Attitudes to Science as they Relate to Gender, Participation, and Achievement

by

VANESSA R. LAPOINTE

B.Sc., The University of British Columbia, 1999

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

in

THE FACULTY OF GRADUATE STUDIES

Faculty of Education; Department of Educational and Counselling Psychology,
and Special Education; School Psychology

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

August, 2002

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Educational and Counselling Psychology, and Special Education.

The University of British Columbia
Vancouver, Canada

Date Aug. 27, 2002.

DE-6 (2/88)

Abstract

The current study was designed to: a) determine the magnitude of existing gender differences in attitudes to science; b) determine the impact of gender on intent to study science at the upper-level in high school, and in post-secondary pursuits; c) evaluate the relationship between attitude to science and achievement in science; d) determine the impact of attitude to science on intent to study science at the upper-level in high school, and in post-secondary pursuits; e) explore and describe those factors which may influence attitude to science development; and, f) explore and describe those factors which may influence student decisions regarding further pursuit of science-based study. Results from the 1995 British Columbia Assessment of Mathematics and Science were analyzed and interviews were conducted.

Results indicated that, although significant, gender differences in attitudes to science were very small and likely not meaningful. Results also showed that there was a significant difference between genders regarding intent to pursue further studies of science in both high school and post-secondary study. In addition, a weak relationship between attitudes and achievement was observed, and a positive relationship between attitude and intent to participate in upper-level high school biology, chemistry and physics courses, and in post-secondary science was also observed.

Exploration of the potential influences that direct attitude to science development and decisions regarding further study of science included parental expectations, teacher instruction, peer influence, enjoyment, interest, perceived relevance, perception of self-ability, and applicability to chosen career path. Implications for prevention and intervention efforts, and future research directions are discussed.

Table of Contents

List of Tables

List of Figures

Acknowledgements

I gratefully acknowledge support from my research advisor, Dr. Kadriye Ercikan, through all stages of this study. In addition, I extend appreciation to Tanya McCreith for assistance with data formatting and analysis. I also wish to thank Mike Marshall for his assistance in both accessing and formatting data from the 1995 British Columbia Assessment of Mathematics and Science. Finally, I wish to thank Dr. Martha Foschi for her continued mentorship.

Dedication

For my husband, Jonathan.

A constant source of love, support and encouragement.

CHAPTER 1

Introduction

Overview

Women are proportionately under-represented in most scientific and technological disciplines. In 1998, women accounted for 58 percent, 70 percent, and 63 percent of the university qualifications granted in Canada in the social sciences, education, and the humanities respectively (Statistics Canada, 2001a). However, in this same year, women accounted for only 21 percent and 31 percent of the university qualifications granted in the engineering and applied sciences, and mathematics and physical sciences respectively (Statistics Canada, 2001a). While many factors contribute to disparate earnings between the sexes, science and technology based careers are arguably more lucrative. The fact that women pursue these careers less often comes to the forefront when one considers that men earned, on average, 36 percent more than women in 1998 (Statistics Canada, 2001b).

Some have argued that the lower numbers of women seeking out scientific professions is a phenomenon that finds its genesis in sex-related biological differences. However, research has suggested that the foundation for this disparity is not necessarily biological in nature. Instead, it appears that gender differences in dropout rates in these disciplines persist even amongst those women who are academically capable of, and prepared for, entrance into science-related careers (Ware & Lee, 1988). Thus, rather than focusing on biologically based factors, it may be more informative to focus on affective variables. The present study examines the component parts of one such affective variable - attitudes to science - that may be contributing to the demise of science-oriented career pursuits among women, and further, investigates the notion of type of science as an important consideration in this delineation.

While attitude presents as a key variable, speculation about the diverse factors that may be contributing to the gendered differential pursuit of science has also focused on a myriad of other variables. Czerniak and Chiarelott (1990) discuss the importance of a range of teacher variables, such as the impact of inadequate teacher preparation, negative teacher attitudes, poor teacher self-efficacy, limited teaching effectiveness, and high teacher anxiety. Simpson and Oliver (1985), alternatively, investigated motivation for science-oriented achievement in grades 6 through 10 students. They found that while achievement motivation declined across the grades, with grade 10 students having the lowest achievement motivation, girls maintained significantly higher levels of achievement motivation than boys – an interesting finding given that girls continue to avoid pursuit of scientific study. Investigating yet another variable, Sayers (1988) examined self-efficacy, consideration, and interest, and found that significant gender differences were expressed within each of the three categories of college majors: fine arts, social sciences and natural sciences. Butler-Kahle and Lakes (1983) investigated exposure to science related phenomena, and found that in elementary school, boys are exposed to far more science experiences than girls in every area surveyed, including science observations, instrument skills, field trips, experimental tasks, and extracurricular activities. Recently, Ercikan and McCreith (2001) explored background variables in sixth through ninth grade students in Canada, the USA, and Norway, and found that friend's expectations and home support for learning were strong predictors of science achievement, that participation in science was highly predicted by expectations, and that for all of these, the relationship was stronger for females than for males. In addition to the research presented thus far, several other variables which may potentially impact the involvement of women in science have been investigated, such as those discussed by Simpson, Koballa, Oliver, and Crawley (1994), which include self-concept, fate control, locus of control, cultural background, belief systems, and social values.

Thus, as evidenced by the above sampling of work, numerous variables have been examined to explain why lower numbers of females pursue scientific study and science-based careers. Beyond this range of variables, however, attitude has received considerable attention as a viable explanation for why boys and girls pursue such different tangents in terms of science-based study. Why consider attitude when so many other variables appear to mediate the pursuit of scientific study and careers? The answer may be found by considering how attitude is defined and operationalized in the literature. Researchers have suggested that attitude is most usefully viewed as a variable that is highly related to, and may even encompass, many of those already discussed. For example, Harty, Samuel, and Beall (1986) examined self-concept, interest in science, science curiosity, and attitudes toward science in sixth graders, and found that the latter three might actually represent a single construct. Thus, it appears that attitude as a variable subsumes many closely related variables that have previously been investigated as separate entities.

Since attitude appears to have such an enveloping nature as regards accounting for the gendered differential pursuit of science, interested researchers have focused on investigating the origins of attitudes to science, analyzing the component parts of such attitudes, and attempting to determine the relationship of these attitudes with other variables. As a result of this quest, gender has been identified as a key factor in the formation of differing attitudes to science, with the relationship between the two being consistently documented. Traditionally, males have more positive attitudes to science, and females have more negative attitudes to science. In a 1975 review of science education literature, Gardner supported this gender-attitude linkage, noting that "Sex is probably the single most important variable related to pupils' attitudes to science" (p. 2).

Further, Schibeci (1984) states that of the myriad of variables that have possible influences on attitudes, sex has generally been shown to be among the most consistent. Thus, it would appear that in attempting to account for the disproportionately small number of females who seek out science-related experiences, the investigation of attitude might yield useful information.

Numerous studies have been done which lend credence to the claim that attitudes to science and gender are interrelated, and further, that attitude is an important predictive variable of future involvement with science-related interests. Ercikan and McCreith (2001) reported findings from an international study which indicated that males in the USA and Norway had significantly more positive attitudes to science than females, while males in Canada had marginally significantly more positive attitudes to science than females. It was also noted in this same study that, for all three countries, males' science achievement scores were significantly higher than females', and participation rates for males in advanced science courses were much larger than for females, with the difference being as large as 28 percent. Jones, Howe, and Rua (2000) also found gender-based discrepancies in attitudes to science, with boys indicating significantly more positive attitudes than girls, and with the breadth and depth of boys' experiences with science related tools and activities, as well as their interest in scientifically-based phenomena, far outweighing that of girls in grade six. From these and other studies, it seems clear that attitude is a key and defining characteristic in determining what separates the attitude to science trajectories on which boys and girls find themselves, even from very young ages.

While attitudes appear to play a significant role in future science involvement, such as enrollment in advanced science courses, and pursuit of science-based post-secondary education and careers, much debate exists regarding the foundations of this negative attitude formation.

The delineation of attitude objects as potential causal factors in this awry attitudinal development is one of the more significant gaps in the attitudes to science literature. Attitude objects are defined as that "thing" toward which attitude is directed. Attitude objects can include everything from the science classroom, to science instruction, to scientific lab equipment, to science as a career, and so on. Knowing the factors that are contributing to the formation of certain attitudes to science is important, as it provides the fodder for directed intervention and remediation. While many researchers have investigated attitude, far fewer have successfully isolated and identified potential attitude objects. In addressing the need for advancement in this area, Schibeci (1984) highlighted for researchers the importance of clearly defining the object(s) towards which attitudes to science are directed. However, the literature has not made great strides in unraveling further the important issue of attitude objects in the formation of negative attitudes to science. With the findings of most studies, whether gender-based differences are found or not, discussion is difficult to direct as attitude objects are not clearly delineated, usually because the researcher(s) either included several defined attitude objects but neglected to isolate them in the analysis, or simply because the researcher(s) did not define the involved attitude objects.

Related to this issue of attitude objects, is the tendency for researchers to neglect to define the type of science addressed in their attitude to science study. Type of science should be viewed as a specific attitude object. Results are often confounded, or at least made incomparable, because the type of science underlying the responses is not controlled for and/or is not addressed. More recent trends indicate that while girls do not shy away from the biological or life sciences, they are significantly more likely to avoid the physical sciences (Jones, et. al, 2000). Thus, if we look upon science as a general unified subject, rather than as several distinct areas of study, we neglect to investigate a very important variable in furthering our understanding of the gender-based differential pursuit of scientific study and careers.

Rationale

The present study proposes examination of the existence of gender-based attitudinal differences in the attitudes to science of grade 10 students. Relationships between such attitudes and goal-oriented variables are explored, including plans for enrollment in secondary and post-secondary science courses. The potential relationship between attitudes to science as measured in grade 10 students, and achievement in science for those same students is also explored. The preceding analyses, which are all quantitative in nature, are followed by an in-depth qualitative analyses of data collected during interviews with female grade 10 students. This data is gleaned for information on the various influences that may guide development and maintenance of attitudes to science, as well as for insight into those factors that influence pursuit of upper-level science courses in secondary and post-secondary school, with specific focus being placed on type of science as an attitude object.

Finally, the present study will contribute to the essential continued investigation of gender and attitudes to science. Since the socialization that is associated with gender is constantly changing, particularly in western cultures, more current information on gender and attitudes to science, and the impact of such on future science involvement, is necessary.

Research Paradigm

While brevity and scope are often promoted as reason to avoid combining two research paradigms in the design of a study, according to Creswell (1994), there are many benefits to including both qualitative and quantitative data collection methods. First, this approach enables the researcher to incorporate the concept of triangulation, whereby bias inherent to one method of data collection may be counterbalanced by a lack of such bias in another method. Second, the use of different paradigms may provide developmental advantages, with results from one method being used to inform development of the second method. Third, the use of two methods may allow greater expansion of concepts and ideas. For these reasons, the current study design incorporates both a quantitative and qualitative portion, termed Phase One and Phase Two respectively.

Quantitative Research Questions

Research Question One

Are there gender differences for grade 10 students in the endorsement of positive attitudes to science, including attitudes about science in school, science in society and science as a career?

Hypothesis One

In grade 10, boys will have more positive attitudes to science than girls in the areas of science in school, science in society and science as a career.

Research Question Two

Is there a gender difference for grade 10 students in enrollment in upper-level secondary science courses?

Hypothesis Two

In grade 10, boys will have more interest than girls in enrollment in upper-level chemistry and physics secondary courses, but girls will have more interest than boys in enrollment in upper-level biology secondary courses.

Research Question Three

Is there a gender difference for grade 10 students in the planned pursuit of science courses in post-secondary study?

Hypothesis Three

Boys will endorse more so than girls plans for pursuit of science-based study in post-secondary education.

Research Question Four

Is there a relationship between attitude to science in grade 10, and achievement in science in grade 10?

Hypothesis Four

Positive attitudes to science in grade 10 will be associated with higher levels of achievement on the British Columbia Assessment of Mathematics and Science (BCAMS) science achievement items.

Research Question Five

Is there a relationship between attitudes to science in grade 10, and intent to enroll in upper-level high school science courses in grades 11 and 12?

Hypothesis Five

Positive attitudes to science in grade 10 will be associated with higher levels of intent to enroll in upper-level high school science courses in grades 11 and 12.

Research Question Six

Is there a relationship between attitudes to science in grade 10, and intent to enroll in post-secondary science courses?

Hypothesis Six

Positive attitudes to science in grade 10 will be associated with higher levels of intent to enroll in post-secondary science courses.

Qualitative Research Questions

Research Question A

What variables play an influential role in students' attitudes to science?

Hypothesis A

A variety of factors, rooted in both environmental and student-focused affective variables influence student development and maintenance of attitudes to science.

Research Question B

What influences students in their decision on whether or not to pursue study of upper-level biology, chemistry and physics courses in both secondary and post-secondary school?

Hypothesis B

Many components of the student's surroundings, such as family and teachers, as well as factors that are inherently more affective in nature, such as perceived ability in science and perceived importance of science, are part of the myriad of variables that guide student selection of upper-level biology, chemistry and physics courses in secondary school, as well as selection of science courses in post-secondary school.

CHAPTER 2

Literature Review

Introduction

Gender differences in attitudes to science have received wide-spread attention in the literature, and have a longstanding research history (e.g. Jones, et al., 2000; Schibeci, 1984; and Shrigley, 1972). Be it via socialization (Joyce, 2000), the processing of differential expectations (Kagan, 1992), or otherwise, girls seem to develop qualitatively different attitudes to science than boys. It seems that children have begun to form their own definitions of science before they even enter school (Osbourne & Whittrock, 1983). If negative frameworks go undetected, the learning and pursuit of science-based courses and careers may be undermined. These undermining tendencies are concretely noted in the significantly lower numbers of women pursing science-based post-secondary study, and ultimately, science-based careers (Lee, 1998).

Attitudes to Science and the Gender-Based Differential Pursuit of Science

Numerous studies have been done which highlight the issue of attitude to science differences among boys and girls as being very salient. Recently, Ercikan and McCreith (2001), using data from the International Mathematics and Science Survey (TIMSS), found significant differences in attitudes to science for senior secondary students from Norway and the USA, and marginally significant differences for senior secondary students in Canada, with males expressing more positive attitudes to science. This finding has been echoed many times in other work, with researchers offering insight into the qualitative underpinnings of such attitude differences. For example, girls' negative attitudes to science do not appear to invade all aspects of the study of science. Hendley and Parkinson (1995) found that girls' attitudes were actually more positive than boys' toward the reading and writing component of science. However, boys held more positive attitudes to all other aspects tested, including importance, enjoyment, perceived level of difficulty, and practicality.

Other research has probed further what qualitatively defines the gender-related differences in attitudes to science. Trankina (1993) looked at nationwide American survey data from 1972-1990 and found that at all education levels and in all age groups, females had less confidence in science than males. In their 2000 study, Jones, et al. found significant gender differences in grade six students, favoring males, in science experiences, attitudes, and perceptions of science courses and careers. Moreover, Jones, et al. note that males report more experiences with tools that are likely to be used in science, such as batteries and electric toys, while females report more experiences with traditionally feminine activities, such as bread making and planting seeds. Males also reported more interest in science topics such as atomic bombs, cars, computers, x-rays and technology, while females reported interest in science topics that were care-related, such as animal communication, healthy eating, and AIDS. In addition, Jones, et al. found that in terms of possible willingness to approach the study of science, females thought science was more difficult to understand (51 percent of females versus 41 percent of males).

Thus, the idea that boys and girls have different attitudes to science is well-supported. However, while the argument can be made that girls have poorer attitudes to science, it may be possible that girls simply have depressed attitudes toward academics in general. That is, perhaps the issue is not one of negative attitudes to science, but more so one of global negative attitudes to school. Morell and Lederman (1998) addressed this problem by administering both attitude to science and attitude to school questions, and then examining the relationship between the two. They found that students' attitudes toward school were relatively positive, while attitudes to science were not, and further, that the relationship between students' attitudes toward school and their attitudes to science was weak, indicating that poor attitudes to science are not part of a global poor attitude toward school.

While attitude to science has received much support in explaining the gendered differential pursuit of science experiences, another variable that has vied for centrality in this same quest is motivation. It is difficult to wholly separate attitude and motivation as forces which govern student involvement with and achievement in science. However, some researchers have attempted this feat, and have found that attitude may present as the more predictive construct in terms of gender differences in participation and achievement in science. For example, Simpson and Oliver (1985) found that science students in grades six through grade 10 differed significantly in their attitudes to science, with boys maintaining more positive attitudes than girls despite the fact that girls were found to be significantly more motivated to achieve in science. Cannon and Simpson (1985) also highlight attitude to science as a more central variable compared to achievement motivation for the grade seven students they studied, with attitude but not achievement motivation playing a role in predicting science achievement; a finding that held true across all ability groupings. Thus, while it may remain somewhat unclear as to the unique roles that attitude and motivation play in science achievement and participation, the present study focuses on attitude.

Other Variables Impacting Attitudes to Science

Ethnicity

Researchers have underlined the centrality of attitudes to science as a factor in the participation and pursuit of science-based activities. What is also very clear, is that such attitudes may be particularly important for ethnic minorities who are further discouraged from scientific careers by prejudiced, stereotyped societal pressures. Fleming and Malone (1983) completed a meta-analysis and report that Anglos scored higher than Blacks ($\Delta = 0.10$) and Hispanics ($\Delta = 0.05$) on science attitude measures. Likewise, Simpson and Oliver (1985) found that for sixth, seventh, and eighth grade students, the mean attitude score reported by whites was significantly higher than that reported by blacks. However, in ninth grade, where the students enrolled in science represent a more advanced subgroup, the situation reversed. Black students enrolled in advanced courses had more positive attitudes to science than white students. The current author proposes that this situation likely developed due to the perseverance afforded by the especially positive attitudes of these advanced black students. Such perseverance may have assisted these black students in overcoming other social barriers as they pursued advanced science study. In more recent work, Greenfield (1996) looked at the science attitudes in the four major ethnic groups in Hawaii, and found that Caucasians expressed the most positive attitudes to science, Japanese expressed the most positive perceptions of scientists, and Hawaiians and Filipino Americans expressed the least positive attitudes and perceptions. Further, Greenfield found that attitudes to science seemed to be directly related to science achievement, with Caucasians and Japanese outscoring Hawaiians and Filipino Americans across all grade levels. Overall, it appears that ethnicity has a role in the development of attitudes to science, and ultimately achievement in and pursuit of advanced science-based study.

Country of Residence

Another relevant issue in the study of attitudes to science is whether or not the gender-based differences in attitudes to science remain constant across countries. Research from various locales around the world seems to indicate that these gender-based attitudes are a salient problem regardless of the participants' origin. For example, Hendley and Parkinson (1995) found that the attitudes of 13-year-old Welsh boys to science were more positive than that of their female counterparts. Ercikan and McCreith (2001) found the same for American and Norwegian senior secondary students, and to a more marginal extent, Canadian senior secondary students.

While many international studies find support for the idea that boys have more positive attitudes to science than girls, other work, specifically that done in less-developed and/or non-westernized countries, does not find gender-based differences in attitudes to science. Rennie and Dunne (1994) studied 16-year-old Fijian students on track for higher education and found no differences between the attitudes to science of boys and girls. Boone (1997) studied middle school students in Shanghai and found that girls were more interested in science topics and issues than boys. While the reasons for these differences are debatable, the present author's opinion is that the students who are receiving science education and/or education at a higher level than most of the rural-based population in these countries, are likely from more affluent and pro-education families. Thus, when these students are surveyed for attitudes to science, they are more likely to produce gender-equal or even more positive female results than when the same surveys are administered to westernized countries where education and science would not be as highly valued by all members of the school-going population.

Socio-Economic Status

Simpson, et al. (1994) state that of the many studies that have examined the relationship between socioeconomic status (SES) and attitudes to science, the resounding conclusion is that these two variables are not strongly related. One such example is found in Schibeci and Riley (1986), who concluded that home environment (e.g. Is there an encyclopedia in your home?) and parental education had significant impact on science achievement, but did not appear related to attitude to science. Haddon and Johnstone (1982), and Fleming and Malone (1983) also reported low relationships between SES and attitude.

Age

Researchers have investigated a possible developmental link between attitude to science and age. As students become older, it seems that they develop less positive attitudes to science. In his 1984 review, Schibeci states, "Many studies reported a decline in attitudes with increasing grade level." For example, Simpson and Oliver (1985) found that as students transitioned from grade six to grade 10, their attitudes declined significantly. The impetus for this decline is likely rooted in a multitude of factors. One factor that has been strongly supported is documented by Eccles, et. al (1993), who suggest that this decline may be attributed to environmental changes within schools, particularly as students transition to junior high school. Eccles, et. al, put forth that these changes do not occur in tandem with the changing developmental needs of adolescent students. The result is decreased motivation and negatively altered self-perception; both constructs that may have considerable overlap with attitude.

Researchers have looked further at the link between development and attitudes to science by investigating the role that gender plays in the onset of negative attitudes. This investigation is based on the rationale that girls develop more negative attitudes to science over time, and that this development parallels their internalization of sex-linked sociological ideals. Research seems to indicate that girls' attitudes to science deteriorate more than those of their male counterparts as they progress through school. Handley and Morse (1984) found that even when studying students for a two-year span from seventh grade through eighth grade, the stereotyped view of male dominance in science became more positively correlated with attitudes to science for both males and females. Related work aimed at accounting for this decay suggests that although nine-year-old girls express great interest in science when compared to their male peers, at this young age they already lag in science-related experience. This lag leads to ever-larger experience discrepancies, ultimately translating into increasingly negative attitudes to science for girls at ages 13 and 17 (Butler-Kahle & Lakes, 1983). Greenfield (1997) found that while boys and girls expressed equal and positive attitudes to science in early elementary school, as they moved through to high school, their attitudes became increasingly negative, with the latter being especially true for girls, as they showed a greater decline. Based on such information, it would appear that there is a developmental trend impacting attitude to science - namely, while attitudes to science decrease in both boys and girls over time, girls' attitudes decrease more than boys' attitudes as sex-roles become more entrenched in the pre-adolescent and adolescent years.

While the developmental trend discussed previously has many supporters, some data has suggested that it is not as stable as it has been made out to be. For example, Barrington and Hendricks (1988) found that overall, student attitudes to science decreased significantly between third and seventh grade, but then increased significantly between seventh and eleventh grade, and further, that there were no gender differences in attitude. Additional work is needed in this area in order to establish the relevance of development in the study of attitudes to science.

Adolescence

Due to the uniqueness of adolescence as a developmental stage, it is worth noting and reflecting on what characterizes adolescent development, and the importance of such characterization as it relates to the present study. Piaget defines four stages of development: sensorimotor, pre-operational, concrete operational and formal operational. The latter intersects with the life-stage typically known as adolescence. Thus, children ages 11 through 15 are immersed in what Piaget termed the formal operational stage. During this stage, adolescents are able to think more abstractly, and are not limited to concrete events to stimulate thought. They are able to reason logically about different abstract and intangible situations. An extension of this abstract reasoning is absorption with idealism, and as such, adolescents are apt to speculate about ideal characteristics in themselves and others, and comprise formulations about future events (Santrock, 1998).

Part of this speculation involves developing self-understanding, a process by which adolescents conceive a representation of self (Santrock, 1998). This is largely social-cognitive in construction whereby self-perception in terms of socio-cultural references becomes intertwined with the adolescent's cognitive development. As suggested by Garcia, Hart and Johnson-Ray (as cited in Santrock, 1998), there are three facets of self-understanding: a) personal memories, b) representations, and c) theories about self. The adolescent thus reflects on past memories, thinks about characteristics that are represented in him or her, and develops ideas about these characteristics in terms of rank-ordered importance. All of this results in formulations of the adolescent's own self-understanding.

Given the emergence of a self-prescribed identity during adolescence, measurement of attitudes to science in this age group are likely to reflect the impact of a variety of influences over the course of their relatively short lives. Moreover, measurement at this stage may be more representative of long-term attitudes, since many of the formative stages of development are complete, and attitudes are less likely to undergo major transformations. All of the interactions that the adolescent may have had with parents, peers and teachers have already settled as part of his or her self-perception, and thus, have already influenced acquisition of various affective traits, such as positive or negative attitudes to science. It is for this reason that 15 and 16 year old grade 10 students are the focus of the present study.

Expectations

Group differentiation, with respect to achievement and participation in science, has been explored in relation to self, peer, parent or teacher initiated expectations. Research related to expectations in the educational context dates back at least to Rosenthal and Jacobson's (1968) controversial self-fulfilling prophecy work, and continues to command attention as it relates to decision-making and success (Kagan, 1992). Although several types of expectations have been investigated, perhaps the most influential are parental expectations, with the child's exposure to such spanning all stages of development and socialization. It follows that parents may foster in their child(ren) the internalization of social ideals, such as the notion that science is traditionally a field in which males, and not females, excel and explore (Butler-Kahle & Lakes, 1983; Joyce, 2000). By the time children reach school age, exposure to parental expectations has played a potentially significant role in the definitions that children form of science, and hence, the extent to which children deem participation in science acceptable (Osbourne & Whittrock, 1983).

Children are exposed to other sources of expectations once they enter the school system, such as peers and teachers. If teachers' are compelled to believe, based on sociological ideals or otherwise, that certain groups excel in specific subject areas, the resultant teacher behavior has the power to alter student performance and choice with regards to achievement and participation (Kagan, 1992; Ware & Lee, 1988). Student exposure to peer expectations also increases as a child enters school. Researchers have found that students are affected by the collective ambition and direction of his/her peer group when applying themselves towards academic success, and when making choices about participation in various subject areas (Wentzel, 1999).

Parent, peer, and teacher expectations logically impact self-expectations, which are also a key component of discussions about predicting achievement and participation. Researchers have found that different groups, such as women or minorities, have lower levels of science-based self-efficacy that prevent them from enrolling in science-based postsecondary programs, have lower expectations for participation in advanced science courses, and have lower expectations for success in science classes and careers (Lorenz & Lupart, 2001; Sayers, 1988). As a result, there is an under-representation of these groups in advanced science-based post-secondary study as well as science-based careers (Lee, 1998).

Attitudes to Science and Prediction of Science Achievement

Researchers have explored attitudes to science as an important predictive variable of science achievement and future involvement with science-related interests, such as course of post-secondary study, participation in advanced science courses, and pursuit of science-based careers. Findings are mixed, with some upholding and others disconfirming the predictive value of attitudes to science, as they relate to achievement.

Regarding the link between attitudes to science and achievement in science, Weinburgh (1995) undertook a meta-analysis, and found that boys have more positive attitudes to science than girls, and that the mean correlation between attitude and achievement was .50 for boys, and .55 for girls. Based on these results, it would appear that achievement and attitude are related. Weinburgh found further that this correlation was stronger for girls than boys when specifically considering biology and physics, and was also stronger for low-performance girls. The unfortunate implication of this is that, for girls in biology and physics, and for low performance girls, their more negative attitudes could impact their science achievement to a greater extent. Ercikan and McCreith (2001) also present results suggesting that achievement may be related to attitude. They found that males in the USA had a stronger relationship between attitudes to science and achievement than females. However, in Canada and Norway, the reverse was true with females having the stronger relationship between attitudes and achievement. Cannon and Simpson (1985), while studying grade seven life sciences students, also present data supporting the idea that science attitude is a good predictor of science achievement.

Since much of the research on the link between attitudes to science and science achievement is correlational in nature, causal data supporting a direction of this linkage is not readily available. In their 1986 study, Schibeci and Riley attempted to address this issue by examining two different models: (a) Perception of science instruction influences attitudes which influences achievement; and (b) Perception of science instruction influences achievement which influences attitudes. Using cross-validation procedures, Schibeci and Riley posit the former as a stronger causal chain. However, much discord exists concerning this opinion, as can be found in a review of science education research, where Peterson and Carlson (1979) present the opinion that a stronger argument can be made for saying that achievement creates positive attitudes and probably not the reverse.

Due to the sometimes-contradictory results found about the predictive value of attitudes to science, some researchers dismiss entirely the idea that attitude and achievement are linked (e.g., Fraser, 1982). Schibeci (1984) refutes such dismissal, suggesting that there are two problems with minimizing the importance of attitude. First, attitude research is often technically poor, making it difficult to draw valid generalizations. Second, Schibeci posits an ideological flaw as reason to question the conclusion that attitude does not matter. This argument acknowledges that achievement can be improved in a number of ways, coercion and force to name but two. All such methods share the common assumption that it is not necessary for the student to enjoy science in order to be successful at it. However, most educators hold at least some value for students' feelings and emotions, and while this position can be debated, it is one that must be considered carefully. Therefore, if we are concerned with improving achievement, we should, at the same time, pay some attention to attitude.

Attitudes to Science and Prediction of Science Participation and Careers

The predictive power of attitudes to science has also been studied in terms of future science course selection, and ultimately, future science career paths. While research results are mixed, most authors report some connection between attitudes and future science involvement. In a 1994 study, Rennie and Dunne found that those students who had nominated a science-related career also had more positive attitudes to science. Joyce and Farenga (1999) found that gender, career interest in science (an approximation of the more general measure of attitudes to science), and informal physical science experiences contribute significantly to a prediction model regarding the number of physical science courses selected, with males selecting more physical science courses than females. In other work related to attitudes and prediction of future science involvement, Joyce (2000) looked at average and high-ability girls ages nine through 13 and found that attitudes to science, including measures of Normality of Scientists, Enjoyment of Science Lessons, and Leisure Interest in Science, were all significantly related to the number of science courses selected. It is important to note that Normality of Scientists, as a variable highly correlated with course selection, has great implications if girls adopt the view of the traditionally male scientist role, since this has high potential to negatively affect the number of science courses they select.

While the aforementioned studies support a link between attitudes to science and future science participation and careers, Shamai (1996) found slightly less convincing results. Shamai measured the science attitudes of grade six students and followed up in grade 11 by looking at course selection, and then again after high school by looking at career selection. Results showed that there was almost no connection between attitudes and course of study in grade 11. However, a significant difference was found with regard to perceived importance of scientific occupations and future pursuit of academic or nonacademic study, with students selecting courses based on the importance they assigned to given occupations.

Attitude Objects

While attitude has established itself as a key component in understanding the gendered differential pursuit of science, the underlying processes that are facilitating this unfortunate circumstance are not yet fully understood. Children form ideas about science, what it is, and how they feel about it, at a very young age, usually before they enter school (Osbourne & Whittrock, 1983). It is thought that these early musings evolve, through exposure to science related topics and curriculum, as well as to societal forces and pressures, and by adolescence, they have established themselves in the form of well-entrenched attitudes. Such attitudes are founded on the child's beliefs and past experiences relating to science, and have the powerful potential of impacting a wide range of decisions related to enrollment in future science courses, both in high school and post-secondary studies, and to career decisions. Thus, the importance of attitude is clear. However, the nature of what is influencing this attitude differential between boys and girls is less clear.

One of the primary pieces needed to further delineate attitude to science development amongst boys and girls is knowledge of those science-related features, referred to as attitude objects, that activate application of the positive or negative attitudes. Attitude objects can range from teacher or instructional variables to scientific equipment, to features of the scientific laboratory, etc.. Schibeci (1984) suggests that the sometimes negligible relationship found between attitude to science, gender, and/or science achievement is the result of including too many attitude objects. For example, Harty, et al. (1986) attempted to measure attitude using a scale with no clearly defined attitude objects, and failed to find significant differences between boys and girls with respect to attitude to science. The results, of course, are inconclusive, since one cannot deduce what aspects of attitude to science either detracted from or added to the students' overall dispositions. Similar criticisms can be made of additional studies that have found significant attitude to science differences between boys and girls (e.g., Cannon & Simpson, 1985). Still other studies have actually defined attitude objects, only to amalgamate all such objects into a composite score when analyzing the data. While such amalgamation may be useful for the purpose of investigating certain prediction models, generally it is more informative to present results for attitude objects separately. One example of a study where attitude objects were combined is Barrington and Hendricks (1988), who went to great lengths to inform the reader of the various attitude objects they were studying, namely, attitudes to science classes, science teachers, usefulness of the information learned in science classes, and being a scientist. Unfortunately, they tabulated final results based on a composite score, arrived at by combining results from all of the individual attitude object scales. By neglecting to analyze and present the data in terms of individual, succinctly defined attitude objects, these researchers made it difficult for the reader to deduce the importance of the various components affecting attitude to science.

Type of Science as an Attitude Object

Related to the issue of attitude objects, is the tendency for researchers to neglect to define the type of science, such as physics, biology and chemistry, addressed in a given attitude to science study. Type of science acts as a specific attitude object, an idea which is reflected by findings suggesting that gender differences in attitudes to science vary in magnitude with the type of science studied. As a case in point, Vockell and Lobonc (1981) found that only the physical sciences are viewed as clearly masculine academic areas. In another study, Jones, et al. (2000) found that students' reported interest fit the gender-typical pattern of boys being drawn more to the physical sciences and girls more to the biological sciences. More specifically, boys expressed interest in learning about planes, cars, computers and radioactivity, things more commonly related to physics, while girls preferred to learn about things such as healthy eating, animal communication and AIDS, which are more commonly related to biology.

Ercikan and McCreith (2001) discuss a common problem related to type of science as an attitude object. They found that a prediction model regarding the link between attitudes to science and science achievement was not as strong as expected. The suggested explanation they provide for this is found in the nature of the attitude questions asked. Specifically, the questions used to measure attitude to science covered a wide range of science areas (biology, chemistry, etc.). Thus, when the composite attitude score is presented, the predictive strength of science attitudes is weakened, as positive attitudes in one area of science are neutralized by negative attitudes in another area of science. Overall, the importance of defining type of science as an attitude object in attitude to science research cannot be undervalued.

Defining Attitudes To Science

Discussion of attitudes to science necessarily involves defining such attitudes. A considerable lack of consensus amongst researchers as to the definition of "attitude" in the area of science education has been problematic in producing a comparable body of research. There exist two major categories that account for science-related attitudes: (a) attitudes to science, and (b) scientific attitudes. Attitudes to science includes those attitudes that are directed towards various aspects of science, such as science careers, science instruction, type of science (e.g., physical versus biological), the institution of science, specific science issues (such as pollution and energy), laboratory work, technology, or scientific processes (Schibeci, 1984). On the other hand, scientific attitudes represent those habits of mind generally associated with critical thinking, and typically meant to characterize the mental processes of a scientist at work (Munby, 1983). Thus, it is obvious that these two labels, which are pragmatically very similar, actually represent measurement of two very different attitude processes. Unfortunately, many researchers have not yet internalized this critical distinction, and the sometimes poor quality of attitude to science measures reflects this weakness. It would appear that for the purposes of the present study, the attitude to science domain is the more relevant area to focus on.

Having determined such, the construct of attitude also requires expansion. Gordon Allport was one of the early attitude theorists, and in 1935 he proposed the following definition for attitude (as cited in Horowitz & Bordens, 1995): "An attitude is a mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related." Horowitz and Bordens propose that attitude is made up of four interconnected components: cognitions, affective responses, behavioral intentions, and behaviors. That is, attitude manifests in processes of the mind, emotion and behavior. But how does one measure such processes?

The transition from these theoretical stipulations of attitude to measurement of attitude is not made with ease. As is the case with most affective constructs, attitude is not readily summarized into discrete, well-quantified, and observable parts. Instead, attitude is a very complex entity, which has been operationalized by researchers in vastly different forms, and with vastly different labels. Harty, et al. (1986) provide interesting discourse on the interrelatedness of four constructs: attitudes toward science, interest in science, science curiosity, and science self-concept. They proposed that theoretical relationships exist amongst all four constructs, and that rather than being four unique entities, it is possible that these constructs may actually operate under the control of a more abstract and conglomerative affective variable. The pursuant analysis in Harty, et al. (1986) supports the idea that attitudes toward science, interest in science, and science curiosity (but not science self-concept) are all similar and highly related attributes, with factor analysis indicating that they might be a single construct.

What then might be touted as the definition of attitude, and for the purposes of the present study, the definition of attitudes to science? Perhaps, as suggested by Harty, et al. (1986), the definitions of attitude, interest and curiosity should all be pursued. Secord and Backman (1964) defined attitudes as "certain regularities of an individual's feelings, thoughts, and predispositions to act towards some aspect of the environment" (p. 97). Rust (1977) referred to interest as "patterns of choice among alternative patterns that demonstrate some stability over time and do not appear to result from external pressures" (p. 132). Penney and McCann (1964) describe curiosity as "(a) a tendency to approach and explore relatively new stimulus situations; (b) a tendency to approach and explore incongruous, complex stimuli, and (c) a tendency to vary stimulation in the presence of frequently experienced stimulation" (p.323). Given the underpinnings of literature focused on explicating attitude, and repeated reference to the very broad scope accorded to attitude as a construct, it may be best to consider the construct of attitudes to science as an amalgamation of all the aforementioned definitions of attitudes, as well as definitions of interest and curiosity, with the intended framework of all such definitions being "science".

CHAPTER 3

Methods

Participants

The present study involved two phases of data collection, and thus, two different groups of participants. The first group was part of the 1995 British Columbia Assessment of Mathematics and Science (BCAMS) (Phase One), while the second group was part of a qualitative data collection phase conducted in 2002 (Phase Two).

Phase One participants

Phase One was completed as part of 1995 BCAMS, under the control of the British Columbia provincial government's Ministry of Education. All grade 10 students, ages fifteen to sixteen in British Columbia, in either public or funded independent schools, participated. Attempts were made to include students who were absent during the testing period by having them complete an assessment instrument upon their return to school. The only exceptions permitted were for students with special needs for whom testing was judged to be inappropriate. A total of 32 419 grade 10 students participated in the final collection. For the purposes of the present study, only data from those students who completed the Careers in Science Scale, the School Science Scale, or the Science in Society Scale are analyzed, for a total of 20 614 cases. It should be noted that each student completed only one such attitude scale, thereby yielding three different sample groups. For ease of discussion in the current paper, when the topic under investigation does not involve the measurement of attitude, these groups are referred to as: Group 1 (completed the Careers in Science Scale), Group 2 (completed the School Science Scale), and Group 3 (completed the Science in Society Scale). Otherwise, the groups are referred to by the scale they completed. The students across these three groups had a mean age of 15.9, with boys and girls equally represented (see Table 1 for age distribution). Eighty-four percent of the students included in the present study were born in Canada (this percentage was the same across all three scales), and 85-86 percent of the students reported that English was spoken in the home always or almost always (see Table 2).

Table 1

Age Distribution of Grade 10 Participants for Phase One Data Collection

	N		
Age	Group 1	Group 2	Group 3
15	3 584 (52%)[a]	3 574 (51%)	3 520 (52%)
16	3 307 (48%)	3 370 (49%)	3 259 (48%)
Group Total	6 891	6 944	6 779

[a]Percentages of total group rounded to the nearest whole.

Table 2

Amount of English Spoken in the Home for Students in the Phase One Data Collection

	N		
English spoken at home	Group 1	Group 2	Group 3
Never	158 (2%)[a]	153 (2%)	170 (3%)
Sometimes	842 (12%)	813 (12%)	811 (12%)
Always or almost always	5 855 (85%)	5 940 (86%)	5 767 (86%)

[a]Percentages of total group rounded to the nearest whole.

Phase Two participants

The second phase of data collection was completed by the present author in the spring of

2002, and involved 14 grade 10 female students, all of which were attending one of two urban public schools within the same provincial school system that the 1995 BCAMS sample was drawn from. Recruitment of student volunteers involved visiting four classes at two secondary schools, containing a total of approximately 50 females. During these recruitment visits, the current author presented students with the research objectives and asked them to consider participating. All female students who returned consent forms signed by their parent/guardian providing permission for them to participate were included in the present study. The students included in this sample were either 15 or 16 years of age (see Table 3), 65 percent (9 out of 14) spoke English in the home always or almost always, and 79 percent (11 out of 14) were born in Canada.

Table 3

Age Distribution of Grade 10 Participants in Phase Two Data Collection

Age	*N*
15	10
16	4

Measures

Attitude measures consist of two discrete resources, one quantitative in nature and used in Phase One, and the other qualitative in nature and used in Phase Two.

Quantitative Attitude Measure

Quantitative data was collected as part of the 1995 BCAMS completed by the British Columbia provincial government. Relevant items were selected from the 1995 BCAMS instrument for analysis, and include a number of individual items, as well as several items that are combined to yield three different attitude to science scales. Of the individual items selected from the 1995 BCAMS instrument, several pertain to students' plans for upper-level science course enrollment in grades 11 and 12, and one pertains to enrollment in post-secondary science courses. The other items that were selected were pooled into three attitude to science scales. These are: (a) The Careers in Science Scale; (b) The School Science Scale; and (c) The Science in Society Scale (see Table 4).

Table 4

Reliability of the Three Attitude Scales From the 1995 BCAMS

Scale	Reliability	Number of Items	*M*[a, b, c]	
			Male	Female
The Careers in Science Scale	.94[d]	10	32.5	31.7
The School Science Scale	.94[e]	10	35.4	35.8
The Science in Society Scale	.75[f]	10	35.6	35.4

[a]The higher the score, the more positive the attitude. [b]Maximum scale score is 50 for all scales. [c]Standard deviations for these scales by sex were not included in the technical report that was the source of the other statistics. [d]According to grade 10, Form T. [e]According to grade 10, Form R. [f]According to grade 10, Form S.

Only one scale was administered to each student, with scales being rotated across the various forms used in the 1995 BCAMS. Each of the attitude to science scales used Likert-type items and all were based on instruments from the 1991, 1986, and 1982 BCAMS. The three scales are reported to be valid to a high degree (Marshall, Taylor, Bateson, Brigden, Cardwell, Deeter, & Martin, 1995). All items have been examined by the current author, and indeed, appear to assess the factors outlined in (a)-(c) above. The three scales are presented in their entirety in Appendices A (The Careers in Science Scale), B (The School Science Scale), and C

(The Science in Society Scale). Relevant scales are listed in conjunction with each corresponding hypothesis in the data analysis section below.

Qualitative Attitude Measure

The second attitude measure, which comprises the qualitative component, is an interview protocol designed by the current author for the present study to provide assessment regarding the types of issues and attitude objects, specifically type of science, that may influence students' attitudes to science. This interview protocol is presented in its entirety in Appendix D. Questions included in this interview protocol were constructed with the purpose of extending findings from the 1995 BCAMS – specifically the 1995 BCAMS attitude scales, and related background questions. In this way, the 1995 BCAMS items provided fodder for the actual composition and structure of the questions. Previous research findings in related areas of work were also used to guide protocol question construction.

Achievement Measure

Science achievement scores are derived from the 1995 BCAMS achievement items, as collected during Phase One. All science achievement items in the 1995 BCAMS were selected from either earlier provincial assessments or the Third International Mathematics and Science Study (TIMSS), and thus, all had known properties that met selection criteria. To ensure curricular validity, however, the items from TIMSS were validated. This involved review and rating by practicing teachers in the field. All potential items were linked to learning outcomes in the curriculum, were rated for curriculum match and appropriateness, and had cognitive behavior levels attached to them. In addition, multiple-choice items were selected upon meeting the following criteria: validation by reviewers, an acceptable range of *p*-values, and sufficient numbers for reporting categories. Items from both the1991 science assessment and TIMSS were used, as outlined in Table 5 and Table 6. Only data from the multiple-choice items is incorporated as part of the present study.

Table 5

Specification of Number and Origin of Grade 10 Science Achievement Items

Origin of items	Multiple choice items	Free response items
1991 Science assessment	49	8
TIMSS	16	6
Total	65	14

Note. Various forms were administered. Each form consisted of 20 science achievement items; five of which were core items, and 15 of which were rotated across forms.

Table 6

Student Performance on 1995 BCAMS Achievement Items

Topic[a]	Mean Percent Correct[b]
Science Skills and Processes	66.0
Scientific Knowledge	57.9
Higher Level Thinking Abilities/Cognitive Processes	48.8

[a]Mean Percent Correct results were provided according to the three topics listed here. [b]Mean Percent Correct refers to the average percent correct attained by all students on all items in a given topic.

In the 1995 BCAMS, students were administered a two-part form. Part one contained background information questions and attitude scales (for both math and science), while part two contained 51 multiple choice achievement items. Of these, 20 were for science (with the other 31 being for math). Of the science items, five were core questions and were common to all forms used (four forms in total), while the other questions were drawn from the remaining bank of questions and were rotated across forms. For the current study, however, results from only 16 questions on each form are analyzed, rather than 20. The excluded four are all restricted items whose use and publication is governed by TIMMS. Since these items were not published, they could not be coded by the current author, and thus, are not included in any analyses presented herein.

Procedure

Quantitative data, documenting both attitudes and achievement, was attained from the British Columbia Ministry of Education as collected during the 1995 BCAMS. For a full report of procedures and instruments, see Marshall, et. al, 1995.

Qualitative data was collected from 14 volunteer grade 10 female students during interviews conducted by the current author. These students were first asked to complete the three attitudes to science scales of the 1995 BCAMS, as well as other selected relevant items from the 1995 BCAMS. Answers to these questions assisted in shaping the specific questions asked during the interview. However, due to the very small number of students participating, no statistical analyses were done on this set of quantitative data. Upon completion of the selected 1995 BCAMS items, the students were interviewed for the purpose of collecting information about the foundation of their responses on the affective scales, and about type of science as an attitude object. All interviews were audio-recorded and transcribed by the current author for subsequent coding and analysis.

Analysis

As mentioned previously, three quantitative attitude scales were used to measure attitudes to science. For presentation of results, when the topic under discussion includes the construct of attitude, the three groups involved are referred to by the attitude scale they completed (Careers in

Science Scale, the School Science Scale, or the Science in Society Scale). However, for ease of discussion, when the topic under investigation does not involve the construct of attitude, the groups are referred to as: Group 1 (completed the Careers in Science Scale), Group 2 (completed the School Science Scale), and Group 3 (completed the Science in Society Scale). In addition, it should be noted that for those analyses that did not include attitude, the three groups were not combined. The rationale for maintaining group level analysis in these cases was that each group was deemed to be randomly equivalent, and had a relatively large *N*, (ranging from approximately 6700 to 6950), and thus, the situation presented as an ideal opportunity for replicating analyses using each sample group separately.

Data Analysis for Quantitative Research Questions: Phase One

Research Question One. Are there gender differences for grade 10 students in the endorsement of positive attitudes to science, including attitudes about science in school, science in society and science as a career?

Hypothesis One. In grade 10, boys will have more positive attitudes to science than girls in the areas of science in school, science in society and science as a career.

Analysis for Research Question One. Results from the three attitude scales (School Science Scale, Science in Society Scale, and Careers in Science Scale) used in the 1995 BCAMS were analyzed to evaluate the different levels with which boys and girls positively endorse the study of science. A score on each scale was created by using the Non-Linear Optimal Scaling Method (Categorical Principal Components Analysis) – a method which enables creation of a composite interval scale based on a set of Likert type items (Gifi, 1990). Scores were compared for boys and girls using the independent samples *t*-test (see Table 7).

Table 7

Relevant Data for Hypothesis One

Source of Data	Scales[a]
BCAMS	The Careers in Science Scale
	The School Science Scale
	The Science in Society Scale

[a]Items for these scales are in Appendices A, B, and C

Research Question Two. Is there a gender difference for grade 10 students in enrollment in upper-level secondary science courses?

Hypothesis Two. In grade 10, boys will have more interest than girls in enrollment in upper-level chemistry and physics secondary courses, but girls will have more interest than boys in enrollment in upper-level biology secondary courses.

Analysis for Research Question Two. Data from the 1995 BCAMS regarding grade 10 students' plans to take provincially prescribed grade 11 and 12 (the last two years of high school in British Columbia) science courses were analyzed using the Chi-Square Test of Independence to test for differences in enrollment rates of boys and girls (see Table 8).

Table 8

Relevant Data for Hypothesis Two

Source of Data	Item
BCAMS	Which science courses do you plan to take in grades 11 and 12? (select all choices that apply) Biology 11 Chemistry 11 Physics 11 Biology 12 Chemistry 12 Physics 12

Research Question Three. Is there a gender difference for grade 10 students in the planned pursuit of science courses in post-secondary study?

Hypothesis Three. Boys will endorse more so than girls plans for pursuit of science-based study in post-secondary education.

Analysis for Research Question Three. Data from the 1995 BCAMS regarding grade 10 students' plans to take post-secondary science courses were analyzed (Do you plan on taking more science courses once you have finished secondary school?) using the Chi-Square Test of Independence to test for differences between boys and girls in their planned pursuit of science-based post-secondary study.

Research Question Four. Is there a relationship between attitude to science in grade 10, and achievement in science in grade 10?

Hypothesis Four. Positive attitudes to science in grade 10 will be associated with higher levels of achievement on the British Columbia Assessment of Mathematics and Science (BCAMS) science achievement items.

Analysis for Research Question Four. Regression analysis was used to examine the relationship between attitudes to science, as measured by each of the three scales (School Science Scale, Science in Society Scale, and Careers in Science Scale) used in the 1995 BCAMS, and achievement, as measured by the science achievement component of the 1995 BCAMS. For the purposes of the present study, the achievement score was arrived at by recoding multiple choice science achievement items (16 in total) into a dichotomous scoring system (1=correct, 0=incorrect) and then summing the result of this dichotomy for all questions (see Tables 9 and 10).

Table 9

Relevant Data for Hypothesis Four

Source of Data	Scales & Items
BCAMS	Careers in Science Scale[a]
	School Science Scale[b]
	Science in Society Scale[c]
	BCAMS science achievement score[d]

[a,b,c]Items for these scales can be found in Appendices A, B, and C.
[d]Sixteen items selected from a bank of items that were rotated across forms.

Table 10

Examples of Science Achievement Items used in 1995 BCAMS

Sample Science Achievement Items
1. Night and day results from:
A. earth revolving about the Sun.
B. spinning of the earth.
C. moon going around the Sun.
D. sun revolving around the Earth.
E. I don't know.
2. The Theory of Plate Tectonics is useful in:
A. the process of glaciation.
B. how fossils were formed.
C. many past and possible future changes in the Earth.
D. how the Earth got the present unchangeable surface features.
E. I don't know.
3. Object X weighs twice as much as object Y when both objects are at the same place on Earth. The mass of object X is:
A. half that of object Y.
B. twice that of object Y.
C. four times that of object Y.
D. the same as that of object Y.
E. I don't know.

Research Question Five. Is there a relationship between attitudes to science in grade 10, and intent to enroll in upper-level high school science courses in grades 11 and 12?

Hypothesis Five. Positive attitudes to science in grade 10 will be associated with higher levels of intent to enroll in upper-level high school science courses in grades 11 and 12.

Analysis for Research Question Five. Binary logistic regression analysis was used to examine the relationship between attitudes to science, as measured by each of the three scales (School Science Scale, Science in Society Scale, and Careers in Science Scale) used in the 1995 BCAMS, and grade 10 students' plans to take provincially prescribed grade 11 and 12 science courses (see Table 11).

Table 11

Relevant Data for Hypothesis Five

Source of Data	Scales & Item
BCAMS	Careers in Science Scale[a]
	School Science Scale[b]
	Science in Society Scale[c]
	Which science courses to you plan to take in grades 11 and 12? (select all choices that apply)
	Biology 11
	Chemistry 11
	Physics 11
	Biology 12
	Chemistry 12
	Physics 12

[a,b,c]Items for these scales can be found in Appendices A, B, and C.

Research Question Six. Is there a relationship between attitudes to science in grade 10, and intent to enroll in post-secondary science courses?

Hypothesis Six. Positive attitudes to science in grade 10 will be associated with higher levels of intent to enroll in post-secondary science courses (see Table 12).

Table 12

Relevant Data for Hypothesis Six

Source of Data	Scales & Item
BCAMS	Careers in Science Scale[a]
	School Science Scale[b]
	Science in Society Scale[c]
	Do you plan on taking more science courses once you have finished secondary school?

[a,b,c]Items for these scales can be found in Appendices A, B, and C.

Analysis for Research Question Six. Binary logistic regression analysis was used to examine the relationship between attitudes to science, as measured by each of the three scales (School Science Scale, Science in Society Scale, and Careers in Science Scale) used in the 1995 BCAMS, and grade 10 students' plans to enroll in post-secondary science courses. Differences in coding required that for Group 1 and Group 3, answers to the question regarding plans for post-secondary science course enrollment were recoded into a dichotomous scoring system (with the choices "Yes, maybe one or two" and "Yes, make a major part of my life" being merged to form one half of the dichotomy, and "No" forming the other half") to equate them with existing coding for Group 2. In addition, for the purposes of the present study, data from students who answered, "I don't know" to this question was not included.

Data Analyses for Qualitative Research Questions: Phase Two

Research Question A. What variables play an influential role in students' attitudes to science?

Hypothesis A. A variety of factors, rooted in both environmental and student-focused affective variables, influence student development and maintenance of attitudes to science.

Analysis for Research Question A. All student interviews were tape-recorded and transcribed. Hard copies of interview transcripts were reviewed thoroughly and themes were identified based on frequency of occurrence. Those themes which emerged on most or all transcripts were considered major and comprised the structure for analyzing the qualitative data. Following this, statements were coded as belonging to identified themes, and using a word processor, these statements were collected under their respective themes. The subsequent analysis involved review of all statements identified as belonging to each theme.

Research Question B. What influences students in their decision on whether or not to pursue study of upper-level biology, chemistry and physics courses in both secondary and post-secondary school?

Hypothesis B. Many components of the student's surroundings, such as family and teachers, as well as factors that are inherently more affective in nature, such as perceived ability in science and perceived importance of science, are part of the myriad of variables that guide student selection of upper-level biology, chemistry and physics courses in secondary school, as well as selection of science courses in post-secondary school.

Analysis for Research Question B. Analysis of qualitative interview data for Research Question B was carried out in the same manner identified under Research Question A above, with particular attention paid to variations in how participation in the different areas of science, namely, biology, chemistry and physics, is influenced according to each emerging theme.

CHAPTER 4

Results

This chapter presents statistics that describe the sample and results of analyses in relation to each of the research questions. The results are presented separately for each of the two phases of the study, namely, Phase One (quantitative) and Phase Two (qualitative).

Descriptive statistics for achievement were computed for the three groups, and an independent samples *t*-test was completed to examine any gender differences. These results are reported in Table 13. Females performed higher than males in science in both Group 2 and Group 3, while males and females perform at almost identical levels in Group 1. Results indicate that the two noted differences for Group 2 ($t(6942) = -2.39$, $p<.05$) and Group 3 ($t(6777) = -3.24$, $p<.001$) are significant (see Table 13). However, despite the significance of these differences, they are very small and likely not meaningful.

Table 13

Independent Samples t-Tests for Achievement Differences Between Males and Females

	N		*M (SD)*				
Group	Males	Females	Males	Females	Difference (Males – Females)	*t*	*df*
Group 1	3317	3574	9.58 (3.54)	9.59 (3.12)	-0.02	-0.20	6889
Group 2	3315	3629	9.23 (3.53)	9.42 (3.09)	-0.19	-2.39*	6942
Group 3	3226	3553	10.28 (3.40)	10.53 (2.95)	-0.25	-3.24***	6777

*$p<.05$. ***$p<.001$.

Quantitative Analyses for Phase One

Analysis for Research Question One: Gender Comparisons in Attitudes to Science

Students' attitudes to science across the three dimensions inherent to each of the three attitude scales were measured. The attitude scores were computed using the Non-Linear Optimal Scaling Method (Categorical Principal Components Analysis) in order to create a composite interval scale based on each set of Likert-type items (Gifi, 1990). Scores that are more positive in numerical value represent more positive attitudes (see Table 14).

Results for males' and females' attitudes to science across the three scales were compared using the independent samples *t*-test (see Table 14). Contrary to the stated hypothesis, girls had significantly more positive attitudes to science in Group 2 ($t(6942) = -2.64$, $p<.01$). However, in accord with the stated hypothesis, boys had significantly more positive attitudes to science in Group 1 ($t(6889) = 2.62, p<.01$), and in Group 3 ($t(6777) = 5.33, p<.001$). The difference in Group 1 was very small (less than 10 percent of one standard deviation), while in Group 3, the difference was larger, although still minimal (greater than 70 percent of one standard deviation).

Table 14

Independent Samples t-Test for Attitude Differences Between Males and Females

		N		*M (SD)*				
Group	Scale	Males	Females	Males	Females	Difference (males – females)	*t*	*df*
1	Careers in Science	3317	3574	0.04 (0.97)	-0.03 (1.01)	0.07	2.62**	6889
2	School Science	3315	3629	-0.03 (1.03)	0.04 (0.95)	-0.06	-2.64**	6942
3	Science in Society	3 226	3553	0.07 (1.04)	-0.06 (0.95)	0.13	5.33***	6777

**$p<.01$. ***$p<.001$.

Analysis for Research Question Two: Gender Comparisons for the Pursuit of Secondary School Science Courses

The frequency with which males and females endorsed intent to pursue secondary school science courses in the areas of biology, chemistry, and physics was measured. These frequencies are reported in Tables 15, 16 and 17. To minimize the probability of false rejections due to multiple comparisons based on the same data, .01 was chosen for identifying significant differences (α / n where n is the number of comparisons and $\alpha = .05$). It appears that girls have a greater interest than boys in taking biology and chemistry in grades 11 and 12. However, boys communicate a greater interest than do girls in taking physics in grades 11 and 12.

These frequency differences between boys and girls regarding intent to enroll in secondary science courses were tested for significance using the Chi-Square Test of Independence. There were significant gender differences in plans to take each of the courses investigated for each of the groups, with one noted exception being Chemistry 11 for Group 2 (see Tables 15, 16 and 17).

Table 15

Summary of Chi-Square Results for Gender Differences in Planned Participation in High School Science Courses for Group 1

Course	Male (% of total males)	Female (% of total females)	χ^2	*df*
Biology 11	1 570 (47%)	2 515 (70%)	378.24***	1
Chemistry 11	1 645 (46%)	1 972 (55%)	21.51***	1
Physics 11	1 582 (48%)	1 299 (36%)	91.06***	1
Biology 12	1 060 (32%)	1 873 (52%)	294.29***	1
Chemistry 12	1 206 (36%)	1 484 (42%)	19.277***	1
Physics 12	1 098 (33%)	756 (21%)	124.91***	1

***p<.001.

Table 16

Summary of Chi-Square Results for Gender Differences in Planned Participation in High School Science Courses for Group 2

Course	Male (% of total males)	Female (% of total females)	χ^2	*df*
Biology 11	1 521 (46%)	2 582 (71%)	457.52***	1
Chemistry 11	1 700 (51%)	1 949 (54%)	4.08	1
Physics 11	1 610 (49%)	1 255 (35%)	139.80***	1
Biology 12	968 (29%)	1 876 (52%)	362.50***	1
Chemistry 12	1 216 (37%)	1 460 (40%)	9.22**	1
Physics 12	1 111 (34%)	745 (21%)	149.16***	1

**$p<.01$. ***$p<.001$.

Table 17

Summary of Chi-Square Results for Gender Differences in Planned Participation in High School Science Courses for Group 3

Course	Male (% of total males)	Female (% of total females)	χ^2	*df*
Biology 11	1 549 (48%)	2 502 (70%)	352.89***	1
Chemistry 11	1 600 (50%)	1 927 (54%)	14.58***	1
Physics 11	1 534 (48%)	1 279 (36%)	92.97***	1
Biology 12	1 002 (31%)	1 810 (51%)	275.36***	1
Chemistry 12	1 150 (36%)	1 429 (40%)	14.99***	1
Physics 12	1 030 (32%)	751 (21%)	101.65***	1

***$p<.001$.

Analysis for Research Question Three: Gender Comparisons For Pursuit of Post-Secondary School Science Courses

Participants indicated whether or not they intended on taking any science courses after high school. Responses were tallied as frequency counts (see Table 18). While Group 2 shows very little differences across gender groups for plans to enroll in post-secondary science courses, both Group 1 and Group 3 show some differences between gender groups. In these groups, girls seem to be more interested than boys in enrolling in post-secondary science courses.

Table 18

Summary of Number of Males and Females Planning to Enroll in Post-Secondary Science Courses

	N					
	Group 1		Group 2		Group 3	
Plans to Pursue Post-Secondary Science Courses	Male	Female	Male	Female	Male	Female
No	745	733	1358	1539	777	752
Yes	1 647	1 805	1917	2061	1 616	1 792
Unsure	903	1016	—	—	813	999

Note. Data for Group 2 was coded as "yes" or "no", with no data presented for those students that were unsure. This lack of data is denoted by dashes.

The significance of the association between gender and intent to take science courses in post-secondary education was assessed using the Chi-Square Test of Independence (see Table 19). This association was not significant for the Group 2 (χ^2_1 = 1.16, $p>.05$), but was significant for both Group 1 (χ^2_3 = 10.17, $p<.05$) and Group 3 (χ^2_3 = 16.46, $p<.001$)

Table 19

Chi-Square Analysis for Gender Differences in Plans to Enroll in Post-Secondary Science Courses

Scale	χ^{2a}	*df*
Group 1	10.17*	3
Group 2	1.16	1
Group 3	16.46***	3

$p<.05$. $^{***}p<.001$.

Analysis for Research Question Four: The Relationship Between Attitude and Achievement

The relationship between attitude to science and achievement in science was examined. The regression model in place distinguished achievement as the dependent variable, and attitude as the independent variable. Initially, regression analysis was performed with an additional independent variable – gender. This analysis indicated that gender was not a significant variable, and thus, a single regression model could be used for the two gender groups.

Investigation of the relationship between attitudes and achievement revealed that attitudes to careers in science, attitudes to school science, and attitudes to science in society were all positively correlated with achievement, $r = .27$, .31, and .30 respectively (see Table 20).

Regression analysis indicated that attitudes to school science accounted for nine percent of variance in achievement; attitudes to science in society accounted for nine percent of variance in achievement; and attitudes to careers in science accounted for seven percent of the variance in achievement (see Table 21).

Table 20

Intercorrelations Between Three Attitude Scales and Achievement

Group	*N*	Attitude Scale	*r*
Group 1	7264	Careers in Science Scale	.31***
Group 2	7297	School Science Scale	.30***
Group 3	7171	Science in Society Scale	.27***

***p<.001.

Table 21

Summary of Regression Analysis for Three Different Measures of Attitude as a Predictor of Achievement

Group	Scale	*B*	*SE B*	β
Group 1	Careers in Science Scale[a]	1.03	0.04	.31***
Group 2	School Science Scale[b]	0.96	0.04	.30***
Group 3	Science in Society Scale[c]	0.92	0.04	.27***

[a]R^2 = .07. [b]R^2 = .09. [c]R^2 = .09.
***p<.001.

Analysis for Research Question Five: The Relationship Between Attitude and Intent to Enroll In Science Courses in Grades 11 and 12

The relationship between attitude to science and intent to enroll in provincially prescribed grade 11 and 12 science courses was examined using logistic regression. Attitudes to science, as measured by each of the three scales formed the independent variable, and intent to enroll in biology, chemistry, and/or physics in grade 11 and/or grade 12 formed the dependent variables.

Data analysis revealed that for all three attitude scales, attitude to science was moderately correlated with intent to enroll in each of Biology 11 and 12, Chemistry 11 and 12, and Physics 11 and 12. These correlations were strongest for chemistry and physics courses, and weakest for biology courses across all three attitude scales (See Tables 22, 23, and 24). Binary logistic regression analysis showed that the classification accuracy of the model was greatest for physics (within grade level) across all three scales. Chemistry had the second strongest classification accuracy, with biology having the weakest (again, within grade levels) (See Tables 22, 23, and 24).

Table 22

Summary of Logistic Regression Analysis for Attitudes to School Science as a Predictor of Intended Participation in High School Science Courses

Course	Classification Accuracy	*r*
Biology 11	61.2	.16**
Chemistry 11	65.4	.32**
Physics 11	66.9	.29**
Biology 12	62.1	.19**
Chemistry 12	68.3	.30**
Physics 12	73.6	.24**

Note. $N = 7297$.
$^{**}p < .01$.

Table 23

Summary of Logistic Regression Analysis for Attitudes to Careers in Science as a Predictor of Intended Participation in High School Science Courses

Course	Classification Accuracy	r
Biology 11	60.4	.16**
Chemistry 11	68.1	.36**
Physics 11	69.1	.33**
Biology 12	62.3	.20**
Chemistry 12	70.0	.34**
Physics 12	74.5	.27**

Note. $N = 7264$.
**$p<.01$.

Table 24

Summary of Logistic Regression Analysis for Attitudes to Science in Society as a Predictor of Intended Participation in High School Science Courses

Course	Classification Accuracy	r
Biology 11	60.3	.11**
Chemistry 11	62.1	.25**
Physics 11	65.5	.26**
Biology 12	59.9	.14**
Chemistry 12	65.8	.24**
Physics 12	73.6	.21**

Note. $N = 7171$.
**$p<.01$.

Analysis for Research Question Six: The Relationship Between Attitude and Intent to Enroll In Post-Secondary Science Courses

The relationship between attitude, as measured by each of the three BCAMS scales, and intent to enroll in science courses after high school was examined. Results illustrated that these variables are moderately correlated, with *r* ranging from .36-.51 (see Table 25). In addition, the classification accuracy of each model was analyzed, with results showing that attitude as measured by the Careers in Science Scale had the strongest classification accuracy (82.8 percent), attitude as measured by the Science in Society Scale had the second strongest prediction accuracy (76.1 percent), and attitudes as measured by the School Science Scale had the third strongest prediction accuracy (72.4 percent) (see Table 25).

Table 25

Summary of Regression Analysis for Three Different Measures of Attitude as a Predictor of Intended Participation In Post-Secondary Science

Scale	*N*	Classification Accuracy	*r*
School Science Scale	7219	72.4	.42**
Science in Society Scale	5225	76.1	.36**
Careers in Science Scale	5192	82.8	.51**

**p<.01.

Qualitative Analyses for Phase Two

Analysis for Research Question A: Variables That Influence Students' Attitudes to Science

Upon reviewing the interview transcripts, the current author identified 10 recurrent themes as potential influences on students' attitudes to science. These themes are illustrated in Figure 1.

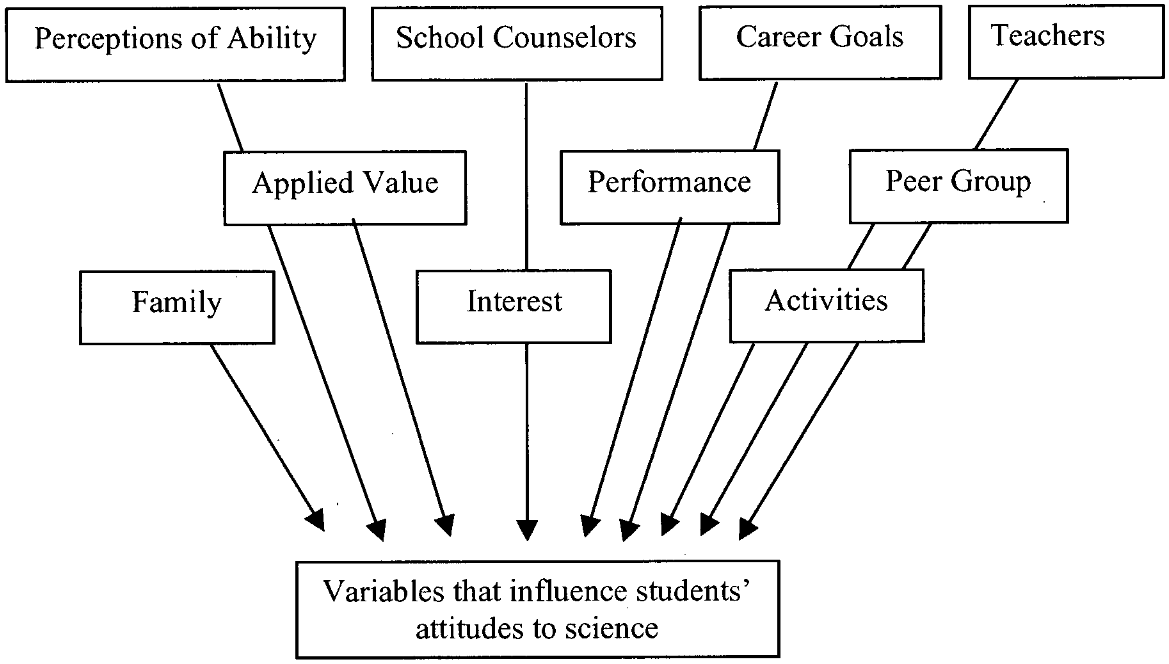

Figure 1. Emergent themes regarding variables that influence attitudes to science.

The interview transcripts were reviewed and statements were coded as they related to the 10 outlined themes. Results are discussed according to each of these themes.

Family. Three sub-themes were identified regarding the interviewees' references to the influence of family on their own attitudes to science. Included amongst these were parental concern for the child's future employment opportunities, and specifically, a desire for the child to pursue a career in science, based primarily on the supposition that such a career would provide financial stability, independence and prestige. One student, when queried as to why she planned on enrolling in science courses replied that, "Because now and in my future, my dad is saying that there is more and better jobs in science." This sentiment was echoed in another student's response when asked what had influenced her decision to participate in science. She replied, "My dad and my aunts just tell me to take sciences so that I have more career options." Other students' highlighted similar parent influences suggesting that parental desire for a stable, wellpaying job, characterized as a job in science, motivated students to become involved in science, and indirectly spurred a more positive attitude towards science.

Beyond the notion of job and financial stability, students also made reference to a certain prestige factor that their parents associated with science involvement, and ultimately a career in science. One student stated that should she become a doctor, her mom would be very proud of her as she "really wants at least one of her kids to be a doctor and do those kinds of things."

Other familial influences on the students' own attitudes to science were rooted in the impressions passed along by older siblings or cousins that had already participated in secondary science courses, and had formed opinions of their own level of difficulty and the worthiness associated with the various sub-areas of science. These opinions were then passed along to the interviewees and became part of the sub-context that informed the interviewees' choices to become involved with science and ultimately, their attitudes to science. One student relayed how she watched her older sister study for biology and, in particular, noted how thick the textbook was. This was enough to steer this student away from involvement with biology beyond what was required for her to graduate. Other students stated that if they received advice from their older sibling about whether or not to take a certain science course, they would apply this advice towards their own decisions. For example, one student said that if her brother told her that a science course "was a lot of work and not worth the time" she would not take it.

The third form of familial influence manifested itself as fear of parental retribution should the student decide not to involve herself with science pursuits. One student, for example, described in quite animated terms that she would face certain reprimand from her parents should she not apply herself in science-related endeavors.

Peer group. Two sub-themes emerged upon analyzing the interview data for influence of peer group on the students' attitudes to science. First, it appeared that the peer group could influence the students' decisions to pursue science - specifically older members of the student's peer group who already had experience with science courses. One student talked about older peers in her church youth group who had not only influenced her decision to enroll in certain science courses, but had also guided her to enroll in specific courses based on which teacher was assigned to instruct that course. When another student was probed for information on why she had decided not to take physics in high school, she stated that, "My friends say physics is really hard..." – an influential sentiment that resulted in the student's decision to avoid physics.

The second sub-theme that emerged under peer group influence was a simple desire for students to engage in interactions with other peers that were enrolled in certain science classes. Students suggested that their desire to attend the science classes they were enrolled in was mediated by the fact that "all of (their) friends are in that class" and that they would "get to see (their) friends." Taken together, the two sub-themes identified under the main theme of peer group influence suggest that such a group wields substantial power in terms of guiding decisions for involvement in science, and thus, indirectly mediates attitudes to science.

Teachers. Students' attitudes to science were influenced by their teachers on two fronts – that teachers often provide direction for students in selection of higher level science courses, and that students are more inclined to pursue science if they enjoy the methods of instruction that the teacher employs. These two fronts comprise the sub-themes under the more major theme of teacher influence.

Several students alluded to the fact that the teachers actually have considerable influence over the students' selection of upper-level science courses. It appears that the teachers made suggestions in this regard primarily based on the students' performance in a general grade 10 science course that incorporates modules in biology, chemistry and physics. One student commented that her decision about which upper-level high school science courses to take was based on her teacher's advice: "He told us what we should take and he told me I should take biology." When this same student was queried as to why she thought he gave her that advice, she responded, "He said that I would actually make it – that I would do good in it." Teachers also made these suggestions, to a lesser extent, based on the students' own interests.

In addition, students highlighted the teachers' style and method of instruction as a major reason for enjoyment and future pursuit of a given science area. When one student was asked about what her teacher does that makes science enjoyable for her, she answered, "My teacher will let us watch Bill Nye the science guy, and she will sometimes write a rap song (about what we are learning) and sing it in class." Another student talks also of what her science teacher does to help her enjoy that class: "(He) is so energetic and he won't just ask you to sit there. He lets you do experiments and touch things and do things." From these responses and several others, it was clear that the teacher's style has potential to influence a student's future involvement with and attitude to science.

School counselors. School counselors surfaced as a potential influential factor in terms of students' involvement with science and the upper-level science courses they had selected. When one student was listing reasons as to why she had selected biology as an upper-level science course, she replied, "...(because) my counselor told me to take biology."

Perceptions of ability. The students made several references to internalized notions of their strengths and weaknesses, and their fear of failure in certain subject areas based on these notions. Thus, internalized perception of strengths and weaknesses, and a fear of failure form the two sub-themes with which perception of ability was analyzed as an influential factor that may govern students' attitudes to science.

The interviewees had some very concrete ideas about which areas in school they may or may not excel in. These ideas were based on comments relayed by family members and teachers, as well as on past experiences with different subject areas. One interviewee commented that she opted for biology as her upper-level science course because her sister "said biology would be better because of my lack of ability to do harder things." The interviewee had taken this to heart and internalized her sister's conception of her skills to the extent that she opted out of the apparently more difficult physics and chemistry options. When another student was questioned as to why she was taking biology as her upper-level science elective, she also highlighted the impact of her perception of what her strengths were by stating, "I would rather take physics (but) I think that I am not that good in math, even though I understand (physics) better...better than biology...."

Related to perception of strengths and weaknesses is a fear of failure associated with science that discourages students from future involvement. When one student was questioned about what discouraged her from taking upper-level chemistry, she stated, "I just don't want to take it. It is too hard. There is no point in me failing a course. I wouldn't mind taking it for the fun of it, it's just that I don't want to fail."

Performance. This theme is closely aligned with Perception of Ability above. However, the statements included for analysis here contain specific reference to past performance that has prompted decisions for either enrolling in upper-level science courses or avoiding them. Several students indicated that they had formed opinions about certain science areas and made decisions regarding whether or not to pursue future studies in these areas based on past performance.

When asked why she had selected biology as her upper-level science elective, one student said simply that "I had higher test marks and I did really well in that." Another student similarly said that she was not taking upper-level chemistry and physics "Because my marks were too low." While there is not a pre-requisite grade for future involvement with a certain area of science, many students' actions, and indirectly their attitudes to science, seem to be governed by the logical principle that past performance predicts future performance. Rather than risk a poor grade, the students opt out of those areas they did not excel in and pursue those they did excel in, regardless of interest.

Interest in subject matter. Upon being asked about why they enjoy or do not enjoy science, and why they may or may not want to pursue future study of science, several students simply stated a keen interest or a lack of interest in the topic areas covered by various science courses. One student said she was going to take biology because "You get to learn about living things and I enjoy that." Another student commented that she would not take physics simply because "… it doesn't interest me."

Activities associated with science. Many students elucidate their reasons for either pursuing or not pursuing science by referring to actual tasks involved with study in specific areas of science. Some students find dissection, often a part of biology labs, enjoyable, while others find it "gross." Some students complain that biology and chemistry require too much memorization of vocabulary, anatomy, and chemical reactions, while others explain that the memorization is what makes courses easier. Some students find "mixing all of the chemicals together" an interesting part of chemistry labs, while others say that the resultant smell is not pleasant. And some students suggest that the math component of physics makes it too difficult while others suggest this is what makes physics appealing to them. Overall, the answers students provided that centered on specific activities to do with the subject areas were varied and seemed to be aligned with each individual's wider perception of their own strengths and tastes.

Career goals. The students interviewed for this study formed two groups in terms of career goals. The first group had a good idea of the vocation they intended to pursue. Members of the second group were uncertain of this, and were currently engaged in exploring their career options. Those students identifying with the former had made decisions about which upper-level science courses to take based on whether or not that course was required for their chosen career path. One student stated that she was taking physics because she wanted to be a massage therapist and "they said she needed it." Another student knew that her chosen vocation would not involve science so there was no need for her to take chemistry and physics, and further, that she was taking biology only because she needed it to graduate. Thus, the extent to which a science course could assist with development of a student's chosen career is identified as the first sub-theme under Career Goals.

Those students who were still uncertain of their future career path, identifying with the second group, sometimes stated that their reasons for taking certain science courses centered on exploring various areas in search of a career that would interest them. One student said she would be encouraged to take chemistry "to see what field I am going into and to see if it helps with that." Another student stated that she was taking chemistry and biology as upper-level science courses because "… I want to see if maybe that's what I want to do when I get older." Thus, the extent to which participation in a science course may help a student identify a potential vocational interest is the second sub-theme under Career Goals.

Perceived applied value of subject area. Whether or not a given science course was perceived to have applied value was highlighted as a potential influence on students' attitudes and their choice to continue involvement with that area of science. If a student understood the applicability of the concepts and topics covered in a science course, they appeared more likely to pursue future involvement with science. Applied relevance was usually expressed as applicability to 'everyday life'. For example, one student suggested that she enjoyed biology because "It is more related to life...." Another student stated she did not enjoy physics because "I can use chemistry and biology in my daily life whereas physics, I can't really use it – what am I going to use it for?" Thus, applied value was conducive to a more positive attitude to science (or a given area of science), and to future involvement.

Analysis for Research Question B: Variables That Influence Students' Decisions to Pursue Secondary and Post-Secondary Science Study

Decisions regarding whether or not to pursue advanced level study of science, and more specifically, the three main areas of science (biology, chemistry and physics) are influenced by a variety of issues. The interview protocol employed in the current study provides opportunity to analyze and explore data using six key points. These are:

1. Factors influencing selection of high school courses.
2. Factors that would encourage students to enroll in or discourage students from enrolling in biology, chemistry, or physics.
3. The impact of each student's perception of her ability in biology, chemistry, and physics.
4. Factors affecting student enjoyment of biology, chemistry, and physics.
5. The perceived importance of biology, chemistry, and physics.
6. The students' interest in a potential science career.

Statements evolving out of discussion prompted by items on the interview protocol were linked to each of the six areas, as was determined appropriate by the current author. These six areas comprise the main structure for the purpose of coding. Results are discussed according to each of these areas, with various themes identified where relevant. Certain areas of this analysis map onto qualitative analyses already discussed, however, these areas are repeated for clarity in relation to the present discussion.

Factors influencing selection of secondary courses. Ten factors were identified as influencing student selection of science courses for grades 11 and 12. These were: Family, teachers, school counselors, graduation requirements, perceptions of ability, actual performance, interest in subject area, activities common to subject area, applied value of subject area, and career goals.

Family guided student decisions to take certain high school science courses over others. According to the students interviewed, parents and other senior family members, such as aunts and uncles, were primarily concerned with the student's future career and employment prospects. They thus encouraged enrollment in science courses out of a desire to see the student succeed in the job market. Siblings and cousins were alternatively more likely to provide advice about which courses were hard and which were easy, which were interesting and which were not, and which courses they thought the student would perform well in according to their knowledge of her skill set. For example, one student, when asked why she planned on taking biology, is quoted as saying, "... my sister took it last year and she said you learn a lot of cool things." Another student indicates how her sister encouraged her to take physics: "My friends say physics is hard...I don't believe them." When asked why she didn't believe them she replied, "(because) my sister says its easy...." Thus, if a student's siblings or cousins have more positive attitudes towards certain areas of science, then the student herself would seem more likely to have a positive attitude towards these same areas.

Teachers also played an influential part in governing students' selection of specific high school science courses. Teachers appear to provide this advice based primarily on the student's performance in the three modules of the grade 10 science curriculum – namely, biology, chemistry, and physics. For example, one student stated that she would take biology because "my teacher just recommended me to take biology because my marks were higher – not that high but high enough."

Students also revealed through various comments that school counselors may influence science course selection. One assumes that this advice is given according to graduation requirements and the student's performance in other related coursework.

Closely related to the information that guidance counselors may act on when providing direction for student course selection, is the actual graduation requirements the student must meet in order to successfully qualify for high school commencement. When one student was queried as to her selection of biology as her sole upper-level science course, she replied, "I need it to graduate and I couldn't take (chemistry or physics) because of my Math 9 grade."

The students' individual perceptions of their own ability in the areas of biology, chemistry, and physics were also influential in guiding course selection. For example, students who were wary of their math skills often stated that they would avoid physics because of this. Students made mention of other specific skills required to excel in a certain science course. The ability to memorize, for example, was often cited as a necessary skill to excel in biology. Those students who felt they were good at memorization seemed more apt to enroll in a biology course ("Biology is a lot of detail and memorization and I am better at that") than those students who did not feel memorization was one of their strengths ("The reason why I didn't take biology is because I don't like memorization"). Similarly, other skills were paired with biology, chemistry and physics; if the students perceived that they possessed this skill, they were encouraged to enroll in the respective course and vice versa.

Actual performance, a variable slightly different than perceived ability, also governed student course selection. One student said, "I had higher test marks" when asked about her selection of biology, and another student stated, "because my marks were too low" when asked why she has opted out of chemistry and physics.

Each student's interest in a given area of science, according to the student's perception of what was included with study of that area, was yet another factor that predisposed students to specific course selections. Most students who opted to enroll in biology cited the fact that it is interesting because it is about life. For example, one student stated, "You get to learn about living things and I enjoy that." Many students who opted not to take certain courses seem to have resigned themselves to disinterest in a topic area. For example, one student is not taking physics because "I don't really like it and I don't see the point in taking it if I am not interested."

Students also made decisions about which courses to enroll in based on their interest in the types of activities associated with studying and learning about that area of science. One student stated that she was planning on taking chemistry because "I like chemistry…we do experiments." Another student said she would not be taking biology "because of the memorizing." In this way, several different facets of learning the three areas of science were communicated as either a reason to pursue study of that area, or as a reason to avoid it.

Students also relied on their perceptions of the applied value of a given area of science to their everyday lives. One student stated that she wanted to take biology because "you can use it for daily life." The importance of a perception of applicability to the students' lives across the three areas of science was similarly highlighted through a variety of such statements.

Finally, the students' goals in terms of career also played a part in their selection of upper-level science courses. One student suggested that she was taking chemistry because "I need it for what I plan to do after high school." Several students had not yet decided on their career goals, and in these cases, they occasionally stated that they were taking certain courses to see if they might develop an interest in that area that could evolve into a career path. Thus, if the student had already solidified plans for a career, course selection was made in accordance with the demands of those plans. If, however, career plans were as yet unknown, possible interest in a given science area appeared to govern course selection.

Factors that would encourage students to enroll or discourage students from enrolling in biology, chemistry, or physics. Students were asked what would encourage them to enroll in biology, chemistry or physics, and alternatively, what would discourage them from enrolling in biology, chemistry, or physics. Three sub-themes were common to all three science areas in terms of factors that would encourage or discourage. The first was knowledge that the content covered would be interesting. Students felt that if they knew they would be interested in the topics covered in the course, they would be more likely to take the course than if they thought the topics covered would be boring. One student said she would be encouraged to take chemistry if someone told her "That it is more interesting than biology or physics."

The second sub-theme to emerge was knowledge that the course would apply to the student's chosen career direction. For example, one student said that before deciding on enrolling in chemistry she would want "to see what field I am going into and to see if it helps with that." Another student stated that she was taking physics because "it is more related to what I think I want to do as a career."

The third sub-theme that emerged was knowledge that the activities involved with the course would be engaging. Students wanted to know that the course was not going to be boring, but instead would involved activities that the student found fun and interesting. One student said she would decide to take physics only if the teacher planned on "Not making it boring – making it fun, not taking down notes, doing experiments and doing cool things in the class related to physics, like projects and stuff like that."

A fourth sub-theme also emerged for chemistry and physics, although interestingly, it did not apply to biology. This sub-theme is defined as knowledge that the student would be successful. Physics and chemistry appear to have a reputation as being the more difficult science courses, and students who worried that they may not be able to handle the demands of these courses were more likely to avoid them. This reputation was elucidated through comments such as "I might fail it", and "It will be hard and I am afraid I will fail" for chemistry, and through comments such as "If it's too hard then I am not into physics", and "If it were a little easier maybe, and if there was not too much math in it" for physics. Alternatively, in all of the students' discussions surrounding biology, fear of failure or a focus on success was never mentioned.

The impact of each student's perception of her ability in biology, chemistry, and physics. If perception of ability impacts attitude to science, it follows that a student who perceives she is adept in a certain area of science may pursue future study of that area. Of the 14 students interviewed, 12 planned to take upper-level high school biology, five planned to take upper-level high school chemistry, and one planned to take upper-level high school physics (with three students selecting to enroll in both biology and chemistry, and one student selecting to enroll in both chemistry and physics). These students' course selections were compared with statements they made regarding how they felt they usually did in biology, chemistry, and physics. All of the 12 students who selected biology as an upper-level science course said that they feel they usually do better or the same in biology when compared to physics and/or chemistry. However, one of these 12 also stated that physics was her best subject in terms of performance, yet she still opted to take biology. When queried on this she said "I would rather take physics…I think I am not that good at math…even though I understand it better." For this student it seems that even a good mark in her grade 10 physics module (her best when compared to chemistry and biology) was not enough to convince her of the merits of selecting physics as an upper-level science course. Her fear of physics, due to the math component, combined with the fact that she was not going into a career in science, and thus only needed to complete one upper-level science course in order to graduate, led her to select biology.

All of the five students who selected chemistry as an upper-level science course felt their performance in chemistry ranked better or the same as their performance in biology and/or physics.

The one student who selected physics as an upper-level science course broke the previously established trend. She did not state that she felt she did better or the same in physics when compared to biology and chemistry. Instead, when asked how she felt she usually did in physics she stated, "I think bad – because of the tests. I failed most of them." When asked why she felt she still wanted to study physics, she simply said that she thought she would like it and that "I want to try physics, I just want to try it." This same student felt she was very good at math and due to the calculation component she thought would play a large role in physics, she thought that she could excel in it despite her track record. In this student's case, her perception of her own abilities overrode even what some would cite as tangible evidence of lack of ability as shown by her grades. Juxtaposed next to the aforementioned student who selected biology despite a strong grade in physics because of her fear of math, it becomes apparent that individual student perceptions of ability, whatever they may be rooted in, may play a very strong role in determining students' participation in science.

Factors affecting student enjoyment of biology, chemistry, and physics. Statements made by the students that participated in the present study were grouped into three main sub-themes that spoke to variables impacting the extent to which students enjoyed biology, chemistry, and physics. The first was whether or not they met with success in the course. Similar to preceding discussion of factors that encourage or discourage students from taking any one of these courses, it is interesting that here again, the students' preoccupation with success did not arise with respect to biology – only with respect to chemistry and physics. The idea that students would avoid biology or engage in it, as a direct function of their experience with success, was not mentioned. However, for chemistry and physics, experience with success was repetitively mentioned as a cause for enjoyment or lack thereof. When one student was asked what she enjoyed about chemistry, she replied, "I like doing chemical equations." When the student was questioned as to why she enjoyed chemical equations, she answered, "I just like the process because I know how to do it." Another student said she did not enjoy chemistry because "I don't do too well in it." With regard to physics, one student stated that she sort of enjoyed physics because "I did sort of well." When asked what she might not enjoy about physics, this same student said, "If I was doing poorly." Through these and other like statements, it appears that there is emphasis placed on the merits of success when students consider whether or not they enjoy chemistry and physics. If students do well in a subject area, they enjoy it. If success eludes them, they do not.

The second of three sub-themes that spoke to whether or not students enjoyed biology, chemistry and physics, was their interest in certain topics covered within each of these subject areas. For all three areas, students maintained that enjoyment of the area increased with their interest in the various issues covered in the curriculum. Some students cited certain topics that simply did or did not interest them as cause for enjoying or not enjoying a course respectively. For example, when asked to cite three things about biology that made the students wish they did not have to study biology, they mentioned things like "The cell", and "Experimental design"; when students were asked to do the same for chemistry, they mentioned things like "All of the people that invented or started chemistry"; and for physics, students mentioned things like "Radioactivity", and "Magnets." While these examples simply highlight areas that were not interesting or enjoyable for the students to learn about, other statements were more explicit in detailing why certain topics were more or less interesting, and therefore made the course more or less enjoyable. Specifically, if students were able to identify with the applied value of such topics, in terms of either impact on their daily lives or relationship to their chosen career path, they were more apt to enjoy the corresponding course. Biology appeared to have the most applied value for students, and statements such as "It is interesting to learn how the reproduction system works," and "It is more related to life" were very common. Chemistry was less likely to be explicitly cited as having applied value for students. One participant simply said that she did not enjoy chemistry because it is "Not related to my career." Physics was the least likely of the three science areas to be explicitly cited as have applied value. Students did not seem to make the connection between the topics learned in physics and impact on their lives. The absence of this connection can be witnessed in statements such as, "I can use chemistry and biology in my daily life, whereas physics I can't really use, what am I going to use it for?" and "...Household electricity, circuits and electromagnets – all of these things I just don't find relevant to what I want to do later in life." These latter examples directly link topic interest with the idea of applied value and relevance to chosen career. Even though previous examples (those that simply cited specific topics covered as not enjoyable) did not make this direct link, it seems probable that the students are not enjoying these topics because they do not understand their relevance in life.

The third sub-theme that categorized student responses as to why they did or did not enjoy biology, chemistry, and physics was the specific activities associated with learning in each of these areas. In biology, several learning activities were mentioned as cause for either enjoyment or lack of enjoyment. Most common amongst these was memorization. Some students felt that the memory demands of biology made it much less enjoyable: for example, "There is a lot of memorizing," and "It is too much to memorize." Of all of the students that discussed the memorization component of biology, only one stated this as cause for enjoyment of the course. When asked why she enjoyed biology, the student replied, "It is easier – all you have to do is memorize things." Students also commonly cited working with microscopes as an activity they did not enjoy in biology, although one student thought that getting to "Look under microscopes and draw things" made biology more enjoyable. Finally, dissection was mentioned as both a cause for enjoyment and lack of enjoyment ("It grosses me out"). In chemistry, the activities that students cited as influencing level of enjoyment also included the memorization component, although it was only ever cited as detracting from enjoyment, for example, "I hate memorizing all of the elements." Many students also cited math as an activity embedded in chemistry that caused them to enjoy the course less. And while two students cited smelling for acids and bases in chemistry labs as detracting from their enjoyment of chemistry overall, many students said that the lab portion of chemistry made it much more enjoyable and fun for them to learn. For example, when students were asked what they enjoyed about chemistry, they said things such as, "The experiments were fun to do," and, "I like experiments," and, "We do all those experiments and stuff - it is interesting to see things." In physics, student also cited memorization and math as activities that detracted from enjoyment, while experiments overall seemed to increase enjoyment. For example, students said that they did not enjoy "All of the numbers," and "The math" in physics. However, when students were asked about if and why they enjoyed physics, statements such as, "Yes, it was a lot of experiments which made it fun," and "Yes – some kinds of experiments I liked a lot" were common. Students also cited increasing the number of experiments as a way of making the course more enjoyable. When asked what would make physics more interesting, one student simply replied, "If there were more experiments."

The perceived importance of biology, chemistry, and physics. Students had various things to say about whether or not the study of the three main branches of science – biology, chemistry, and physics – were important at school, and to our daily lives. With respect to biology, most students interviewed felt that it was important for students to study biology at school so that they would be knowledgeable about the human body for the purpose of their own health and the ability to help others. All students felt that the study of biology was important to their lives for these same reasons. For example, one student stated that the study of biology is important to our lives, "Because it is the life science," while others said things such as, "If it wasn't for biology, we wouldn't know how to take care of ourselves," and "It is important because it involves the human body." About half of the students indicated that the study of biology was necessary to their daily lives and primarily cited reasons to do with their own health, such as having doctors to take care of them, and eating healthfully. Most of the students said further that they have actually used biology ideas and facts to function in their daily lives, and made references to knowing how to eat healthfully and being able to communicate effectively with their doctor if they were unwell.

Regarding chemistry, most of the students felt that it was important to study chemistry in school for the purpose of being aware of the various chemicals that pose health risks if handled improperly ("To know what chemicals are dangerous to mix and to handle"), and if it applied to their chosen career path. About one third of the students (fewer than with biology) interviewed communicated that they thought the study of chemistry was important to their lives with statements such as "It has to do with pharmacy," and "You need to know how hazardous chemicals are to your health." Again, about one third of the students also felt that the study of chemistry was necessary to their daily lives and stated things such as, "Because it makes up all of the stuff we use," and, "Pollution and stuff" to support this claim. Only two of the respondents could recall actually having used chemistry ideas and/or facts in their daily lives with one saying that she had been able to identify salt as NaCl, and another saying that she knew not to mix certain chemicals.

Students were also asked the same questions regarding physics. Physics appears to be thought of as the least important of the three science areas for study at school and to daily life, with biology being viewed as the most important and chemistry as the next most important. Most students said that physics is not really important to study at school. For example, one student commented, "You don't really think you are going to use half of that stuff," while another stated, "I don't see why it is that important." The couple of students that did say it was important for students to study physics at school were unable to articulate why. About one third of the students (fewer than biology but similar to chemistry) felt the study of physics was important to their lives and was necessary for daily life if it was relevant to their chosen career path, and because physics provides the foundation for useful commodities such as energy and transportation. Only one student said that she had actually used physics in her daily life. When queried as to the nature of this use, she said, "Just that I have lights."

The students' intended career direction. The career that students intend to pursue, their attitudes about whether or not that would enjoy a career in biology, chemistry and/or physics, and the prestige they associate with such a career may govern selection of high school science courses. About one fourth of the students interviewed stated that they planned on going into a career that involved science and their course selections reflected this.

Of the remaining students, most said that even though they were not planning on going into a science-based career, they thought they would enjoy a career that involved some aspect of science. Many thought a career in biology would be interesting, while a small number thought a career in chemistry would be interesting. None thought a career in physics would be interesting. When asked to provide an opinion regarding the impression others might have of them if they did go into a career involving biology, chemistry, or physics, most responses reflected that they thought a career in any of the three would command respect, as they would be thought of as "smart" and as making "a lot of money". However, some responses were more reflective of a negative reaction, specifically with regard to physics and chemistry, with a small number of students thinking that if they had a career in physics, people would look at them as "boring," and another small group thought that if they had a career in chemistry, people would think they were "a dork" or would ask them, "are you sure you don't want to do something else?"

CHAPTER 5

Discussion

Historically, the sciences have been a male dominated discipline. While outdated traditions of thought attributed this to biological differences that predisposed males more so than females to success with learning science, more progressive research has indicated that this is not the case. Instead, other variables appear to be operating to discourage women from entering into science-related disciplines, even if they have the academic prowess to do so (Ware & Lee, 1988). These other variables are broad in scope and application, and include: teacher variables such as teacher preparation, teacher attitudes, teacher self-efficacy and teacher anxiety (Czerniak & Chiarelott, 1990); motivation (Simpson & Oliver, 1985); self-efficacy (Sayers, 1988); home support (Ercikan & McCreith, 2001); and self-concept, fate control, locus of control, cultural background, belief systems, and social values (Simpson, et. al, 1994).

In addition to this myriad of variables, attitude to science has also been shown to impact the level to which women choose to engage in science-based study, their level of achievement in such studies, and their involvement with science-based careers (Joyce, 2000; Rennie & Dunne, 1994; Weinburgh, 1995). These attitudes begin to develop at a very early age, and grow out of exposure, socialization and other processes inherent to development (Butler-Kahle & Lakes, 1983; Handley & Morse, 1984). If these processes yield negative attitudes to science, by the time students reach high school, which is typically the point at which they make critical decisions about future engagement with advanced level study of the sciences, these negative attitudes are already well entrenched.

In pursuing the investigation of the gender-based differential pursuit of the sciences, researchers have highlighted the importance of identifying attitude objects – that "thing" towards which attitude is directed – in order to strengthen the relevance of outcomes (Schibeci, 1984). One example of an important attitude object is type of science - namely, biology, chemistry, and physics. Students' attitudes to science can show substantial variability depending on the type of science within which those attitudes are formulated. Typically, boys have more positive attitudes to the physical sciences, while girls have more positive attitudes to the biological sciences (Jones, et. al, 2000).

The present study was designed to replicate and extend previous findings in this area. Specifically, the continued existence of a gender difference in attitudes to science was addressed. The relationship between these attitudes and participation in both high school and post-secondary science courses was also examined. At the high school level, this examination included type of science as an attitude object. In addition, the relationship between gender and participation was explored at both the high school and post-secondary levels, again with type of science being included as an attitude object at the high school level. Further analyses explored the relationship between attitudes and achievement. Finally, the bases for formulation of attitudes, and the impact of attitudes on decisions for participation in specific areas of science were qualitatively examined for further insight.

Gender and Attitudes to Science

Gender has long been touted as one of the key variables governing the orientation of attitudes to science (Gardner, 1975; and Schibeci, 1984). The identity of gender as a key variable appears logical, since it infiltrates and influences a variety of transactions across a child's development, such as processes involved in aspects of socialization, including, for example, parental and teacher expectations (Kagan, 1992) and exposure (Butler-Kahle & Lakes, 1983). Due to the ever-changing dynamic of gender, especially in western cultures where the persistence of societal challenge regarding traditional gender beliefs and gender roles is very evident, it is important to continuously modify and update various research issues that involve gender. The current study sought to provide such an update. While Hypothesis One, which stipulated that boys would uniformly have more positive attitudes to science, was partially supported, it was not supported in its entirety. Instead, it was found that girls had more positive attitudes than boys in the area of attitudes to school science. However, in alignment with the stated hypothesis, boys had more positive attitudes to science in the areas of science as a career and science in society. It should be noted that despite the statistical significance of these differences, they were likely not large enough to be meaningful.

The reasons behind this lack of meaningful differences may be found in an investigation of the instruments used. Attitude to science is a very broad and encompassing construct. The scales used in the present study address only a small portion of the entire scope of attitudes to science. Thus, it may be that gender differences to science did not emerge in the present findings because the measures used were too general, and did not incorporate enough attitude objects. This would, in turn, challenge the validity of these scales and bring into question their ability to garner a realistic and representative measure of attitudes to science.

Beyond this limitation, what continues to remain un-addressed by the present analysis is determination of the influences and factors that precede internalization of attitudes to science. Thus, while measurement of attitudes on these scales is indicative of the present orientation of boys' and girls' attitudes to science in each of the three areas inherent to each of the three scales, it does not speak to the precursors, encountered during development and exposure to science, that influenced such. What aspects of science at school make it enjoyable, important, dull, fun, valuable or interesting? Are there specific components of curriculum, instructional practices, school climate and teacher, parental or peer expectations that play a role? These issues are broached, in part, in a later discussion of qualitative findings of the present paper. However, quantitative findings would provide additional valuable insight. With such information, early prevention and subsequent intervention could be more aptly approached and implemented.

An additional area which remains undifferentiated is the extent to which boys and girls may vary in their attitudes towards science, as measured by the three scales included in the 1995 BCAMS, if the notion of type of science as an attitude object was imbedded in the instrument design. Specifically, it would be useful to know how results would vary if each scale was framed as strictly involving biology, chemistry, or physics. It may be that girls would have overall more positive attitudes than boys for science at school, in society and as a career if answers were formulated in terms of biology, whereas boys may be more positive if answers were formulated in terms of physics. Information obtained through such investigation could further be applied towards the development and implementation of changes aimed at early prevention and intervention.

Gender and the Pursuit of Science Courses in Secondary School

Previous research speaks to the phenomenon of differentiation in the pursuit of secondary school science courses based on gender. Specifically, boys tend to endorse engagement with secondary science courses to a higher extent than do girls (see, for example, Ercikan & McCreith, 2001). Researchers have linked this tendency to attitude development, suggesting that as children progress from elementary to secondary school, girls, in particular, develop increasingly negative attitudes to science (Butler-Kahle & Lakes, 1983). The logic behind such differentiation is broad in scope, and includes discussion of self-concept, fate control, locus of control, cultural background, belief systems, and social values (Simpson, et al., 1994).

Instruments employed in the present study extend this discussion by including type of science as an attitude object whilst surveying intent to pursue secondary science study. Type of science is a very important attitude object to consider when measuring any component of attitudes to science. This importance is founded in related research that has shown the physical sciences are typically viewed as clearly masculine, while the biological sciences are typically seen as feminine (Jones, et al., 2000; and Vockell & Lobonc, 1981). If researchers opt to study science as a whole, instead of dissecting it into its component areas (such as, biology, chemistry, and physics), results are likely to be confounded by type of science. That is, researchers will not know how much positive attitudes in one area of science are neutralized by negative attitudes in another area of science, making the results ambiguous. It is thus ideal that, rather than measuring differences between boys and girls and their pursuit of science in general, the scale used in the present study measured such differences in terms of biology, chemistry and physics.

Based on results from the present study, Hypothesis Two, which suggested that boys would pursue chemistry and physics to a greater extent than girls, and that girls would pursue biology to a greater extent than boys, was only partially supported. Boys were more often inclined to study physics, as predicted, and girls were more often inclined to study biology, as predicted. However, unlike the prediction made in Hypothesis Two, girls were also more often inclined than boys to study chemistry. While past research supports the findings that girls are more likely to study biology, and boys are more likely to study physics, such research is not as clear regarding chemistry. Hypothesis Two was formulated by generalizing from the reasons often cited regarding girls' avoidance of physics. Usually, girls opt out of physics because of the math component, and the fact that it is more technical and 'pure' in nature. Given that chemistry also involves math, and is often considered a more technical and 'pure' science, albeit less so than physics, it was thought that girls would be less drawn to chemistry. Current results suggest the contrary. Explanation of this unexpected finding may emerge from examining more closely the reasons girls pursue the study of chemistry.

The finding that girls are more likely to study secondary school chemistry than boys, may suggest that girls enjoy chemistry more and/or are more interested in chemistry than boys. However, if one also considers that girls are more likely to pursue careers in the life sciences than boys, an additional explanation materializes. Girls often cite career aspirations to include doctor, veterinarian, and nurse, in accordance with their tendency to pursue biology-based careers. While these chosen career paths are primarily biological in focus, they also require knowledge of the field of chemistry. For example, the aforementioned careers of doctor, veterinarian, and nurse all require at least some background in chemistry. Thus, girls may be endorsing pursuit of chemistry courses in secondary school based on the fact that chemistry, by default, is a requirement if they are to realize their biology-based career aspirations.

While the present results are useful in documenting current trends, and in fact, may contribute new findings with regards to chemistry, these results are not able to provide descriptive information about the nature of the association that exists between gender and pursuit of the various areas of science. Current results cite only differences in frequencies, and do not advance thought regarding the myriad of variables that likely influence the stated trends. Information on such variables – their identification, qualitative description, and measurement in both boys and girls – would be useful in aiming early educational practices at encouraging development of positive attitudes to science across all disciplines for both genders.

Gender and the Pursuit of Science Courses in Post-Secondary School

The gender differences that seem to exist regarding engagement in science as a component of post-secondary study are very similar to those delineated above for pursuit of science in secondary study. Overall, gender, career interest in science (which is naturally correlated with post-secondary study of science), and informal experience with science all predict engagement with post-secondary science, with the outcome favoring males, especially in the physical sciences (Joyce & Farenga, 1999). In agreement with such research, Hypothesis Three of the current study suggested that boys would be more likely to pursue post-secondary study of science than girls. This hypothesis, however, was not supported. Instead, findings indicated that girls are more likely to pursue the study of science in post-secondary school in two of three groups, with boys and girls being equally likely to pursue the study of science in post-secondary school in the third group. This result may rest on two explanations: the first speaks to flaws inherent to the instrument design, while the second speaks to the overall strength of girls' affinity to biology compared to boys' affinity to physics.

As has been highlighted numerous times in the present paper, type of science as an attitude object is an important consideration when creating instruments for the purpose of measuring attitudes to science. In fact, as may be the case with the present study, neglecting to consider the impact of type of science on the validity of the scale may be at the root of many of the discrepant or negligible findings in this area of research (see, for example, Schibeci, 1984). The instrument used in the present study simply asked the question "Do you plan on taking more science courses once you have finished secondary school?" The question is obviously void of consideration regarding the impact of type of science. While girls may communicate a higher level of intent than boys for studying science at the post-secondary level, results procured by the current instrument do not provide descriptive enlightenment as to the form that this increased participation takes. For example, are more girls pursuing science, but only in the area of biology?

This consideration of descriptive enlightenment links directly with the second of two explanations being suggested for the partial lack of support for Hypothesis Three. Specifically, the second explanation involves previously presented results from the current study regarding which areas of science boys and girls intend to study at the secondary school level. These results showed that girls were more inclined to study biology and chemistry, while boys were more inclined to study physics. It may intuitively be assumed that participation by boys and girls in any given area of science in secondary school will map directly onto participation for each gender in post-secondary study. Further, one needs to consider level of participation – that is, the strength of affinity for each gender to a given area of science. Closer analysis of previous results by intended area of science study at the secondary level suggest that, in terms of strength of affinity to a given area of science, girls' affinity to biology is much stronger than boys' affinity to physics. Based on pure volume, induced by pronounced differences in strength of affinity, one would expect far more girls to study science at the post-secondary level, albeit mostly in the area of biology.

While the instrument used in the present study did not incorporate type of science as an attitude object, and thus enables the drawing of limited conclusions, the conclusions that are reached assist in establishing direction for future study. In particular, it would be useful to replicate design of the present study, including type of science as an extension. Such study would enable more descriptive observations of the shape and form that boys' versus girls' participation in science at the post-secondary level takes. This information would be especially valuable if coupled with further design extensions that incorporated establishment of the variables that influence boys' and girls' decisions to opt for study at the post-secondary level in any given area of science. The latter is an issue that is touched upon in subsequent discussion of qualitative findings in the present paper.

The Link Between Attitudes to Science and Achievement in Science

Research concerning the link between attitudes to science and achievement in science has provided mixed findings. Some authors purport that there is a strong correlation between the two (see, for example, Weinburgh, 1995), while others propose that this link is minimal (see, for example, Fraser, 1982). Results from the current study suggest that attitude and achievement are moderately correlated. However, also based on results from the present study, attitude appears to be only one small piece of the puzzle in accounting for achievement. In this way, Hypothesis Four of the present study was only minimally supported.

If attitude does indeed predict achievement more strongly than suggested by the current results, lack of such finding may be attributed to design aspects of the survey instrument employed. This suggestion may be warranted for the following reason. When considering design of attitude survey instruments, it is important to understand and internalize the breadth and depth of attitude as a construct. Attitude theorists and social psychologists have offered definitions of attitudes, and methods through which attitudes may be operationalized. However, the abstract level at which these formulations are presented makes it difficult for researchers in the area of education and science to determine the extent to which attitudes to science have been captured and measured by the instrument at hand.

It may be, then, that the instrument used in the current study was only capturing a small portion of the students' overall attitudes to science. Thus, while results for the prediction of achievement in science by attitudes to science was not especially convincing, perhaps this was due to the limited scope of the attitude to science measures used. If one considers the relatively narrow definition of attitude to science, operationalized by the current instruments, in light of the expanse of information and variables documented as contributing to attitudes to science in the literature, this explanation becomes even more feasible. Indeed, when research in this area is reviewed, it becomes very apparent that there exists a multitude of attitude objects that contribute to a student's overall attitude to science. These may include, but are not limited to: instructional practices (Czerniak & Chiarelott, 1990), laboratory materials (Butler-Kahle & Lakes, 1983), expectations from parents, teachers, and peers (Ercikan & McCreith, 2001; Joyce, 2000; and Kagan, 1992), careers in science (Ware & Lee, 1988), and exposure to science phenomenon (Butler-Kahle & Lakes, 1983). It is likely that such a list incorporates a very small number of the many attitude objects that influence overall attitude to science. Even within the presented list, certain objects could be further clarified, such as exposure to science phenomenon being composed of: play activities as a child, hands-on experience with objects specific to an area of science, simple observation of science events, and so on.

Collection of such information in an effort to improve the measurement of attitudes in this area of research is likely to be a very involved process. This process may include identification of relevant attitude objects through research that is more qualitative and inductive in nature, followed by quantitative measurement of the identified attitude objects. Such quantification, in turn, will involve repeated assessment to determine the level of each attitude object's individual contribution to overall attitudes to science.

The Relationship Between Attitudes to Science and Participation in Science

Attitudes to science have previously been documented as a predictor variable of future participation in science (Joyce & Farenga, 1999; Rennie & Dunne, 1994). Results from the current study support this claim in terms of participation at both the high school level and the post-secondary level, thereby supporting Hypotheses Five and Six.

One of the unique contributions of the present results is the inclusion of type of science for analysis of this relationship at the high school level. Comparisons across science areas, namely biology, chemistry, and physics, enabled observation of an interesting trend; it appears that the prediction model in place was strongest when considering physics or chemistry, and weakest when considering biology. This trend is likely the result of a combination of factors; specifically graduation requirements, and perception of course difficulty. In the British Columbia school system where the present study was conducted, students are required to complete at least one upper-level (grade 11 or 12) science course to satisfy graduation requirements. In this way, students have a forced choice as regards selecting a science course, and most opt to select biology due to its reputation of being easier than chemistry or physics. As a result, in this case it is not attitude that governs course selection. Rather, course selection is mediated by graduation requirements and students' perceptions of the route of least resistance in terms of satisfying these requirements. Thus, one would expect that attitude as a predictor of participation would not be as strong in the case of biology, as other variables are playing additional key roles. However, in the case of physics and chemistry, attitude is more likely to play a central role in selection, as students who seek these courses over biology are more likely to be truly interested in them.

It would thus appear that in an attempt to encourage students to participate in a broad range of science courses, rather than just biology, students need to be exposed to the merits of chemistry and physics, and in turn, have their perceptions of what is involved in these courses altered prior to their grade 10 year, when they will be making decisions about future participation. Qualitative results from the present study, which are discussed in a later section, highlight: a) experience with success in chemistry and physics; and b) enunciation of the applied relevance of any area of science to the students' lives as very important in improving students' likelihood of engaging in further study in these areas. It follows that if alteration of current trends are sought, this alteration needs to materialize in the formative years of a child's education, such that attitude development is able to follow a more positive trajectory, spurring the child on to participate in all areas of science at advanced levels.

A worthwhile extension of the current study would be to reformulate the question addressing selection of science courses at the post-secondary level to include type of science. Results from such a reformulation would provide a more concise picture of the role of attitude. This increased conciseness would be due to the fact that in post-secondary education, students are only required to enroll in science courses if they select a science major. Thus, attitude as it impacts participation in biology would not be occluded by the role of graduation requirements as it is at the high school level. Instead, investigation of the role that attitude plays in selection of specific science courses at the post-secondary level would capture a more pure measure of the impact of attitude on such decisions. Results would enable further examination of the role of type of science as an attitude object.

Students' Attitudes to Science and Decisions to Pursue Future Study of Science in Either Biology, Chemistry or Physics

As has been discussed in relation to previous findings in the current paper, the delineation of the multitude of variables that guide and influence students' attitudes to science and participation in science is particularly important. Amongst development of a more inclusive account of these variables, it must also be highlighted that one cannot overlook type of science as an attitude object. It may be that attitudes to biology, chemistry, and physics are affected differently by these variables. The impetus for identifying, describing, and measuring such variables resides in objectives aimed at promoting positive attitudes to science at home, at school, and in the community, and specifically, in making these objectives more conquerable. Results from the present study are useful in highlighting key areas that may become the focus of efforts to this end.

Family

It emerged that family was a very important factor in the nature of students' attitudes towards science, and further, that this familial influence on attitudes actually extends to impact student decisions regarding whether or not to enroll in chemistry, biology, and/or physics. Familial impact was characterized by parental expectations that stemmed from desire for the independence and financial success of the student after high school, as well as the notable prestige that would be attributed to the family should the student decide to pursue science as a career. Through these expectations, parents appear to exert some influence on the area of science the student chooses to focus on. For example, if parents champion a career as a doctor, biology becomes the obvious choice for improved attitudes and higher engagement in terms of course enrollment. Older siblings' also wielded some influential clout regarding both students' attitudes to science, and their intent to pursue study in certain areas of science. If the older sibling suggested that a given science course was very difficult or boring, for example, the student may internalize these opinions. In addition, if the older sibling made these suggestions in the framework of specific areas of science but not others, the student may be more prone to study in promoted areas (usually biology) and less prone to study in criticized areas (usually physics).

Related research has indeed documented certain aspects of familial dynamics as influencing various components of attitudes to and involvement with science, including parental expectations (Osbourne & Whittrock, 2000). However, the influence imbedded in an older sibling's science-related opinions may have been previously underestimated. If familial influence does indeed extend beyond the usual parental boundaries, efforts directed at improving students' attitudes to science may also need to challenge siblings' attitudes. Prevention and intervention strategies developed at the community level have the potential of reaching all members of a familial unit, but may be a lofty ideal as restricted by the realities surrounding their implementation. Alternatively, 'grassroots' strategies may be more accessible in efforts to reach older siblings in the school system, assist them to develop positive attitudes to science, and then have them share those attitudes with younger siblings. In this way, the movement of change and acknowledgement of goals towards improving students' attitudes to science, specifically girls' attitudes to science areas in which they are currently underrepresented (mostly physics), will be an iterative process.

Peer Group

The peer group was also identified as a potential influencing factor on students' attitudes to science and engagement in certain areas of science. Past research has documented that peer expectations, founded in a collective ambition and direction, can guide student development of attitudes to science (Wentzel, 1999). Indeed, results from the present study confirmed the command that peer groups may have over student attitudes and decisions for involvement. Peer influence presented in the form of guidance from older peers who already had experience with science courses and instructors, and in the form of a desire to engage in activities similar to those of their friends, seemingly for group cohesion and social stimulation.

The force that peer influence may direct on student attitudes to science and decisions for involvement with certain areas of science may in fact, extend beyond past and present findings, when one reflects on the potential power attributed to the collective orientation of a group. If this power is considered in the context of underrepresentation of girls in physics at the high school level, and of women in science and technology based careers, the actual force of peer influence, in all of its cyclical glory is revealed. Thus, if the peer group, to which girls belong, osmotically absorbs qualities of the status quo from the societal context in which it is imbedded, future implications are bleak; girls will continue to band together in their mutual avoidance of physics and more technology-based disciplines.

The answer to overcoming such barriers may reside in challenging the status quo from within the peer group. Successful female engineers could, for example, be recruited for involvement with younger girls in a peer mentor program. An alternative may be found in programs that provide incentive for overriding peer influence, such as national scholarship programs that are meant to encourage female participation in certain areas of science where women are otherwise underrepresented.

Teachers and School Guidance Counselors

Teachers and school guidance counselors also maintained some power of influence over students' attitudes to science. Teachers and guidance counselors appeared to apply this influence by providing direction to students regarding what courses to take, based mostly on the student's aptitude, and less so on the student's personal interests. While most teachers, true to the merits of their profession, likely have the best interests of the student at heart, streaming or tracking becomes a worrisome artifact of well-intended guidance (Gaskell, 1992). This is especially so when one considers the vulnerability of adolescent students, who are at the developmental stage of more frequently seeking adult role models outside the home, with teachers being an obvious source to fill this role. It may be worthwhile then to probe further the role that teachers currently play in directing students into certain disciplines, and more specifically, what this direction is based on.

The influence of teachers was noted further in the students' voiced preference for certain classes based on the known teaching style of the involved instructor. This finding supports previous work documenting the central role that school personnel may play in development of student attitudes to science (Kagan, 1992). As was also derived from present results, it appears that students are more keen on taking a course that they enjoy, that they perceive as interesting, and that they feel to be applicable. For example, common across all three areas of science was the enunciation of experiments as being a very enjoyable activity that boosted interest and desire to engage in a given science course if associated with it. Teachers, and the instructional methods employed in the classroom, thus, have stakes in student enjoyment, interest and perceived applicability and, in turn, student participation. In specific and overly simplistic terms, if teachers are able to orient instruction towards increasing the applied relevance of topics and engagement of students, level of interest, enjoyment and perceived applicability will all improve. Attitudes and engagement will intuitively follow suit.

Self-Perception of Science Ability

Students also appeared to rely on internalized perceptions of their own strengths and weaknesses, combined with ideas about skill sets required for success in a given science course, when formulating attitudes to science and plans for future involvement with specific areas of science. Self-perception is indeed a known contributor to attitudes to science (see, for example, Simpson, et al., 1994). It appears that if a student believes a discrepancy exists between her strengths and the required skill set in a given area of science, she is more likely to voice disapproval of the involved course and area. Math was often touted as the evil of physics, while memorization was identified as a peril in biology and chemistry.

The notion of self-perception of ability became evermore important in light of the students' apparent focus on a fear of failure. The students seemed particularly concerned with failure should the skill set they deem inherent to an area of science and their own self-perceptions of strengths and weaknesses be too disparate. One very interesting observation was that this preoccupation with failure was common to physics and slightly less so to chemistry, but did not even bear mention by the students with respect to biology. It would seem that biology has avoided the pitfall of being labeled a very difficult subject, despite that fact that it demands substantial cognitive strengths in terms of memorization and recall, and the ability to cope with and organize a substantial amount of detailed information.

This observation of fear of failure had ripple effects in terms of participation. The students focused on a fear of failure as reason to disengage from chemistry and physics; however, such was not the case for biology where not a single student mentioned a fear of failure as reason to avoid the course. This speaks again to the engrained reputation of chemistry and physics as being more difficult courses. In fact, related research supports the notion that perceived level of difficulty is often higher for girls as regards science and is, in part, responsible for girls' less positive attitudes to some areas of science (Hendley & Parkinson, 1995). Alternatively, experiences of success were touted across all three areas of science as cause for higher levels of participation.

Self-perception of ability seemed to further impact decisions regarding enrollment when it was related to interest in a given science area. That is, students who stated an interest in biology and/or chemistry, usually had good self-perceptions of ability in biology and/or chemistry. However, with respect to physics, this was not always the case. Students who stated an interest in physics either: a) had poor self-perception of ability and thus avoided it; or b) had poor self-perception of ability, but such a strong interest that they ignored their poor self-perception of ability. Such an observation provides interesting information about self-perception and its role. If a student has good self-perception of ability in a given area, then pursuit of the course is a non-issue. However, if a student has poor self-perception of ability, such as is usually the case with physics, the most beneficial approach to encouraging involvement may be to provoke exceptionally keen interest in the topic area. How such provocation may be accomplished is likely very dependent on the individual student, but as has been discussed, may include things such as altering instructional methods, and highlighting perceived applicability and relevance.

Perceived Relevance of Science Areas

Students endorsed perceived relevance repetitively as a key variable that influences attitude development and decisions for engagement within particular areas of science. Perceived applicability was also closely linked with interest and enjoyment. Thus, it appears to be very important for a student to draw connections between presented concepts and their applied relevance within the context of the student's life. If the student was able to understand how concepts within that area of science were applicable to their own lives, they were much more likely to pursue involvement with the respective area of science, and further, to communicate more positive attitudes to that science area. Perception of relevance may be linked with insight the student has had through field trips to science learning centers and other types of exposure. Indeed, related work has documented that this type of exposure leads to more positive attitudes to science (Butler-Kahle & Lakes, 1983; and Jones, et al., 2000) – an observation that appears to be convergent with the present finding quite possibly because such exposure highlights relevance.

Perceived relevance takes on added dimension when considered in terms of applicability to biology, chemistry, and physics. Biology was praised as having the most relevance (which is intuitively reasonable given girls' affinity to engaging in biology-based careers), and chemistry and physics in turn, each having less applied value. While students were easily able to make connections between biology and either their own lives, or their chosen vocation, these associations were far less likely with physics. The implication of this observation may be that to encourage engagement via means of enjoyment, curriculum, teachers and parents may need to highlight applied relevance. It is important to underscore the applied value of science to girls at school and at home in an effort to promote positive attitude to science development, and to encourage decisions to engage in upper-level science study and science careers. This may involve early childhood projects, whereby parents and children are educated regarding the merits of science and its relevance to life. It may also involve reorganization of instructional practices and school curriculum, such that learning outcomes are accomplished in the broader context of the applied value of science. That is, the necessary concepts may need to be presented whilst highlighting the overall impact of such on society and life. Some overly simplified examples include: a) the study of energy and motion in physics could be paired with demonstrations and discussion of their relevance to transportation; and b) the study of exothermic reactions in chemistry could be discussed in the context of how resultant energy is utilized in daily life.

Importance of Studying Science Area At School

Students also seemed to have concocted their own interpretations of the importance of studying biology, chemistry and physics at school, based mostly on importance to their daily lives. These interpretations comprise yet another guiding factor for students in terms of course selection. Most students felt that the study of biology was very important to their lives. Students also felt, to a much lesser extent that chemistry could be important to our lives. However, students appeared to have a very difficult time making the link between physics and importance to daily lives. Since it is known that girls pursue physics to a much lesser extent than biology, and that perceived relevance is a prominent influence on attitudes to a given area of science, it is not surprising that the girls participating in the present study did not find physics particularly important or relevant to their daily lives.

Career Goals

Career goals were also endorsed as contributing to student attitudes and participation in science. It appears that if students have identified a science-based vocation as their career of choice, they are more likely to speak positively of science and their involvement in science. Past research has documented that gender, attitude to science, and careers in science are indeed related (Joyce & Farenga, 1991; Lee, 1998; Lorenz & Lupart, 2001; Rennie & Dunne, 1994; Shamai, 1996; and Trankina, 1993). Unfortunately, current results do not enable insight as to the nature and direction of this relationship.

Emergence of another interesting component related to careers, was investigation of students' thoughts regarding whether or not they might be interested in a science career, regardless of whether they had plans to actualize such involvement. Most students thought they might be interested in a career in biology, very few thought they would be interested in a career in chemistry, and none thought they would be interested in a career in physics. What was especially interesting is that while only one fourth of the students interviewed are actually planning on science careers, almost all said that they would be interested in a some type of a science career, usually to do with biology. A re-visitation of the individual students' perceptions of ability was thought logical for examination of this occurrence. That is, maybe only one-fourth of the students actually had positive self-perception of science-based ability. However, an examination of each individual's perception of their own ability in biology, chemistry and physics yielded results that appeared to be in line with their supposition that they might enjoy a science career, rather than in-line with their actual career plans. That is, in all cases, if a student stated interest in a career in biology, perception of ability in biology was average or higher. Thus, while perception of ability in a given area of science may mediate interest in a career in that area, perception of ability did not carry with it enough influence to encourage actual pursuit if such a career.

From the above discussion, it would appear that the present study was advantageous in determining support for key variables that are thought to influence attitudes to science, and further that type of science is a pervasive attitude object and needs to be accounted for in all investigations of attitudes to science. A review of all documented variables provides perspective that enables further categorization for the purpose of applying the insight gained. The rationale for such is that identification and documented support of specific attitude objects that govern both attitudinal development and attitudinal outcomes (such as course selection) may be applied in instrument design, towards the previously stated end of developing more comprehensive measures of attitudes to science (see section entitled "Link Between Attitudes to Science and Achievement in Science"). In addition, information about mediating variables in the development of attitudes to science may be used to design appropriate prevention and intervention programs at school, at home and in the community (see section entitled "Gender and Attitudes to Science") in an effort to promote more positive attitudes to science.

Strengths, Limitations, and Future Directions

Strengths

Large sample size in Phase One. The sample included in Phase One was very large (N = 20 614) and represented the population of grade 10 students in British Columbia. The obvious advantage of this is that results from the quantitative portion of the present study are highly generalizable to the greater population.

Qualitative paradigm. Inclusion of a qualitative component in Phase Two enabled emergence of a wide variety of factors as potential contributors to the development of attitudes to science, as well as to decisions regarding future involvement with science-based study. Since attitude to science is a very broad construct, the measures used to assess it, and in turn, its relationship to variables such as participation and achievement, must also be broad in nature. Identification and documentation of support for this wide variety of variables is important in this continued pursuit of designing more inclusive instruments for measuring and assessing attitudes to science.

Type of science as an attitude object measured for high school participation. Type of science as an attitude object was included in the measurement of high school science course participation. This information resulted in valuable observations regarding the relationship of participation to gender and attitudes.

Limitations and Future Directions

Expanding the qualitative component. The sample size for Phase Two, the qualitative component, was small ($N = 14$). While the information gained from this phase was very insightful and valuable, the impact of the results would be further heightened and strengthened if generalization was not an issue. Obviously, overcoming the issue of generalization necessarily involves increasing the sample size.

With further respect to expanding the qualitative component of the current study, it would be very useful to interview boys as well as girls. Insight expected to be gained from such extension includes incorporation of logic regarding boys' affinity to studying physics as compared to girls. Also, while there seems to be great importance placed on the lack of representation of women and girls in physics and the more technological science disciplines, it cannot be overlooked that men and boys have increasingly diminished representation in biology. The overall aim of any investigation into attitudes to science necessarily needs to focus on eradicating inequities for both genders.

Necessity of up-to-date data. The data employed in Phase One was collected in 1995. While this is the most recently available data of its kind, the constantly changing dynamic of gender as a social construct is an important consideration. Western cultures have seen a large shift in gender roles over the last several decades, and it is important when investigating affective issues that include the role of gender in society as a mediating variable, to update information frequently. While the results obtained from analysis of this 1995 sample provide important information, a timely update of this is necessary.

Type of science as an attitude object not measured for post-secondary participation. Analysis of the relationship between attitudes and intent to participate in post-secondary science courses, as well as between gender and intent to participate in post-secondary science courses did not include type of science as an attitude object. The instrument employed simply phrased the question in terms of general participation, rather than highlighting specific areas of science, such as biology, chemistry, and physics. It would be useful to rephrase this question to incorporate type of science as an attitude object. Measurement of participation in specific areas of post-secondary science would yield additional information about the strength of attitude as a predictor variable of such, since other variables, including high school graduation requirements, would not interfere with the strength of the prediction model.

Documentation of developmental trend and increased scope of measures. The data analyzed in both Phase One and Phase Two was obtained only from grade 10 students. As outlined previously, there is a very important developmental component involved with the formation of attitudes to science (see, for example, Greenfield, 1997). It would be useful to extend the analyses conducted to other age groups in an attempt to document the developmental nature of all relationships investigated.

Further qualitative studies, that include large samples across both genders and a variety of age groups would also be helpful in documenting the developmental nature of attitude to science formation, and the role that various attitude objects play in the different developmental stages of this formation. Information gained from such investigation would be especially useful in creating quantitative instruments for the purpose of measuring attitudes that were sensitive to developmental stage, and that were sufficiently broad in scope. The quantitative results obtained from employment of these instruments could then inform educators and parents as regards efforts for improving the developmental trajectory of attitudes to science for both genders.

The role of teachers. It appears that teachers may be playing an integral role in the course selection of students. Several of the students interviewed in the present study made reference to the influence of a teacher or guidance counselor when explaining why they had selected certain science courses over others. It is likely that teacher direction in this regard is well intended, however, it may also be unintentionally ill formed. Gaskell (1992) discussed the issue of 'tracking' or 'streaming' students into certain courses, based primarily on gender. However, the current state of this phenomenon is not known. Are teachers imposing undue influence on students' decisions to engage in upper-level science courses? If so, what is guiding this influence? Is it based on aptitude; student interest; teacher expectations founded on stereotypes? Qualitative and quantitative analyses of this phenomenon from both the students' perspective, as well as the teachers' perspective is necessary to unravel this issue.

Summary

Girls tend to pursue advanced level study of the sciences, as well as involvement with science-based careers, to a lesser extent than boys. Much evidence has been proffered in support of a gender differential in attitudes to science as contributing to this trend; namely, that girls have poorer attitudes to science than boys (Ercikan & McCreith, 2001; Jones, Howe, & Rua, 2000). The present investigation sought to provide current information on the extent to which there continues to exist a gender-based difference in attitudes to science, and the impact that such a difference may have on future plans of boys and girls to pursue the study of science. Specifically, the current study was designed to: a) determine the presence and, if confirmed, magnitude of existing attitude to science differences between boys and girls; b) determine the impact of gender on intent to study science at the upper-level in high school, and in any post-secondary pursuits; c) evaluate the relationship between attitude to science and achievement in science; d) determine the potential impact of attitude to science on boys' and girls' intent to study science at the upper-level in high school, and in any post-secondary pursuits; e) explore and describe those factors which may influence attitude to science development; and, f) explore and describe those factors which may influence student decisions regarding further pursuit of science-based study. To this end, results from three separate scales addressing attitudes to science (The Careers in Science Scale, The School Science Scale, and The Science in Society Scale), administered as part of the 1995 British Columbia Assessment of Mathematics and Science, were analyzed ($N = 20\ 614$). This analysis was followed by an interview component designed to address e) and f) above.

Results showed that very small differences in attitudes to science as measured by three different scales were observed between the two gender groups. Even though these differences were statistically significant, they were not large enough to be meaningful.

Despite boys and girls having similar attitudes to science, results also revealed that there continues to be a significant difference between genders as regards intent to pursue further studies of science. At the high school level, girls indicated higher levels of intent to study both biology and chemistry, while boys indicated higher levels of intent to study physics. Results showed further that the level of girls who intend to study science in general at the post-secondary level is higher than that of boys; a finding that may be attributed to the disproportionately high levels of girls compared to boys that are studying biology in high school.

Results also indicated that the relationship between attitudes to science and achievement in science, as measured by a standardized achievement test, is minimal. This finding may have been more pronounced had the assessment instrument accounted for type of science as an attitude object.

Further analysis of results showed that there is a positive relationship between attitude and intent to participate in upper-level biology, chemistry and physics courses. The predictive strength of attitude was greatest for participation in physics and chemistry, and weakest for participation in biology; a result likely attributed to the interference of graduation requirements, whereby most students, since they are forced to select a science course to graduate, select biology for its reputation as being easier, thus interfering with the predictive validity of attitude. In addition, results showed further that attitudes to science were also predictive of intent to participate in science at the post-secondary level.

Finally, exploration of the potential influences that direct attitude to science development and decisions regarding further study of science revealed that various components of the environment within which the student develops play a key role, including parental expectations, teacher instruction, and peer influence, as do other factors which contribute to level of enjoyment and interest, including perceived relevance, perception of self-ability, and applicability to chosen career path. Implications for prevention and intervention efforts are discussed in relation to such findings, as are suggestions for future research directions.

References

Barrington, B., & Hendricks, B. (1988). Attitudes toward science and science knowledge of intellectually gifted and average students in third, seventh, and eleventh grades. *Journal of Research in Science Teaching, 25,* 679-687.

Bateson, D., Anderson, J., Dale, T., McConnell, V., & Rutherford, C. (1986). *The 1986 British Columbia science assessment: General report.* Victoria, British Columbia: British Columbia Ministry of Education.

Boone, W. (1997). Science attitudes of selected middle school students in China: A preliminary investigation of similarities and differences as a function of gender. *School Science and Mathematics, 37,* 96-103.

Butler-Kahle, J., & Lakes, M. (1983). The myth of equality in science classrooms. *Journal of Research in Science Teaching, 20,* 131-140.

Cannon, R., & Simpson, R. (1985). Relationships among attitude, motivation, and achievement of ability grouped, seventh-grade, life science students. *Science Education, 69,* 121-138.

Creswell, J. (1994). *Research Design: Qualitative and Quantitative Approaches.* Thousand Oaks, CA: Sage Publications.

Czerniak, C., & Chiarelott, L. (1990). Teacher education for effective science instruction – A social cognitive perspective. *Journal of Teacher Education, 41,* 49-58.

Eccles, J., Midgley, C., Wigfield, A., Buchanan, C., Reuman, D., Flanagan, C., & Mac Iver, D. (1993). Development during adolescence: The impact of stage-environment fit on young adolescents' experiences in school and in families. *American Psychologist, 48(2),* 90-101.

Ercikan, K., & McCreith, T. (2001, April). *Factors affecting student participation and achievement in mathematics and science: A comparison of effects of peer groups, parents and student attitudes in three countries.* Paper presented at the annual meeting of the American Educational Research Association, Seattle, WA.

Fleming, M.L., & Malone, M.R. (1983). The relationship of student characteristics and student performance in science as viewed by meta-analysis research. *Journal of Research in Science Teaching, 20,* 481-495.

Fraser, B.J. (1982). How strongly are attitude and achievement related? *School Science Review, 63(224),* 557-559.

Gardner, P.L. (1975). Attitudes to science: A review. *Studies in Science Education, 2,* 1-41.

Gaskell, J. (1992). *Gender Matters from School to Work.* Toronto, Ontario: OISE Press.

Gifi, A. (1990). *Nonlinear multivariate analysis.* Chichester: John Wiley and Sons.

Greenfield, T.A. (1997). Gender- and grade-level differences in science interest and participation. *Science Education, 81,* 259-276.

Greenfield, T.A. (1996). Gender, ethnicity, science achievement, and attitudes. *Journal of Research in Science Teaching, 33,* 901-933.

Haddon, R.A., & Johnstone, A.H. (1982). Primary school pupils' attitudes to science: The years of formation. *European Journal of Science Education, 4,* 397-407.

Handley, H. & Morse, L. (1984). Two-year study relating adolescents' self-concept and gender role perceptions to achievement and attitudes toward science. *Journal of Research in Science Teaching, 21,* 599-607.

Harty, H., Samuel, K., & Beall, D. (1986). Exploring relationships among four science teaching-learning affective attributes of sixth grade students. *Journal of Research in Science Teaching, 23,* 51-60.

Hendley, D., & Parkinson, J. (1995). Gender differences in pupil attitudes to the national curriculum foundation subjects of English, mathematics, science and technology in key stage three in South Wales. *Educational Studies, 21,* 85-97.

Horowitz, I., & Bordens, K. (1995). *Social Psychology.* Mountain View, California: Mayfield Publishing Company.

Jones, G., Howe, A., & Rua, M. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Teacher Education, 84,* 180-192.

Joyce, B. (2000). Young girls in science: Academic ability perceptions and future participation in science. *Roeper Review, 22,* 261-262.

Joyce, B., & Farenga, S. (1999). Informal science experience, attitudes, future interest in science, and gender of high-ability students: An exploratory study. *School Science and Mathematics, 99,* 431-437.

Kagan, D.M. (1992). Implications of research on teacher belief. *Educational Psychologist, 27(1),* 65-90.

Lee, J. (1998). Which kids can "become" scientists? Effects of gender, self-concepts, and perceptions of scientists. *Social Psychology Quarterly, 61,* 199-219.

Lorenz, E., & Lupart, J. (2001, May). *Gender differences in mathematics, English, and science for grade 7 and 10 students' expectation for success.* Paper presented at the annual conferences of the Canadian Society for Studies in Education, Quebec, Canada.

Marshall, M., Taylor, A., Bateson, D., Brigden, S., Cardwell, S., Deeter, B., & Martin, S. (1995). *Technical Report: 1995 British Columbia Assessment of Mathematics and Science.* Victoria, British Columbia: British Columbia Ministry of Education.

Morrell, P., & Lederman, N. (1998). Students' attitudes toward school and classroom science: Are they independent phenomena? *School Science and Mathematics, 98(2),* 76-83.

Munby, H. (1983). Thirty studies involving the "Scientific Attitude Inventory": What confidence can we have in this instrument? *Journal of Research in Science Teaching, 20,* 141-162.

Osbourne, R., & Whittrock, M. (1983). Learning science: A generative process. *Science Education, 67,* 489-508.

Penney, R.K., & McCann, B. (1964). The children's reactive curiosity scale. *Psychological Reports, 15,* 323-334.

Peterson, R.W., & Carlson, G.R. (1979). A summary of research in science education: 1977. *Science Education,63,* 425-554.

Rennie, L. & Dunne, M. (1994). Gender, ethnicity, and students' perceptions about science and science-related careers in Fiji. *Science Education, 78,* 285-300.

Rosenthal, R. & Jacobson, L. (1968). Teacher expectations for the disadvantaged. *Scientific American, 218*(4), 19-23.

Rust, L.W. (1977). Interests. In S. Bell (Ed.), *Motivation in education* (131-146). New York: Academic.

Santrock, J. (1998). *Adolescence: Seventh Edition.* Boston: McGraw-Hill.

Sayers, M.P. (1988). The relationship of self-efficacy expectations, interests, and academic ability to the selection of science and nonscience college majors. *Dissertation Abstracts International, 48(10-A)*:2544.

Schibeci, R. (1984). Attitudes to science: An update. *Studies in science education, 11,* 26-59.

Schibeci, R. & Riley, J. (1986). Influence of students' background and perceptions on science attitudes and achievement. *Journal of Research in Science Teaching, 23,* 177-187.

Secord, P., & Backman, C. (1964). *Social Psychology.* New York: McGraw-Hill.

Shamai, S. (1996). Elementary school students' attitudes toward science and their course of studies in high school. *Adolescence, 31,*677-689.

Shrigley, R. (1972). Sex differences and its implications on attitude and achievement in elementary school science. *School Science and Mathematics, 72,* 789-793.

Simpson, R., & Oliver, J. (1985). Attitude toward science and achievement motivation profiles of male and female science students in grades six through ten. *Science Education, 69,* 511-526.

Simpson, R., Koballa, T. Jr., Oliver, J., & Crawley, F. (1994). Research on the affective dimension of science learning. In D. L. Gabel (ed.), *Handbook of research on science teaching and learning* (pp. 211-234). Don Mills, ON: Maxwell Macmillan Canada Inc.

Statistics Canada (2001a). *Canadian Statistics.* Retrieved February 9, 2002, from http://www.statcan.ca/english/Pgdb/People/Education/educ21.htm

Statistics Canada (2001b). *Canadian Statistics.* Retrieved February 9, 2002, from http://www.statcan.ca/english/Pgdb/People/Labour/labor01a.htm

Trankina, M. (1993). Gender differences in attitudes toward science. *Psychological Reports, 73,* 123-130.

Vockell, E. & Lobonc, S. (1981). Sex-role stereotyping by high school females in science. *Journal of Research in Science Teaching, 18,* 209-219.

Ware, N., & Lee, V. (1988). Sex differences in choice of college science majors. *American Educational Research Journal, 25,* 593-614.

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32,* 387-398.

Wentzel, K. (1999). Social-motivational processes and interpersonal relationships: Implications for understanding motivation at school. *Journal of Educational Psychology, 91,* 76-97.

Appendix A

The Careers in Science Scale

1. Going in to science as a career would be well worth the time and effort required

2. A career in science would be very satisfying

3. A scientific career might be right for some people but not for me

4. Scientific work does not interest me

5. Working as a scientist would be a desirable occupation

6. I would be satisfied to spend the rest of my life as a scientist

7. I would be willing to take a job related to scientific work

8. Science would be terrible as a life's career

9. Science work would give me a great deal of pleasure

10. I would hate to be a scientist

Appendix B

The School Science Scale

1. I like to study science in school
2. I feel the study of science in school is important
3. Science is dull
4. I do NOT enjoy science
5. I would like to study more science
6. Science classes are boring
7. Science is a valuable subject
8. Science is fun
9. Everyone should learn about science
10. I have NO interest in science

Appendix C

The Science in Society Scale

1. Science is important to our lives
2. In everyday life, common sense is more practical than science
3. Science is NOT necessary to society
4. I never use the products of science
5. Scientific inventions and discoveries have done more good than harm
6. Science is NOT important in everyday life
7. Science exists for the benefit of mankind
8. I use scientific ideas or facts in everyday life
9. Science has ruined the environment
10. Our society depends on science to exist

Appendix D

Interview Protocol

1. Why do you plan on taking _____________ science courses in Grade 11 (list courses as they appear in student's answer to corresponding item on written questionnaire)? (may prompt with graduation requirements, interest, desired career path, etc.)
2. Why are you not planning on taking ______________ science courses in Grade 11 (the science courses not included above)?
3. When you think of the science courses you are planning on taking in Grade 11, as well as those that you are not planning on taking in Grade 11, can you comment on the types of things that have influenced these decisions? For example, have you received advice from family, friends, a school guidance counselor? Anything or anyone else?
4. What would encourage you to enroll in a chemistry course? What would discourage you from enrolling in a chemistry course?
5. What would encourage you to enroll in a physics course? What would discourage you from enrolling in a physics course?
6. What would encourage you to enroll in a biology course? What would discourage you from enrolling in a biology course?
7. How do you feel you usually do in science courses overall?
8. How do you feel you usually do in physics?
9. How do you feel you usually do in biology?
10. How do you feel you usually do in chemistry?
11. Do you enjoy science courses? Why or why not?

12. Do you enjoy physics? Why or why not?
13. Do you enjoy chemistry? Why or why not?
14. Do you enjoy biology? Why or why not?
15. Why do you think the study of biology at school is important/unimportant?
16. Why do you think the study of chemistry at school is important/unimportant?
17. Why do you think the study of physics at school is important/unimportant?
18. What makes you want to attend your Science 10 class/Science & Technology class?
19. If you could name 3 things about biology that make you wish you did not have to study biology, what would they be?
20. If you could name 3 things about chemistry that make you wish you did not have to study chemistry, what would they be?
21. If you could name 3 things about physics that make you wish you did not have to study physics, what would they be?
22. Do your parents/other family members/guardians have jobs that involve some aspect of science? If so, what?
23. What were your favorite things to do as a child growing up?
24. What kind of job do you want to have as a career?
25. Why do you plan to take _____ years of future schooling? Are there certain issues you have considered or taken into account when deciding to take _____ years of future schooling?
26. Would you like to go into a career that required biology, physics, or chemistry? If yes, which one? Explain why you would like to go into such a career or why you would not want to go into such a career?

27. How do you think other people would view you if you chose to go into a career that was based on biology? What about physics? What about chemistry?
28. How important do you think the study of biology is to our lives? Is it necessary for daily life? Why?
29. How important do you think the study of chemistry is to our lives? Is it necessary for daily life? Why?
30. How important do you think the study of physics is to our lives? Is it necessary for daily life? Why?
31. Do you use biology ideas or facts in your daily life? If so, what are some examples?
32. Do you use chemistry ideas or facts in your daily life? If so, what are some examples?
33. Do you use physics ideas or facts in your daily life? If so, what are some examples?
34. What do you think would happen if we were to stop studying science altogether? What would the impact be on society, and what would the impact be on you personally?