“calculations,” “equations,” “number”) in the foreground. Perhaps dampening slightly their exhilarated choice-induced state is students’ recognition that their choices are finite and should not to be squandered on unnecessary, undesirable, or relatively unknown subjects. Whereas students selected courses they have never studied, some did not select physics based on the exposure they have had thus far in school.

> Our course for grade ten at school... well, it was split mainly to bio and chem, and physics was a weeklong... So, we really didn’t focus on physics in grade ten (Ida, interview, September 15, 2012).

> I decided not to take physics because I was more into Chem and Bio, and didn’t want to risk not enjoying the subject... All we learned over the years was electricity, weather and optics. Are any of those related to physics? I’m not entirely sure (Erin, interview, September 2, 2012).

This limitation, combined with an unclear understanding of physics, left the majority of students selecting courses that they feel more confident and familiar with rather than venturing into the unknown
and rumored difficult, math-heavy, realm of physics. Kristen did advocate for selecting physics over other courses, even as she expressed her inability to identify what a physicist would do:

... you have this opportunity. I think that physics is one of the courses that you should take. Because a lot of people don’t have the chance to learn about stuff and should [not] waste is on courses that don’t bring you good knowledge (interview, September 15, 2012).

This value-laden statement echoes findings that courses have hierarchical value (Kompf, 2005) and physics, to Kristen, holds a higher value than some other (unnamed) subjects.

To summarize, students were able to articulate the interests they hold in science, many of which are in physics, but those topics are lost under their view of the copious calculations students would be required to complete. This makes physics seem “painstaking” and “arduous” rather than a fun subject to learn. For many students these challenges are enough to dissuade them from registering in physics, however, for a few the perception that physics knowledge is worthwhile is enough to entice them to select physics.

4.3.2.2.4.2 Career. Congruent with the findings of Finson (2002), students’ intended careers and the prerequisite courses for those programs are dominant factors that drive their course selection. Whereas some students have elected to take physics to satisfy an interest in the subject, it is more commonly selected when the student needs the course for his/her future. This is seen in the questionnaire data, as a moderately strong positive correlation was found (r=.625, significant at the 0.01 level (2-tailed)) between those students who selected physics and their agreement with the statement “I think that the physics I learn at school will improve my career choices.” Like the findings of Finson (2002), students who know what they want to do for their careers will select courses needed to enter those programs over courses they want to take out of interest or ability:

I would say if I did not need physics to get into health sciences I probably would not take it. I would have liked to take American history but I took physics instead (Zelda, interview, September 7, 2012).

My friends and I tried to choose courses according to what we hope to be in the future... [Biology] is recommended for one of the concurrent programs I am interested in (Grace, interview, August 31, 2012).
The courses this year will really benefit me in the future and I know I need them all for University (Zelda, interview, September 7, 2012).

Courses are selected to “keep options open” for university entrance. Often students do not consider that the career they might want requires a course they dislike. Courses are categorized as “needed” or “necessary” as they apply to their future careers, while interesting, popular, or fun courses are sometimes not selected in order to make room for less desirable but required courses. The students who had selected physics explained that they selected physics because it was a requirement for their intended studies at university. Only two students, Ida and Kristen, selected physics because they wanted to know more about physics without intending to pursue physics related fields.

I don’t plan to go into [physics] or anything related to it but I took it ‘cause I thought it was, like, life knowledge. In grade ten especially we learned things that we were never aware of, but physics even more so (Ida, interview, September 15, 2012).

I think [physics] is something you would know. If you are going to be publically educated... you have this opportunity. I think that physics is one of the courses that you should take (Kristen, interview, September 15, 2012).

These statements connect to one of the fundamental goals of science education: to produce scientifically literate citizens (Pedretti & Little, 2008; Wellington, 2001). Similar to the views of Hughes (2001) and Krusberg (2007) who find that physics contributes to scientific literacy in ways that other sciences do not, these students selected to study physics because they believe that a physics education would help them in a unique way towards understanding and interacting with their world.

Those students who did not select physics see themselves in careers other than in the physical sciences. Grace wants to become an elementary school teacher and has selected biology as a requirement for a program in which she holds an interest. D’Arcy selected biology as she has an interest in animals but confesses that she has linked her selections to a possible career as a veterinarian:

I don’t know what I want to do, but I probably wouldn’t chose something that involves a lot of science unless I really wanted to specifically to do something like a veterinarian (interview, September 2, 2012).
Eunice selected biology to have a third science credit (although it is no longer a requirement for graduation). Others, Xi-Wang, Pedro and Erin selected both biology and chemistry as they found these subjects interesting and they were considered the easier of the sciences. Furthermore, it kept their options open for programs in university.

4.3.2.4.3 Physics as an Absolute. Like Kessels et al. (2006), I also found the recurrent theme that most students view physics as a less creative space than other subjects, and even less than other sciences (contrary to a basic tenet of NOS that science is a “highly creative endeavor” (McComas, 2004, p. 26)), which for the majority of students acts as a deterrent. Looking again at Pedro’s perception of physics, he sees it further away from the “art side of the spectrum” than biology and chemistry.

The majority of students hold the view that physics as a subject can be learned by exclusively doing mathematical problems. Furthermore, students explain that one understands physics if one can do the mathematical problems. The perception that physics can be reduced to a right or wrong answer leaves little space for creativity in physics. The lack of creativity is not always a disincentive for students. Revisiting Terry’s comment, “Physics comes easy to me... I’m very equation based; either right or wrong” he expresses a view of physics as a positivist science that for him makes physics simpler and more attractive to take. Even while his view of physics is congruent with the Hughes (2001) and Kessels et al. (2006), in Terry’s case this view of physics is seen as a benefit and incitement rather than as a detriment and deterrent.

4.3.2.3 What other factors, extrinsic or intrinsic, affect their choices to pursue physics?

From analyzing the semi-structured interview and focus group transcripts, two other themes relevant to this question emerged: classes with friends and university. I found that most students prefer to be in the same class (or at least taking the same subjects) as their friends, but this desire does not override the prevailing reason a student takes a course, which is to fulfill the prerequisites to apply to a university program of interest. A detailed discussion follows in the next two subsections regarding these factors.
4.3.2.3.1 Classes with friends. The consistent message from students was that they would not take a course just to be with their friends. While students expressed a desire to have common lunches with their friends and hoped to be taking similar courses, they did not feel it necessary to be in class with their friends. D’Arcy made this point quite clear.

But in my case, certain classes I don’t really care if I have friends in my classes ‘cause I just want to go to the class. I don’t really care who’s in my class (interview, September 2, 2012).

Two students expressed that an advantage of common courses with their friends was that they would be able to discuss homework and assist one another with difficulties they encountered. But again this did not supersede their personal invested interests in taking one course over another.

I would not change my course to be in a course I do not need or like in order to be with them in the same course (Adam, interview, August 11, 2012).

Maintaining social contact in class also emerged as a theme. In some interviews students expressed a fracturing of their peer group due to their diverging interests and competencies.

I found most of my friends are more academic, more into university than college... I was actually really sad that I would probably be the only one who’s going to be in mixed math for first semester (Beverly, interview, August 17, 2012).

Some of my friends are taking university math to get into business programs. I am taking mixed math so my average doesn’t drop (Grace, interview, August 31, 2012).

While most students described course selection as an independent endeavor, separate from their friends, a few also spoke about course selection as a group decision with their peers.

I know me and all my friends took anthropology ‘cause we thought that was interesting but at the same time I’ve heard that it’s pretty easy (D’Arcy, interview, September 2, 2012).

At this juncture in the participants’ lives, pursuing their own goals appears to be more important than coordinating timetables with their peers. At no time did students express that they would not select a course because their friends disapproved or would think of them differently. I have interpreted this to mean that issues associated with border crossing did not impact students’ decisions about selecting physics.
Grade ten students are put in the position of making selections that will be instrumental to their future selves and the students interviewed made reference to this in terms of their intended careers and keeping their options open for university. The reasons why these grade ten students selected the courses they did that connect to intended careers are much more in line with why upper year undergraduate students select courses than first year undergraduate students (Babad, 2001).

**4.3.2.3.2 University.** Parental expectations were not directly related to the selection of physics. Students unanimously declared that their parents gave them the freedom to choose subjects they were interested in and that connected with their desired career goals. However, parents expected that their children would select courses that would allow them to go to university.

Well, [my parents] expect me to go to university so they said to take all university courses (Terry, interview, September 9, 2012).

We discussed future career opportunities with each course and my mum and I thought it would be best to have different types of courses to keep my options open for uni (Zelda, interview, September 7, 2012).

Recall that all of the students who participated in the interviews had completed grade ten science at the academic level. Completion of academic level courses in grade ten allows a student to take senior level courses in any strand (university, mixed, college, open or workplace), but is generally considered to be the precursor to studies that are called university preparation. During the eight interviews, university was mentioned 21 times. The expectation to go to university overrides a student’s performance or competence in science (similar to Hazari et al., 2000 findings). In all likelihood this expectation is related to SES and cultural capital. This expectation to be able to go to university overrides a student’s performance or competence in science (as per Hazari et al (2010)).

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7 I presume that the SES profile of the student body from Independent School A differs from the random sample student body, and so according to Nye et al. (2004), Teacher Effects should have a greater impact on students from the random sample (lower SES profiles). My findings, however are contrary to this (two students in the convenient sample indicated they had selected courses based on teacher recommendations, whereas, only one student in the random sample indicated that Teacher Effects affected their course selection), however, my sample size is very small. While SES profiles may play a part in student course selection, it is beyond the scope of this study to analyze this relationship.
I talked to my mom about it and she said for all the mandatory ones, like English and math, to definitely do the university - 'cause we thought, I agree with her, too - it’s better to go higher than lower. Say I took college, it would probably be easier but then if I want to go to university I wouldn’t be able to, so, we thought it would be a good idea to do the harder one (D’Arcy, interview, September 2, 2012).

In this case, D’Arcy has concerns about her success in grade eleven biology but will still take the course at a university level rather than a college level as she, in agreement with her mother, wants to be able to go into university. Those students who did not directly connect their selection of university level courses with parental expectations expressed a personal desire to go to university to pursue their career aspirations.

Students are very aware that they need prerequisite courses for some programs and universities, they need a minimum grades to gain admission (and the higher the grade the more choices they will have), and that only specific strands are considered for admission. While students are excited about the selections they are able to make, once they factor in the above considerations, the courses they can elect in secondary school are limited. Physics is then a hoop that some students need to jump through in order to pursue the careers in which they presently have an interest. Students chose physics, even when it does not interest them or they are very nervous about the math involved in the course, without questioning whether a career that requires that subject is one that they would enjoy or should pursue. Babad (2001) summarizes the consequences of course selections for college students in a way that mirror the implications for grade ten students:

Throughout their years in college, prior to every semester, students make a series of course selection (CS) decisions. Some of these decisions may directly influence their future by widening or delimiting further study and future educational and occupational possibilities. Most CS decisions determine and color the nature of the student's school experience in both intellectual and social domains. Because early decisions lead to, and often determine later ones, CS decisions have more import on the lives of students making them than they realize at the time. Later in life, many graduates recall particular CS decisions that turned out, in retrospect, to be fateful in their life path (p. 469).

While some students select physics because they have to, some students avoid physics because they do not need it for their intended program. The over riding fear of a lowered grade point average deters
students that lack the confidence in their own physics identity to pursue further studies in physics for curiosities sake. These students join the 60 plus percent of students globally who opt out of physics. The implications of this decision and recommendations arising out of this study are discussed in Chapter 5.
Chapter 5. Conclusion

5.1 Overview

Within this chapter I summarize the findings found from my analysis of the data, identify limitations of the study, identify implications of the findings with respect to physics education, and finally make recommendations that arise from the findings for physics curriculum design and delivery.

5.2 Rethinking the research questions: conclusions

This study explored the factors that influenced Ontario grade ten students in deciding to select or reject school physics. Specifically, the research asked:

1. Why do students select or reject physics courses?
2. What role does physics identity play in student course selection?
3. What other factors, extrinsic or intrinsic, affect their choices to pursue physics?

The following three subsections summarize my conclusions with respect to the above guiding questions.

5.2.1 Why do students select or reject physics courses? University admission was the prevailing theme for selecting physics. The students in this study reported choosing physics if it was a requirement for a university program (even when they were not interested in physics, and sometimes even to the exclusion of courses in which they do hold an interest). To a lesser extent, they chose physics based on their curiosity about the subject.

When physics was not a university requirement the most common reasons students told me they rejected physics was because physics was too difficult and could potentially bring down their average, thus limiting the number of universities to which they could apply. Physics is viewed as “too difficult” a subject in part due to its reliance on mathematical formulae. Although physics education is intended to develop strategies for problem analysis and qualitative reasoning prior to mathematical applications (Krusberg, 2007) students primarily connect physics education to its mathematical manipulations.

There was one exception. One student told me he thought physics would be easy to get a high mark due to its dependence on the mathematical applications.
The second most common reason students told me they had not selected physics was that they were unsure what they would study in a physics course and so opted to not select physics in favour of courses they felt more familiar. Their uncertainty of what they would study in physics blurs the line between general reasons students would or would not select physics with the students’ (underdeveloped) physics identity. The findings regarding the role that physics identity played in these students’ course selections is summarized in the next section.

5.2.2 What role does physics identity play in student course selection? An analysis of the data through the physics identity framework of Hazari et al. (2010), showed that recognition, competence and interest influenced student course selection more than performance. Where parents influenced the general course selections most students made (university streamed courses versus non university stream courses) students’ parents and friends did not influence the students’ decisions to select or reject physics courses even as course selections will “influence student intellectual and social domains” (Babad, 2001, p. 469).

Although further studies in physics is believed to expand future career opportunities (r=.625), the students did not want to pursue a career in technology, and to an even lesser extent, as a physicist (which they believed would use more technology than a general scientist). The data revealed that students viewed physicists as males who rely on technology and math. Students’ connection of physicists to technology compounded by the students’ own declaration that they do not want a career in technology explains, in part, their overwhelming rejection of seeing themselves as (and subsequently not choosing to become) physicists. Students reported that physics is a difficult subject, more appropriate for a “science-minded” rather than an “artsy” student. This suggests that they questioned their own competence in physics, which deterred them from studying senior physics when it was not a prerequisite course (congruent with Kessels et al. (2006)). While math was not a focus of this study, students’ believe there is a strong connection between physics and math. A moderately strong positive correlation (N=8, r=.647) was found between the focus group participants’ self reported math
competency and their selection of physics. Further studies are required to tease out the influence of this relationship.

The students’ performance in grade ten academic science was examined as a predictor for science course selections in grade eleven. Their performance in grade ten science (as measured by the final mark) showed a modest positive correlation ($r=.263$) with their selection of grade eleven physics, and modest positive correlation ($r=.339$) with the course combinations students selected for grade eleven with students over 1.5 times more likely to select a combination that includes physics for students with marks greater than 80% in grade ten (but not to the exclusion of biology).

Two other students, knowing that the programs they wanted to study in university did not need physics still selected physics to increase their general knowledge. In their cases physics knowledge was viewed as worthwhile, congruent with Krusberg (2007) who identifies physics education as connected to the expansion of a student’s knowledge base. This is an important observation as it ties to one of the fundamental goals of science education, to help produce scientifically literate citizens. As one student described it, “if you are going to be publically educated... physics is one course you should take.”

5.2.3 What other factors, extrinsic or intrinsic, affect their choices to pursue physics? The intrinsic factors (personal interest or social networking) that influenced students’ course selections were not found to be as important as extrinsic factors (university requirements).

While social desires were discussed more when considering whether to take courses with friends, academic reasons were also given to justify taking common courses with their friends, such getting homework assistance. For such assistance it was not necessary for students to be in the same physical classroom and so students told me they would not manipulate their timetable to be in classes with their friends. I also found that students own interests were more important than taking a common course and so they would not choose to endure an unnecessary course just to be with their friends. Issues associated with border crossings were also not identified by students as factors that would influence their course selections.
The extrinsic motivation provided by universities for admissions (both to the institution as well as a specific program) was more consequential than any intrinsic factors that influenced students to select a course. A high graduating grade point average for admissions was on the forefront of students’ minds when selecting courses as students wanted to maximize their options with respect to both universities and programs.

5.3 Limitations

Limitations exist within each phase of the study. These will be discussed as limitations due to sampling procedures, and then specifically limitations with the methods of this study, including: questionnaire, drawings, semi-structured interviews, and the focus groups.

5.3.1 Limitations from sampling procedures. The students were selected using a snowball sampling method within the GTA. The result of this sampling procedure was a small sample of Ontario students. As an extension of this study, it would be important to follow-up with students that attend school outside of GTA. Further research would be required into the attitudes and science identities of students in other school boards to discover if students from GTA hold perspectives distinct from other grade ten students in Ontario.

The sampling procedure used was also limiting in that I had to rely on others to represent this study and have them relay my contact information to potential participants. Due to the difficulty of recruiting participants I contacted numerous organizations and also found that students were generally unwilling to participate in the study. Therefore, I enlisted the help of a teacher within an Independent School to recruit participants. The outcome was two distinct groups, the first made up of a random sample from the public and Catholic school boards, and the other a convenient sample from an Independent School board.

The greatest impact of the differences in sampling procedures lies in the correlation calculations between student marks and other items on the questionnaire, and student selection of physics with other items on the questionnaire. Since, the students who were conveniently sampled to complete the
questionnaire were necessarily taking physics, there was an inflation of the number of students selecting physics. The comparison of the respondent course selections with school enrolment reveals that while biology is the least selected for the school (36%) and the respondents (30%), students within the school more commonly select chemistry (68% for the school, 92% for the respondents) than physics (46% for the school, 85% for respondents) in grade eleven. This indicates that the physics enrolment of the sample is inflated as compared to the school and therefore is not representative of the student population.

There was also an absence of correlation found between students’ marks and other items on the questionnaire. The students in the convenient sample reported higher marks than the random sample. All of the students attending Independent School A are necessarily university bound (there are no courses offered in the applied or college strands). Exceptional students may be recruited and can attend with financial assistance if it is required. I interpret this to mean that students’ marks are generally higher within Independent School A as compared to a general student population in a public or Catholic school board. The removal of their data from correlation calculations then reduced the sample size. All of the respondents were included for descriptive statistics of the statement agreement ratings, as well as their interests in scientific research.

5.3.2 Limitations with Questionnaire. The questionnaire was not piloted prior to its use within this study. The factor analysis revealed four dimensions with Eigenvalues above 1 using SPSS (Mac OS X V21.0.0). Examining these four dimensions reveals that the instrument is unbalanced (8 statements loaded for factor 1; 4 statements for factor 2; 2 statements each for factors 3 and 4). The last dimension included statements 6 and 13 (Eigenvalues 1.104) both of which had been flagged as potentially problematic.

Statement 11 was also problematic as four of the five students who participated in the retest changed their position of agreement. It is unclear if the changes in participants’ responses are due to
poorly written statements, changes in the participants’ contexts, changes in how the test was administered, or some other factor.

To use this instrument for further studies, work on item construction (specifically statements 6, 11 and 13), piloting, and validation is essential to produce a more balanced instrument.

5.3.3 Limitations with Interviews. Interviews conducted remotely (either through a Google doc or through email) suffered a loss of data. Using a Google doc allows a real-time interaction between the interviewer and interviewee, although there is some loss of data due to the ability to edit and change responses. In a face-to-face interview some data was lost due to noise interference. In a recorded face-to-face interview the resulting verbatim transcript would retain the respondent’s initial response, but in the remote medium this data is lost.

5.3.4 Limitations with Focus Groups. The two focus groups were from very different origins. The first from a co-educational semestered public school and the second from an all-boys, non-semestered, Independent School. The first focus group had all selected to study physics and half of that group had already begun their studies (they had completed the first two weeks of the semester at the time of the focus group). Therefore they may have held a different perspective of what physics was than the other two respondents as they had already begun their studies of kinematics (motion). Also, as the group was friends they all may have had prior conversations about the type of work they were currently doing in their physics course in preparation for the focus group.

The second focus group was made up of two students in their second year that intended to take physics in their third year of secondary school and two students were in their third year who were not going to take physics. The two second year students both took grade ten science at summer school (different schools) and thought that they may not have covered the content in the same degree of detail as the other student who had they taken science at day school.

5.3.5 Drawings to collect data. The use of drawings to capture students’ perceptions of scientists and physicists produced mixed results. While some students enjoyed this activity, others
resisted (one student chose not to complete the second drawing of the physicist, and when questioned he said he thought a physicist looked just like any other scientist). The amount of detail also varied which may be more of a measure of the student’s competence of drawing rather than their vision of a scientist or physicist.

5.4 Lessons learned about physics education

Often students were unsure about what they had studied in physics or what a physicist does. I found this striking as the students who participated in this study had already completed two courses in secondary school science, both of which contain (arguably) two sections of physics each (grade nine includes electricity and astronomy; grade ten includes optics and meteorology). It was unclear to some students when they were studying physics and that physics was in fact what they were studying. The significance that some students were unable to recognize when they had studied physics is that they were unable to expand their physics identity. When a student is unable to cultivate their identity through their own experiences information about others’ experiences will influence the development of their physics identity (as an example, hearsay from senior students that their marks will drop can impact a student’s belief that they will be able to succeed in physics). Connecting physics identity (Hazari et al., 2010) to course selection, I suggest that students who are not able to identify what kind of success they have had in physics will make decisions about whether to study physics based on someone else’s identity rather than their own. This is a reminder to me as a secondary school physics teacher that students do not necessarily make the same distinctions between subject matter that I do and that I need to check my own assumptions.

In addition to uncertainty about subject matter, careers related to or depending on a physics education do not seem to be communicated to students in a way that is meaningful to them. While the Ontario Ministry of Education includes a section on Scientific Investigation Skills and Career Exploration within each science course (Ontario Ministry of Education, 2008b), findings from this
study reveal that students connect technology to careers in physics but are unable to identify what kinds of activities physicists would do.

The reasons for this divide were not uncovered in this study, however, based on the data, I speculate that there are two possible reasons: a disproportionate amount of time spent on each strand in class, and a disconnect between topics covered in physics strands and students’ interests.

I was told by one focus group that their physics unit had been condensed to one week of study rather than one fourth of the minimum 110 hours for a full credit course, which is equivalent to more than four weeks in a semestered school. There could be many reasons for the reduction of instructional time on physics, but whatever the reason, a reduction of time spent on one strand in favour of others provides increased opportunities for students to develop other subject identities with fewer opportunities to develop their physics identity. While some students indicated that they rejected physics because they were unsure what physics was, they also suggested that they selected biology and chemistry because they knew what those subjects were about.

The second reason that students may feel disconnected from physics is that the topics covered in grades nine and ten (with the exception of astronomy) do not match students’ interests. Looking exclusively at the group of students that did not select physics (to remove the extrinsic factor of university institution and program prerequisites), they opted out of physics education primarily because they thought they would not do well in physics and that it was too difficult (which I interpret to mean that they expect their grade point average will drop by including senior physics education in their educational plan), they did not know what they would study, and uninteresting. I created a word cloud using the Big Ideas from the Ontario Ministry of Education (2008a, 2008b) document to help identify the prevailing themes included in the physics units of intermediate science and core senior physics courses (see Figure 23: Word cloud of physics curriculum for grades 9 to 12, academic and university strands). The prominent topics covered in the existing core physics courses are the environment, energy and light. Only 6.3% of respondents indicated that they were interested in doing research connected to
either the environment or in energy, while 30.4% expressed interest in human biology (most of those are in sickness and medicine) and 22.8% in astrophysics.

A better match to students’ research interest is the grade twelve Earth and space science course (SES4U). A word cloud for this courses’ Big Ideas revealed that the prominent themes are astrophysics, Earth science, and technology use (see Figure 24: Word cloud of Big Ideas from grade 12 Earth and space science (Ontario Ministry of Education, 2008a)).
Of the students that participated in this study, none of them enrolled in SES4U even though they were eligible (grade ten academic science is the prerequisite).

5.5 Recommendations

An understanding of physics contributes to scientific literacy in ways that other sciences do not as physics emphasizes problem solving (Krusberg, 2007) and physics is the foundation for understanding other sciences (Bybee & Gardner, 2006). While it is not imperative that a student be able to identify every branch of physics, as educators we are paying students a disservice if they are opting out of physics education because they do not recognize the importance of a physics education or that they are taught that physics leaves no room for creativity and original thought. The consequence of having fewer students studying physics is fewer future citizens who have the benefit of the unique contributions physics education can make to scientific literacy.

Based on the findings of this study I make two recommendations: first, the necessity of including the “pupil’s voice” and NOS perspectives in physics education; and second, I suggest ways to enhance the delivery of physics education and promote positive physics identities.

5.5.1 Context of physics instruction. The physics education content in Ontario continues to evolve with the most recent change in 2008. While the curricular content continues to be developed, I recommend that students’ interests be considered in how the content is delivered because when physics is presented as abstract and decontextualize, students tend to tune out, or opt out entirely (Hazari et al. 2010; Osborne & Dillon, 2008; Qualter, 1993). Not unlike the “pupil’s voice” movement started in England I suggest that more student input be incorporated into physics lessons to shape its delivery (Moran & Murphy, 2012). By increasing a student’s investment and involvement in curriculum design, or delivering physics in the context of students’ interests, an educator is more likely to capture a student’s interest (Baram-Tsabari & Yarden, 2005; Baram-Tsabari & Yarden, 2007; Riley & Docking, 2004; Sjøberg & Schreiner, 2010). As an example, in a grade nine class that expresses an interest in learning about diseases rather than learning about electricity, a teacher could introduce biological
models to help students understand the concepts of conductors and resistors (such as, the importance of pad placement and the use of Automated External Defibrillators (AED) and the Public Access Defibrillation program (Lifesaving Society, 2011)). Teachers could weave in information about physics knowledge that paramedics apply within their own jobs and then look into case studies about how to apply physics knowledge to type cases (for example, different doses for defibrillation that are needed for adults, children or infants, why that is the case, and how adaptations can be achieved with a generic adult AED accessible through the Public Defibrillation program (ILCOR Advisory Statement, 2003)). Through this kind of approach, educators can address student and curricular interests while teaching the innate problem-solving skills included in physics education. Building on students’ interests can help to shape a student’s understanding of how physics fits into their world, and how students could fit into the world of physics.

If students perceive physics as stagnant, absolute, boring, physics educators need to include NOS perspectives to help students move towards seeing physics as dynamic, tentative, and creative (McComas, 2004). By situating physics education in NOS, physics may become more accessible as students learn that science is shaped by not only empirical evidence but also by society. Physics educators create opportunities for students to engage with physics without binding students to recipe labs or simplistic plug-and-chug calculations; instead a space may emerge for students to incorporate their own interests and styles to answer their own physics questions. While this will not necessarily change a student’s physics identity with respect to their domain of recognition, drawing more attention to physics and careers that rely on a physics understanding, students’ performance, competence, and interest domains may become more clearly defined.

5.5.2 Delivery of physics education. Students need to be taught about the connections between physics education and physics-related opportunities (Cleaves, 2005; Stokking, 2010; Woolnough et al., 1997) and would benefit from a teacher who is trained in physics and has a positive physics identity (Cornell University Physics Teacher Coalition, 2011). Analyzing the Ontario College of Teachers
(OCT) 2010 Annual Report I found that only 10.7% of teachers are physics specialists (Ontario College of Teachers, 2010). If an Ontario secondary school has one physics specialist on staff (assuming ten science teachers) it is unlikely that this teacher would be teaching all of the grade nine and ten science courses in addition to the senior physics courses they would likely be assigned. The implication is that the majority of grade nine and ten science courses are taught by teachers that are trained or specialized in subjects other than physics (which are most likely general science or biology). This is a point for reflections as it is from the experiences students have in their grade nine and ten science courses that some students will base their course selection decisions (others may make the decision to study based on their extra- and co-curricular activities (Ainley & Ainley, 2011; Woolnough et al., 1997), and others may do so based on the recommendations of upper year students). In an attempt to place those with positive physics identities in front of students learning physics I recommend that schools make efforts to schedule teachers who have a positive physics identity to teach the physics sections of the intermediate science courses (possibly by using a team-teaching approach that allows all teachers to teach their specialties). This would ensure that science strands have dedicated amounts of time as well as allow teachers of physics education to develop students’ understanding of physics beyond mathematical manipulations (Krusberg, 2007). While this author recognizes that this approach would take a tremendous amount of coordination on the part of the school’s administration and teaching staff, it may provide the opportunity needed to help our students develop their physics identity domains of recognition, performance, competence, and interest to the point that when the option to select physics exists without the influence of university admissions that students may chose to explore what else physics courses can offer. In cases where there are not enough teachers qualified in physics to teach intermediate science courses, it is important to provide teachers who teach grade nine and ten science with professional development opportunities (such as mentoring, workshops, conferences) to explore and enrich their own physics identity.
5.6 Further research

Based on the findings of this study there are three areas I have identified for further research: the relationship between math competence and physics identity, what students think a career in technology would look like, and teacher attitudes towards physics education.

A recurrent theme throughout this study is the strong connection students made between physics and math. Perhaps a better predictor of whether or not a student would select to study physics in grade eleven is the students’ performance in grade ten math rather than their performance in science, and their overall math competence. To this end, by modifying the existing questionnaire to have students self-report their mark in math in addition to their mark in science would provide the data necessary to explore if a correlation exists between their performance in math with their selection of math, as well as their level of agreement with the statements “school physics is a difficult subject”, “I like school physics better than most other subjects”, “I would like to have as much physics as possible at school”.

A second area that emerges is what students think a career in technology would include or exclude. Our society is increasingly dependent on technology and I was surprised that students somewhat disagreed with the statement, “I would like to get a job in technology.” Since students clearly connected physicists with technology through their drawings, an extension of this study would be to explore whether being a physicist is inseparable from working with technology, if it is the connection between physics and technology that contributes to students overwhelming aversion to becoming a physicist, or perhaps if students view a type of technology connected with being a physicist that is undesirable.

The third extension of this study would be to investigate the profile and practices of those teachers who teach intermediate science (grades 9 and 10) and their physics identity. To this end one could identify which teachers are assigned to teach the intermediate science courses (beginning or senior teacher, unspecialized or a specialist, single teacher or community of teachers). In addition to teacher profiles, the study could explore the time teachers spend on each strand of science in grade nine.
and ten, and to investigate any discrepancies. Furthermore, class and student needs, teacher attitudes, teacher efficacy, or other possible factors could be explored.

5.7 Concluding thoughts

The implications of students opting out of a physics education are layered as physics education contributes to scientific literacy in ways that other sciences do not. There is no denying that physics uses math to explain and predict the physical world; but physics is more than an abstract, disjointed plug-and-chug approach to word problems. The qualitative aspect of problem solving (problem analysis, problem definition, understanding relationships, qualitative reasoning, planning solutions and evaluating outcomes (Krusberg, 2007)) is a skill that physics education is designed to address and that students need. When we, as educators, focus on the quantitative part of problem solving I believe we feed into the perception that physics is the most difficult of the sciences due in part to its reliance on formulae (Kessels et al., 2006). This perception deters students from reaping the benefits that additional physics education could provide them.

Those students who experience condensed programs in physics (or later opt out of physics) may have underdeveloped or incomplete physics identities. The additional time students have spent with other subjects may then lead them to think that their accumulated descriptive knowledge equates to a greater mastery of other sciences, but in reality they may lack the ability to apply, analyze, synthesize and evaluate that knowledge without a physics education underpinning (Bybee & Gardner, 2006). We owe it to our students to ensure that they have equal opportunities to develop their subject identities.

By cultivating a physics education program that moves beyond mathematical applications and matches the interests of students, more students may select physics and benefit from its multidimensional offerings rather than dismiss physics because it is too difficult, it relies too many formulae, or they are not sure what physics classes will cover. Students are making life decisions about their intended careers at fifteen or sixteen years of age, decisions that Babad (2001) eloquently describes as “decisions that [may turn] out ... to be fateful in their life path” (p. 469). Practitioners and
curriculum developers need to support students by providing an interesting, doable program in physics that helps them develop their own physics identity and strengthen their scientific literacy. When students opt out of a physics education they limit themselves in terms of understanding science and in terms of career opportunities (Udo et al., 2001). An improved design and delivery of a physics course that students are invested and interested in taking could potentially lead to more students becoming interested in considering scientific careers (Krusberg, 2007; McComas, 2004; Tobias, 1993). However, more importantly, a physics education that students choose to take will contribute to their scientific literacy that will empower them to make informed and responsible decisions in an increasingly technological world.
References


Appendix A: Consent and Assent Forms

Informed Consent Form - Focus Group

Dear Parent or Guardian:

I am both a researcher affiliated with the Ontario Institute for Studies in Education at the University of Toronto (OISE/UT) and a teacher with the Toronto District School Board. I am interested in exploring the factors that influence grade ten students as they make their course selections for grade eleven. Such information will be useful to schools, staff, and curriculum developers in designing better programs and providing better support for students.

This is a multiphase study consisting of three phases: focus groups, online questionnaire, and follow-up interviews. The focus group will take place at TBD. The focus group will be made up of 6-8 randomly selected grade ten students that will take 40 minutes. Students will be asked about their attitudes and perceptions of science and physics, and the factors that have influenced their course selections for grade eleven. Please note: There is no “right” answer to these questions.

During the focus groups respondents will be audio taped. The recording will not be published for public use and will be destroyed after they have been transcribed. Because this is a group activity, individual confidentiality obviously will not be able to be ensured within this group activity, but your child’s data and responses will be anonymous in all subsequent reports and summaries from the focus group. All names will be substituted by a code to maintain anonymity of the participants on all transcripts, and all data will be stored in password protected folders on a private computer in a locked office and original files deleted five years after the study is complete.

Participation is voluntary and participants may withdraw in part or in total from the study at any time.

If you are under 18 years of age, you will require your parent/guardian’s permission to participate. Please return this form by: _______________.

If you have any questions about your child’s rights as a participant, you may contact the Office of Research Ethics at ethics.review@utoronto.ca or 416-946-3273. If you have further questions about the study please contact me at Tasha.Richardson@mail.utoronto.ca. Your consideration for allowing your son/daughter to participate in this study is greatly appreciated.

Sincerely, Tasha Richardson, B.Sc., B.Ed., MA Student

PARENTAL/GUARDIAN CONSENT FORM

Please return this form by: _______________.

YES, I agree to allow my child ___________________ to participate in the focus group

son/daughter name

NO, I do not wish my child ___________________ to participate in the focus group

son/daughter name

Parent/Guardian signature __________________________ date ______________

If your child will be participating in the study please include his/her school email address below. It is to this email address that notification of focus group and/or follow-up interview participation will be sent. The link to the questionnaire will also be sent to this email address. Email communication about this study will come from Tasha.Richardson@mail.utoronto.ca.

Participant email __________________________
Informed Consent Form - Online Survey

Dear Parent or Guardian:

I am both a researcher affiliated with the Ontario Institute for Studies in Education at the University of Toronto (OISE/UT) and a teacher with the Toronto District School Board. I am interested in exploring the factors that influence grade ten students as they make their course selections for grade eleven. Such information will be useful to schools, staff, and curriculum developers in designing better programs and providing better support for students.

This is a multiphase study consisting of three phases: focus groups, online questionnaire, and follow-up interviews. All of the participating grade ten student body that have completed grade ten science will be asked to participate in the online questionnaire, which will take 20 minutes. Students will be asked about their attitudes and perceptions of science and physics, and the factors that have influenced their course selections for grade eleven. Please note: There is no “right” answer to these questions. All names will be substituted by a code to maintain anonymity of the participants, and all data will be stored in password protected folders on a private computer in a locked office and original files deleted five years after the study is complete.

Participation is voluntary and participants may withdraw in part or in total from the study at any time.

If you are under 18 years of age, you will require your parent/guardian’s permission to participate. Please return this form by: _______________.

If you have any questions about your rights as a participant, you may contact the Office of Research Ethics at ethics.review@utoronto.ca or 416-946-3273. If you have further questions about the study please contact me at Tasha.Richardson@mail.utoronto.ca. You consideration for allowing your son/daughter to participate in this study is greatly appreciated.

Sincerely,  Tasha Richardson, B.Sc., B.Ed., MA Student

PARENTAL/GUARDIAN CONSENT FORM

Please return this form by: _______________.

YES, I agree to allow my child ________________ to participate in the online questionnaire

son/daughter name

NO, I do not wish my child ________________ to participate in the online questionnaire

son/daughter name

Parent/Guardian signature ____________________________  date ______________

If your child will be participating in the study please include his/her school email address below. It is to this email address that notification of focus group and/or follow-up interview participation will be sent. The link to the questionnaire will also be sent to this email address. Email communication about this study will come from Tasha.Richardson@mail.utoronto.ca.

Participant email ______________________________________
Dear Parent or Guardian:

I am both a researcher affiliated with the Ontario Institute for Studies in Education at the University of Toronto (OISE/UT) and a teacher with the Toronto District School Board. I am interested in exploring the factors that influence grade ten students as they make their course selections for grade eleven. Such information will be useful to schools, staff, and curriculum developers in designing better programs and providing better support for students.

This is a multiphase study consisting of three phases: focus groups, online questionnaire, and follow-up interviews. The follow-up interviews will take place at the TBD. There will 8 students invited to participate in individual interviews at the end of the study and each interview will take 20 minutes. Students will be asked about their attitudes and perceptions of science and physics, and the factors that have influenced their course selections for grade eleven. Please note: There is no “right” answer to these questions.

During and interviews respondents will be audio taped. The recording will not be published for public use and will be destroyed after they have been transcribed. All names will be substituted by a code to maintain anonymity of the participants on all transcripts, and all data will be stored in password protected folders on a private computer in a locked office and original files deleted five years after the study is complete. Participation is voluntary and participants may withdraw in part or in total from the study at any time.

If you are under 18 years of age, you will require your parent/guardian’s permission to participate. Please return this form by: ____________________ .

If you have any questions about your rights as a participant, you may contact the Office of Research Ethics at ethics.review@utoronto.ca or 416-946-3273. If you have further questions about the study please contact me at Tasha.Richardson@mail.utoronto.ca. You consideration for allowing your son/daughter to participate in this study is greatly appreciated.

Sincerely,  Tasha Richardson, B.Sc., B.Ed., MA Student

PARENTAL/GUARDIAN CONSENT FORM

Please return this form by: ____________________ .

YES, I agree to allow my child __________________ to participate in the follow-up interviews

son/daughter name

NO, I do not wish my child __________________ to participate in the follow-up interviews

son/daughter name

Parent/Guardian signature ___________________________ date ____________

If your child will be participating in the study please include his/her school email address below. It is to this email address that notification of focus group and/or follow-up interview participation will be sent. The link to the questionnaire will also be sent to this email address. Email communication about this study will come from Tasha.Richardson@mail.utoronto.ca.

Participant email ____________________________________________
Dear Student,

In addition to being a graduate student in Education at the Ontario Institute for Learning at the University of Toronto, I am also a high school science teacher. As part of my study, I am conducting a research study in York Region. A research study is a way to find out information about teaching and learning. I am trying to find out why students select the courses they do for grade eleven. In particular, I am interested in the reasons students do and do not pick physics.

You are being asked to participate in this study because you are going into grade eleven in the fall and have successfully completed grade ten science. There are three stages of the study. The first stage is involvement in a Focus Group. For this study, a Focus Group will be made up of six to eight students who will be entering grade eleven in the fall. The Focus Group will be approximately forty minutes in duration. Because this is a group activity, individual confidentiality obviously will not be able to be ensured within this group activity, but your data and responses will be anonymous and confidential in all subsequent reports and summaries from the focus group. Your name will be substituted by a code on all transcripts from the focus group, and all data will be stored in password protected folders on a private computer in a locked office and original files deleted five years after the study is complete.

There will be no adverse consequences to you in any way if you decide not to participate in the study. If you say that you want to participate now but later change your mind contact Tasha Richardson at the email address below and your data and name will be removed from the study.

If you have any questions about the study, please ask me. I can be reached at Tasha.Richardson@mail.utoronto.ca.

If you would like to participate in the study, please print your name, sign your name, and return this form to Tasha Richardson.

I, ___________________________________________________, want to be in this research study.

Print your first and last name here

____________________________________________________  __________________________
Sign your name here                                           Date
Assent Letter for Students - Online Survey

Dear Student,

In addition to being a graduate student in Education at the Ontario Institute for Learning at the University of Toronto, I am also a high school science teacher. As part of my study, I am conducting a research study in York Region. A research study is a way to find out information about teaching and learning. I am trying to find out why students select the courses they do for grade eleven. In particular, I am interested in the reasons students do and do not pick physics.

You are being asked to participate in this study because you are going into grade eleven in the fall and have successfully completed grade ten science. There are three stages of the study. The second stage is participation in an Online Survey. For this study, the Online Survey consists of 23 closed and open-ended questions that will take approximately fifteen minutes to complete. The questions are about your opinions about (not your mastery of) science and physics. Your name will be substituted by a code on all reports from the study, and all data will be stored in password protected folders on a private computer in a locked office and original files deleted five years after the study is complete.

There will be no adverse consequences to you in any way if you decide not to participate in the study. If you say that you want to participate now but later change your mind contact Tasha Richardson at the email address below and your data and name will be removed from the study.

If you have any questions about the study, please ask me. I can be reached at Tasha.Richardson@mail.utoronto.ca.

If you would like to participate in the study, please print your name, sign your name, and return this form to Tasha Richardson.

I, ____________________________, want to be in this research study.

Print your first and last name here:

_____________________________    ______________________________

Sign your name here                  Date
Assent Letter for Students - Semi-Structured Interviews

Dear Student,

In addition to being a graduate student in Education at the Ontario Institute for Learning at the University of Toronto, I am also a high school science teacher. As part of my study, I am conducting a research study in York Region. A research study is a way to find out information about teaching and learning. I am trying to find out why students select the courses they do for grade eleven. In particular, I am interested in the reasons students do and do not pick physics.

You are being asked to participate in this study because you are going into grade eleven in the fall and have successfully completed grade ten science. There are three stages of the study. The third stage is involvement in a Semi-Structured Interview. For this study, the Semi-Structured Interview consists of six questions that ask about the factors that influenced your decision to select the courses you did for grade eleven. The Semi-Structured Interview will be approximately twenty minutes in duration. Your data and responses will be anonymous and confidential in all subsequent reports and summaries from the Semi-Structured Interview. Your name will be substituted by a code on all transcripts from the Semi-Structured Interview, and all data will be stored in password protected folders on a private computer in a locked office and original files deleted five years after the study is complete.

There will be no adverse consequences to you in any way if you decide not to participate in the study. If you say that you want to participate now but later change your mind contact Tasha Richardson at the email address below and your data and name will be removed from the study.

If you have any questions about the study, please ask me. I can be reached at Tasha.Richardson@mail.utoronto.ca.

If you would like to participate in the study, please print your name, sign your name, and return this form to Tasha Richardson.

I, ___________________________________________________, want to be in this research study.

Print your first and last name here

_________________________________________  ________________________
Sign your name here  Date
Appendix B: Instruments

Online Questionnaire (Based on ROSE Questionnaire)
Thank you for agreeing to complete the following survey on Grade 10 Physics Identity. The first set of questions will provide some context for the primary researcher regarding your answers. The second set of questions asks about your opinions on physics.

Please remember, your opinions on physics, science and technology are very important. Answer what you think and how you feel for each question. All of your answers will be kept confidential.

Please answer the following questions about yourself.

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>3) What is your gender?</td>
<td>☐ Female, ☐ Male, or ☐ Other</td>
</tr>
<tr>
<td>4) Please indicate the school board where you took grade ten science.</td>
<td>If you are homeschooling indicate the school board to which you are connected.</td>
</tr>
<tr>
<td>5) What is the name of the school where you took grade ten science?</td>
<td></td>
</tr>
<tr>
<td>6) What grade ten science course did you complete?</td>
<td>☐ Academic&lt;br&gt;☐ Applied&lt;br&gt;☐ Other</td>
</tr>
<tr>
<td>7) What mark did you earn in grade ten science?</td>
<td>☐ 50-59,&lt;br&gt;☐ 60-69,&lt;br&gt;☐ 70-79,&lt;br&gt;☐ 80-89,&lt;br&gt;☐ 90-100,&lt;br&gt;☐ Don’t remember,&lt;br&gt;☐ Prefer not to answer</td>
</tr>
<tr>
<td>8) Please indicate which course(s) you have selected to study in grade eleven. Select as many as apply.</td>
<td>☐ grade 11 biology - college&lt;br&gt;☐ grade 11 biology - university&lt;br&gt;☐ grade 11 chemistry - university&lt;br&gt;☐ grade 11 environmental science - university/college&lt;br&gt;☐ grade 11 physics - university&lt;br&gt;☐ grade 12 chemistry - college&lt;br&gt;☐ grade 12 earth and space science - university&lt;br&gt;☐ grade 12 physics - college&lt;br&gt;☐ grade 12 science - university/college&lt;br&gt;☐ grade 12 science - workplace&lt;br&gt;☐ other science course&lt;br&gt;☐ not taking any science</td>
</tr>
</tbody>
</table>
9) Please answer the following questions about school physics.

a) School physics is a difficult subject.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

b) School physics is interesting.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

c) School physics is rather interesting for me to learn.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

d) School physics has opened my eyes to new and exciting jobs.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

e) I like school physics better than most other subjects.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

f) I think everybody should learn physics at school.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

 g) The things that I learn in physics at school will be helpful in my everyday life.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

h) I think that the physics I learn at school will improve my career choices.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

i) School physics has made me more critical and sceptical.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

j) School physics has increased my curiosity about things we cannot yet explain.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

k) School physics has increased my appreciation of nature.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

l) School physics has shown me the importance of physics for our way of living.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

m) School physics has taught me how to take better care of my health.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

n) I would like to become a physicist.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

o) I would like to have as much physics as possible at school.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

p) I would like to get a job in technology.
   □ Disagree  □ Somewhat Disagree  □ Somewhat Agree  □ Agree

Assume that you are grown up and work as a scientist. You are free to do research that you find important and interesting. Write some sentences about what you would like to do as a researcher and why.

I would like to ... Because ...
Questions for Follow-Up Interview - Sample

1. At your school, course selection for grade eleven began in ______ (site dependent, to be determined prior to interviews). At the school the following events were going on (have this information from the school calendars, staff prior to interview stage). Describe what was happening in your life during that time.

2. Describe a conversation you had with your peers about the courses you selected to study in grade eleven. Probes: What courses have your friends selected?

3. Describe a conversation you had with your parents about the courses you wanted to select to study in grade eleven. Probes: What do your parents/guardians do? What are your parent(s)/guardian(s)’ attitude towards science?

4. Give me an example of how your family participated in your selections for grade eleven. Probes: Are you happy/confident/excited/anxious about your courses for next year?

5. If the student has selected physics (based on questionnaire completion) You selected to study physics. Tell me about that choice. Probes: Are you thinking about a career in science/engineering? Why or why not?

6. If the student did not select physics (based on questionnaire completion) You opted not to select physics. Tell me about that choice. Probes: Are you thinking about a career in science/engineering? Why or why not?

Questions for Focus Group - Sample

1. Welcome to session. Anonymity. Right to withdrawal. Audio recorded - Speak one at a time. Wait to be acknowledged before speaking. Please state name prior to speaking to aid with transcription. Respect for others opinions. Post these rules at the front prior to beginning. Get something to eat (light lunch provided).

2. Distribute paper and pencil. Draw a scientist exercise. These will be collected, please write your name on the back of the paper. Your name will not be distributed or included in any reports but are for information purposes for the primary researcher.
   a. Draw what you think a scientist looks like.
   b. Include as much detail as you like.
   c. Seven minutes
   d. Would someone like to share their drawing? If no volunteers have pictures of scientists ready, including: Albert Einstein, Sheldon Cooper, Rajesh Koothrappali, Marie Curie, Sylvester Gates, Jr., Shirley Ann Jackson,
   e. What are some of the elements we see as a group in the drawings? Commonalities? Differences?
   f. Is this really what you think a scientist is? Does? Why or why not?

   a. How are the drawings different/same? Why?

4. Grade ten science.
   a. Topics covered in physics included:
      i. SNC2D Light and Geometric Optics
      ii. SNC2P Light and Applications of Optics
   b. If you could use three words to describe what you learned in physics what would they be? Why?
      i. Provide opportunity for all students to contribute to the discussion by stating their words.
      ii. Ask for discussion once all words are shared.
      iii. Is there a common thread through the words.
Table 18: Test-retest results from SPSS (Mac OS X V21.0.0) for ICC

<table>
<thead>
<tr>
<th>Statement</th>
<th>Intraclass Correlation Coefficient, ICC</th>
<th>Lower bound of 95% confidence interval</th>
<th>Upper bound of 95% confidence interval</th>
<th>F test</th>
<th>Significance level, p</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;School physics is a difficult subject.&quot;</td>
<td>0.698</td>
<td>-1.904</td>
<td>0.969</td>
<td>0.615</td>
<td>0.477</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;School physics is interesting.&quot;</td>
<td>1.000</td>
<td>1.000</td>
<td>no value</td>
<td>no value</td>
<td>no value</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;School physics is rather interesting for me to learn.&quot;</td>
<td>0.921</td>
<td>0.238</td>
<td>0.992</td>
<td>0.000</td>
<td>1.000</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;School physics has opened my eyes to new and exciting jobs.&quot;</td>
<td>0.964</td>
<td>0.653</td>
<td>0.996</td>
<td>2.667</td>
<td>0.178</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;I like school physics better than most other subjects.&quot;</td>
<td>0.968</td>
<td>0.690</td>
<td>0.997</td>
<td>1.000</td>
<td>0.374</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;I think everybody should learn physics at school.&quot;</td>
<td>0.964</td>
<td>0.442</td>
<td>0.998</td>
<td>9.000</td>
<td>0.058</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;The things that I learn in physics at school will be helpful in my everyday life.&quot;</td>
<td>0.921</td>
<td>0.238</td>
<td>0.992</td>
<td>0.000</td>
<td>1.000</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;I think that the physics I learn at school will improve my career choices.&quot;</td>
<td>0.925</td>
<td>0.283</td>
<td>0.992</td>
<td>0.000</td>
<td>1.000</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;School physics has made me more critical and sceptical.&quot;</td>
<td>0.720</td>
<td>-1.689</td>
<td>0.971</td>
<td>4.571</td>
<td>0.099</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;School physics has increased my curiosity about things we cannot yet explain.&quot;</td>
<td>0.571</td>
<td>-3.116</td>
<td>0.955</td>
<td>2.667</td>
<td>0.178</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;School physics has increased my appreciation of nature.&quot;</td>
<td>-0.471</td>
<td>-13.124</td>
<td>0.847</td>
<td>2.000</td>
<td>0.230</td>
<td>violate reliability model assumptions/no significant difference</td>
</tr>
<tr>
<td>&quot;School physics has shown me the importance of physics for our way of living.&quot;</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>no value</td>
<td>no value</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;School physics has taught me how to take better care of my health.&quot;</td>
<td>0.000</td>
<td>-8.605</td>
<td>0.896</td>
<td>0.000</td>
<td>1.000</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;I would like to become a physicist.&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>error returned</td>
</tr>
<tr>
<td>&quot;I would like to have as much physics as possible at school.&quot;</td>
<td>0.978</td>
<td>0.791</td>
<td>0.998</td>
<td>1.000</td>
<td>0.374</td>
<td>no significant difference</td>
</tr>
<tr>
<td>&quot;I would like to get a job in technology.&quot;</td>
<td>0.625</td>
<td>-2.605</td>
<td>0.961</td>
<td>0.167</td>
<td>0.704</td>
<td>no significant difference</td>
</tr>
</tbody>
</table>

p=0.05 confidence interval
Table 19: Relevance of physics education

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>$\bar{x}$</th>
<th>Standard Deviation, $\sigma$</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;School physics is a difficult subject.&quot;</td>
<td>27</td>
<td>26</td>
<td>6</td>
<td>5</td>
<td>3.17</td>
<td>0.90</td>
<td>Agree</td>
</tr>
<tr>
<td>&quot;School physics is interesting.&quot;</td>
<td>33</td>
<td>22</td>
<td>5</td>
<td>4</td>
<td>3.31</td>
<td>0.87</td>
<td>Agree</td>
</tr>
<tr>
<td>&quot;School physics is rather interesting for me to learn.&quot;</td>
<td>28</td>
<td>21</td>
<td>8</td>
<td>7</td>
<td>3.09</td>
<td>1.00</td>
<td>Agree</td>
</tr>
<tr>
<td>&quot;School physics has opened my eyes to new and exciting jobs.&quot;</td>
<td>13</td>
<td>20</td>
<td>15</td>
<td>16</td>
<td>2.47</td>
<td>1.08</td>
<td>Somewhat Disagree</td>
</tr>
<tr>
<td>&quot;I like school physics better than most other subjects.&quot;</td>
<td>6</td>
<td>21</td>
<td>15</td>
<td>22</td>
<td>2.17</td>
<td>1.02</td>
<td>Somewhat Disagree</td>
</tr>
<tr>
<td>&quot;I think everybody should learn physics at school.&quot;</td>
<td>7</td>
<td>18</td>
<td>20</td>
<td>19</td>
<td>2.20</td>
<td>0.99</td>
<td>Somewhat Disagree</td>
</tr>
<tr>
<td>&quot;The things that I learn in physics at school will be helpful in my everyday life.&quot;</td>
<td>14</td>
<td>30</td>
<td>10</td>
<td>10</td>
<td>2.75</td>
<td>0.98</td>
<td>Somewhat Agree</td>
</tr>
<tr>
<td>&quot;I think that the physics I learn at school will improve my career choices.&quot;</td>
<td>30</td>
<td>20</td>
<td>5</td>
<td>9</td>
<td>3.11</td>
<td>1.06</td>
<td>Agree</td>
</tr>
<tr>
<td>&quot;School physics has made me more critical and sceptical.&quot;</td>
<td>10</td>
<td>24</td>
<td>17</td>
<td>13</td>
<td>2.48</td>
<td>0.99</td>
<td>Somewhat Disagree</td>
</tr>
<tr>
<td>&quot;School physics has increased my curiosity about things we cannot yet explain.&quot;</td>
<td>29</td>
<td>27</td>
<td>4</td>
<td>4</td>
<td>3.27</td>
<td>0.84</td>
<td>Agree</td>
</tr>
<tr>
<td>&quot;School physics has increased my appreciation of nature.&quot;</td>
<td>18</td>
<td>16</td>
<td>19</td>
<td>11</td>
<td>2.64</td>
<td>1.07</td>
<td>Somewhat Agree</td>
</tr>
<tr>
<td>&quot;School physics has shown me the importance of physics for our way of living.&quot;</td>
<td>18</td>
<td>29</td>
<td>11</td>
<td>6</td>
<td>2.92</td>
<td>0.91</td>
<td>Somewhat Agree</td>
</tr>
<tr>
<td>&quot;School physics has taught me how to take better care of my health.&quot;</td>
<td>4</td>
<td>13</td>
<td>18</td>
<td>29</td>
<td>1.88</td>
<td>0.95</td>
<td>Disagree</td>
</tr>
<tr>
<td>&quot;I would like to become a physicist.&quot;</td>
<td>1</td>
<td>10</td>
<td>17</td>
<td>36</td>
<td>1.63</td>
<td>0.81</td>
<td>Disagree</td>
</tr>
<tr>
<td>&quot;I would like to have as much physics as possible at school.&quot;</td>
<td>9</td>
<td>18</td>
<td>22</td>
<td>15</td>
<td>2.33</td>
<td>0.99</td>
<td>Somewhat Disagree</td>
</tr>
<tr>
<td>&quot;I would like to get a job in technology.&quot;</td>
<td>15</td>
<td>18</td>
<td>12</td>
<td>19</td>
<td>2.45</td>
<td>1.15</td>
<td>Somewhat Disagree</td>
</tr>
</tbody>
</table>
### Table 20: Correlation coefficient, r, between students’ marks and their questionnaire statement ratings (Inferential Statistics)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Correlation Coefficient, r (single school data), n=28</th>
<th>Correlation Coefficient, r (random sample), n=29 (redone)</th>
<th>Correlation Coefficient, r (including single school data), n=57 (redone)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;School physics is a difficult subject.&quot;</td>
<td>-0.32</td>
<td>-0.42*</td>
<td>-0.33</td>
</tr>
<tr>
<td>&quot;School physics is interesting.&quot;</td>
<td>-0.01**</td>
<td>0.35</td>
<td>0.33</td>
</tr>
<tr>
<td>&quot;School physics is rather interesting for me to learn.&quot;</td>
<td>0.08**</td>
<td>0.32</td>
<td>0.32</td>
</tr>
<tr>
<td>&quot;School physics has opened my eyes to new and exciting jobs.&quot;</td>
<td>-0.01**</td>
<td>0.22</td>
<td>0.23</td>
</tr>
<tr>
<td>&quot;I like school physics better than most other subjects.&quot;</td>
<td>0.09**</td>
<td>0.33</td>
<td>0.32</td>
</tr>
<tr>
<td>&quot;I think everybody should learn physics at school.&quot;</td>
<td>0.02**</td>
<td>0.09**</td>
<td>0.01**</td>
</tr>
<tr>
<td>&quot;The things that I learn in physics at school will be helpful in my everyday life.&quot;</td>
<td>0.05**</td>
<td>0.40*</td>
<td>0.27</td>
</tr>
<tr>
<td>&quot;I think that the physics I learn at school will improve my career choices.&quot;</td>
<td>0.32</td>
<td>0.25</td>
<td>0.36</td>
</tr>
<tr>
<td>&quot;School physics has made me more critical and sceptical.&quot;</td>
<td>0.41*</td>
<td>0.03**</td>
<td>0.43*</td>
</tr>
<tr>
<td>&quot;School physics has increased my curiosity about things we cannot yet explain.&quot;</td>
<td>0.17</td>
<td>0.34</td>
<td>0.33</td>
</tr>
<tr>
<td>&quot;School physics has increased my appreciation of nature.&quot;</td>
<td>-0.01**</td>
<td>0.20</td>
<td>0.21</td>
</tr>
<tr>
<td>&quot;School physics has shown me the importance of physics for our way of living.&quot;</td>
<td>-0.08**</td>
<td>0.20</td>
<td>0.16</td>
</tr>
<tr>
<td>&quot;School physics has taught me how to take better care of my health.&quot;</td>
<td>0.22</td>
<td>-0.18</td>
<td>-0.11</td>
</tr>
<tr>
<td>&quot;I would like to become a physicist.&quot;</td>
<td>0.03**</td>
<td>0.18</td>
<td>0.19</td>
</tr>
<tr>
<td>&quot;I would like to have as much physics as possible at school.&quot;</td>
<td>0.17</td>
<td>0.23</td>
<td>0.30</td>
</tr>
<tr>
<td>&quot;I would like to get a job in technology.&quot;</td>
<td>0.26</td>
<td>0.30</td>
<td>0.34</td>
</tr>
</tbody>
</table>

* Denotes moderate correlation between student marks and rating (0.40 to 0.80)
** Absence of correlation found between student marks and rating (below 0.10)