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Attracting and Retaining Science Students

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Key Words: Science Education, Post-secondary Education, Perseverance, Motivation, Cognitive Style, Academic Emotions

Summary

This research addresses an issue raised in recent reports that demonstrate that Quebec and Sweden lag behind countries with emerging economies in the number of science graduates, as measured by the proportion of degrees earned in the sciences. Our objective was to investigate a set of factors that might, directly and/or indirectly, impact on student achievement and perseverance in science studies. We aimed to assess cultural (Quebec vs. Sweden) and gender differences in students' scores on these factors, and in the strength of the relationships that these factors have to achievement and perseverance. Participants (N=2184) were recruited from two populations: students who enrolled in one of the four public Anglophone CEGEPs in Montreal the Fall 2007 and Swedish students who attended twelfth grade in high schools in Linköping and Stockholm in the school year 2007-2008. With the consent of students, demographic, achievement and enrollment data were acquired from the databases of the Quebec and Swedish ministries of education. Data on independent variables: parental support (for autonomy, competence and science acculturation); teacher support (for autonomy, competence, relatedness and science acculturation); and, cognitive style (systemizing and empathizing) were collected via surveys. Similarly, data on mediating variables: self-efficacy; five sub-scales of motivation; and, academic emotions (boredom, anxiety and enjoyment) were also collected via surveys. Data on perseverance were exclusively collected via survey in the Swedish sample. We used both surveys and information provided by college registrars to assess perseverance of Quebecers. Confirmatory Factor Analysis was used to validate instruments used in this study. ANOVA and CORRELATION were statistics used to assess differences and strengths of relationships between variables. We have found that Swedish students persevere more than their Quebec counterparts. Furthermore, female students persevere less than their male peers although their achievement is not significantly different and the achievement was found to be the most important factor in perseverance. We have also found several promising factors that might be at the root of the gender differences in perseverance, namely, female students have: higher negative emotions (anxiety and boredom); lower self-efficacy; and lower systemizing cognitive style. All of these variables were shown to influence perseverance. We determined that parental support for science acculturation is very low. Thus, teacher support for science acculturation, which influences student intrinsic motivation and self-efficacy, which in turn influence perseverance, is an important part of teachers' classroom role. Increasing teacher support for science acculturation may impact positively on students with lower systemizing cognitive style, encouraging them to persevere in the pursuit of a career in the sciences.

Mots clés : Enseignement des sciences, enseignement postsecondaire, persévérance, motivation, style cognitif, émotions académiques

Résumé

La présente recherche aborde un sujet soulevé dans de récents comptes rendus démontrant que le Québec et la Suède se distancent des pays jouissant d'une économie croissante dans le nombre de diplômés en sciences, fondé sur la proportion de diplômes obtenus dans cette matière. Notre objectif était de vérifier une série de facteurs susceptibles d'avoir un impact, directement et/ou indirectement, sur la réussite et la persévérance des étudiantes et étudiants inscrits au programme de sciences. Nous avons tenté d'évaluer les divergences culturelles (Québec c. Suède) et le décalage entre hommes et femmes à partir des résultats des étudiantes et étudiants selon ces facteurs et à partir de la force des liens qu'ont ces facteurs face à la réussite et la persévérance. Les participantes et participants (N=2184) ont été recrutés dans deux populations : des étudiantes et étudiants inscrits dans l'un des quatre cégeps publics anglophones de Montréal à la rentrée scolaire de 2007 et des étudiantes et étudiants suédois inscrits en 12e année dans des écoles secondaires de Linköping et Stockholm pour l'année scolaire 2007-2008. Avec le consentement de ces derniers, nous avons pu obtenir des ministères québécois et suédois de l'Éducation, à partir de leur banque de données, des détails sur la démographie, la réussite et les inscriptions. Des données sur des variables indépendantes : soutien parental (pour l'autonomie, la compétence et l'acculturation des sciences); soutien professoral (pour l'autonomie, la compétence, le rapport et l'acculturation des sciences); et sur le style cognitif (systémisation et empathie) ont été recueillies par le biais de sondages. De la même façon, des données sur les moyennes des variables : efficacité personnelle; les cinq échelles mobiles de motivation; et les émotions en milieu scolaire (ennui, anxiété et plaisir) ont aussi été recueillies au moyen de sondages. Les données sur la persévérance ont été exclusivement recueillies à l'aide d'un sondage de l'échantillonnage suédois. Nous avons utilisé les deux sondages et l'information fournie par le registraire des institutions collégiales pour mesurer la persévérance des québécoises et québécois. L'analyse factorielle confirmatoire a été utilisée pour valider les instruments employés dans cette étude. ANOVA et CORRELATION sont les statistiques utilisées pour mesurer les divergences et la force des liens entre les variables. Nous avons constaté que les étudiantes et étudiants suédois persévèrent davantage que leurs contreparties québécoises. En outre, les étudiantes persévèrent moins que leurs camarades masculins, bien que leur réussite ne soit pas de façon significative différente. Nous avons aussi trouvé que la réussite était le facteur le plus important dans la persévérance. Nous avons également trouvé plusieurs autres facteurs prometteurs qui pourraient être la source des décalages entres hommes et femmes pour ce qui est de la persévérance, notamment, que les étudiantes ont : un plus haut degré d'émotions négatives (anxiété et ennui); un niveau moindre d'efficacité personnelle; et un style cognitif de systémisation moins élevé. Nous avons démontré que toutes ces variables influent sur la persévérance. Nous avons conclu que le soutien parental pour l'acculturation des sciences est très minime. Par conséquent, le soutien professoral pour l'acculturation des sciences, qui influe sur la motivation intrinsèque de l'étudiante ou de l'étudiant et l'efficacité personnelle, qui en retour influent sur la persévérance, est un volet important du rôle du groupe rencontré par les professeurs. Un soutien professoral accru pour l'acculturation des sciences peut avoir un impact positif sur les étudiantes et étudiants avec un style cognitif de systémisation moins élevé, les encourageant persévérer dans la poursuite d'une carrière scientifique.

Introduction

This research addresses an issue raised in a report by Baillargeon, Demers, Ducharme, Foucault, Lavigne, Lespérance, Lavallée, Ristic, Sylvain, Vigneault (2001) who pointed out that Quebec lags behind other OECD (Organization for Economic Cooperation and Development) countries in the number of science graduates, as measured by the proportion of degrees earned in the sciences (natural sciences, engineering and architecture, mathematics and computer science) to the total number of degrees (22% in Quebec versus 28% for the average OECD country). This problem is not limited to Quebec or Canada. It also affects developed countries in Europe (*e.g.,* Sweden). To maintain a competitive edge with the emerging economies in the Far East, where enrollment in science, technology, engineering and mathematics (STEM) studies is still climbing, educators in developed countries need to know which factors might have a positive impact on student decisions to enrol in STEM programs at University.

Objectives

We aimed to investigate a set of factors that might, directly and/or indirectly, impact on student achievement and perseverance in science studies. We assessed cultural (Quebec vs. Sweden) and gender differences in students' scores on these factors, and in the strength of the relationships that these factors have to achievement and perseverance. We also investigated multivariate models concerning how these factors interrelate in their impact on achievement and perseverance in science studies.

State of Knowledge

There are two critical points in students' academic trajectory, points in time when they are making decisions about their future career. First, in Quebec students elect to enroll in a program of study at CEGEP upon graduating from high school, or in Sweden they elect to enroll in advanced mathematics and science courses in their last year at high school. The second critical point occurs when students in Quebec graduate from CEGEP, or in Sweden upon graduating from high school. At this time the students need to decide just which program to apply to for University studies. According to Astin and Astin (1993), it is at the second of these two critical junctures: between high school and the first year of college, that the number of students intending to pursue careers in the sciences or mathematics drops by 40% . More recently, Daempfle (2003) found that the greatest proportion of students with an aptitude for science/engineering studies decide to abandon the pursuit of science careers just prior to, or shortly after, enrollment in college. To pursue STEM studies at University, students need to enroll in the Science Program at CEGEP or take advanced mathematics and science courses in their last year in Swedish high schools. The two school systems differ, and in the next two paragraphs we will briefly describe what we know about the populations of students who are eligible to follow the trajectory towards science careers in either of the two systems.

In Quebec, Rosenfield and his colleagues (Rosenfield, Dedic, Dickie, Rosenfield, Aulls, Koestner, Krishtalka, Milkman & Abrami, 2005) examined the population of students who were admissible to enroll in the Science Program in CEGEP in 2003 in the public anglophone colleges in Montreal. They found that 94.5% of students in this population eventually obtained a DEC. This success rate indicates that these students were indeed high achievers (Rosenfield, *et al.,* 2005) and also seems to confirm a general trend that was reported on by the Fédération des cégeps (1999). The report showed that failures in science and mathematics courses lead science students to abandon their pursuit of science careers and instead obtain a DEC in another program. Amongst those students enrolled in Anglophone CEGEPs in 2003 and whose high school academic record (grades and choices of courses) allowed them to enroll in the Science Program, 48% of them abandoned their goal of having a science career, because they either graduated from programs other than science, or declared that they **did not** intend to enroll in science programs in University. Interestingly, judging by their high school course choices, more female students expressed interest in studying sciences than males in high school. This difference evaporated by the time of transition to University because 55% of female students abandoned their goal of continued studies in the sciences. It should be noted that Quebec students face a known challenge in their academic journey from high school to university: the transition from high school to CEGEP. Roy, Mainguy, Gauthier & Giroux (2005) have shown that this transition poses a triple challenge: adaptation to the collegial system of studies; adaptation to a new social milieu of peers; and in some cases, adaptation to a new city. These authors have also shown that students who do not adapt often fail to graduate. It is possible that in the student population of interest, failure to adapt in any of these ways also increases the rate at which these students abandon their goal of a career in the sciences.

Swedish students remain in the same school system until the time they apply to University. Based on their academic performance in lower grades, Swedish high school administrators allow (or do not allow) their students to enroll in advanced mathematics and science courses in their last year of high school. Generally, only high performing students are permitted to enrol in advanced courses. We were informed by our Swedish colleagues that a large majority of students (over 85 %) graduates from high school. In contrast, according to the Commission d'évaluation de l'enseignement collégial (2004) there is a low rate of graduation (64%) from CEGEP.

In the text below we will present a theoretical overview, including empirical studies of student success in science studies, the methodology employed in this study, the results of our analysis and a discussion of these results. We will then present two papers, already submitted for publication or presentation, that are based on this research.

Theoretical Overview

In this study we have relied on several theoretical perspectives. These include theories of motivation such as self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000) and social-cognitive theory (Bandura, 1997), as well as theories of academic emotions (Pekrun, Goetz & Perry, 2002) and a theory of mind (Baron-Cohen, 2002).

Self-determination theory (SDT) integrates human needs and social-cognitive constructs (Pintrich, 2003). According to SDT all human beings have an innate propensity for assimilating new information and integrating it into their own knowledge structure, but they also have psychological needs to feel autonomous, competent and related to other human beings. Family and learning environments provide social contexts in which students' basic needs for autonomy, competence and relatedness must be satisfied if their innate motivation to learn is to be supported. Students feel autonomous in learning environments which provide them with some control over what is being taught and the pace of instruction, and in which their thoughts and feelings are being acknowledged (Filak & Sheldon, 2002). The greater the perception of autonomy in the learning environment, the higher the student's self-determined motivation to learn the subject (Sheldon, Elliot, Kim & Kasser, 2001). In some cases, a student may not be intrinsically interested in a subject, but he/she recognizes the value of knowledge of the subject for his/her chosen career. This extrinsic motivation (identified regulation) to learn such subjects rises with higher perceptions of an autonomy supportive learning environment. Students' self-determined motivation, intrinsic and identified regulation have been shown to be thwarted in environments where a teacher assumes most, if not all, control of the learning process (Ryan & Deci, 2000). Within the context of SDT, researchers have shown that students' classroom performance and persistence are positively influenced in learning environments in which teachers employ autonomy-supportive practices (*e.g.*, Vansteenkiste, Simons, Lens, Sheldon & Deci, 2004) and negatively influenced when teachers employ controlling practices, *e.g.,* rewards and punishments (*e.g.*, Deci, Koestner & Ryan, 1999, 2001). Even subtle cues of control undermine student motivation (Ratelle, Guay, Larose & Senécal, 2004). Parental support for autonomy impacts persistence in sciences directly and indirectly through increased perceptions of autonomy in learning environments (Ratelle, Larose, Guay & Senécal, 2005).

In the classroom context, relatedness refers to the need to interact with others in order to promote enjoyment of a task or lesson (Deci & Ryan, 2000). The perception of relatedness in an academic context functions as a motivational resource needed to activate effort and to motivate persistence when students are faced with challenging academic tasks (Furrer & Skinner, 2003). In particular, relatedness to the instructor has been shown to impact positively at the high school level (*e.g.,* Klem & Connell, 2004) and at the post-secondary level (*e.g.,* Black & Deci, 2000). Psychological needs for relatedness, or perceptions of "being related" to their peers or the instructor, differ for men and women (Parker, Rennie & Harding, 1995). Seymour and Hewitt (1997) determined that a cause of poor persistence amongst females is that women in both graduate and undergraduate levels experience feelings of psychological alienation. Kubanek and Waller (1996) followed a randomly selected sample of women for four semesters, beginning with entry into CEGEP, and ending with graduation and abandonment of science or continued studies in science. They determined that women's perceptions that their questions were not encouraged, and that they could not relate to their teachers were associated with decisions to abandon science. Similar findings were reported by Davis & Steiger (1996).

Students' need for competence has rarely been studied in isolation in an academic context (Levesque, Zuehlke, Stanek, & Ryan, 2004) because numerous studies, beginning with Ryan

(1982), have shown that increased perceptions of competence must be accompanied by perceptions of autonomy if they are to have a positive effect on performance. In addition, parental support for autonomy has been shown to positively impact on perceptions of competence in sciences (Ratelle, *et al.,*, 2005). Students perceive themselves to be competent when they are effective in learning. To be effective, students must be given tasks of optimal challenge. Viewing learning from a constructivist perspective, instructors who carefully assess student prior knowledge are more likely to choose tasks of optimal challenge, and thus, to create learning environments supportive of students' need for competence.

The need to perceive oneself as competent is a central issue in social cognitive theory (Bandura, 1986, 1997; Pajares, 1996). In this theory people are seen as self-organizing, proactive and self-regulating, rather than reactive and governed by external events. Self-efficacy is defined as "the belief in one's capabilities to organize and execute courses of action required to produce desired attainments". According to Pintrich (2003), students' self-efficacy beliefs are enhanced, and consequently their innate motivation to learn is triggered, when their psychological needs for autonomy, competence and relatedness are met. In our studies of post-secondary science students we have validated models that demonstrate that perceptions of autonomy supportive learning environment, self-efficacy beliefs and intrinsic motivation to learn sciences correlate positively and result in enhanced achievement and perseverance in science studies (Dedic, *et al.,* 2006; Simon, *et al.,* 2006).

The self-efficacy beliefs of male and female students differ (Pajares, 2002). Women have greater confidence in their use of self-regulated strategies (*e.g.,* completing homework on time, general time management, *etc*.), but tend to have lower self-efficacy beliefs concerning mathematics/science, (Schunk & Pajares, 2001). For example, in the 2003 cohort of CEGEP male had significantly ($p < 0.001$) higher self-efficacy beliefs in mathematics at the time of enrollment than their female peers (Rosenfield, *et al*., 2005). In the same study, self-efficacy beliefs in mathematics/science of all students significantly decreased after one semester in CEGEP. These results confirm that self-efficacy beliefs are not stable, and vary with academic experience. Dedic *et al*., (2006) showed that perceptions of controlling environments had a negative impact on male CEGEP students' positive emotional experiences, and through it, on their self-efficacy, while perceptions of autonomous environments had a large positive impact on female CEGEP students' positive emotional experiences, and through it, on their self-efficacy.

Bandura (1997) identified four sources of self-efficacy beliefs: mastery experiences, vicarious experiences, social persuasion and physiological states. When students experience discomfort such as anxiety while performing a task, they tend to interpret that as being vulnerable and not up to the task. In contrast, experiences such as flow and enjoyment tend to be interpreted as having mastery. In other words, these physiological states affect students' self-efficacy beliefs. The realization that emotional arousal plays an important role in student academic performance has only lately become the subject of intensive research. It should be noted that emotional states are also linked to motivation. For example, Vallerand *et al.* (1989) found that students who were highly intrinsically motivated reported that they frequently experienced joy while performing academic tasks. A review of prior research on classroom motivation by Meyer and Turner (2002), showed that emotions are central to understanding students' self-efficacy and involvement in learning. Pekrun, Goetz, Titz and Perry (2002) developed a questionnaire to assess students' emotional states while they are learning. These authors demonstrated that experiences of positive emotional states, such as joy, have a positive impact on achievement, while experiences of negative emotional states, such as fear or anxiety, adversely affect students' academic performance. In addition, Pritchard and Wilson (2003) have demonstrated that positive emotions are an important factor in students' perseverance.

Studies of perseverance and achievement in sciences often focus on the fact that women tend to abandon science studies in larger numbers than men (*e.g.,* Rosenfield *et al.,* 2005). Many of those studies show that there are no differences in achievement or motivation to which one could attribute the differences in abandonment. Further, differences in self-efficacy alone don't seem to be able to explain the lower perseverance of female students. Baron-Cohen (2002) developed his theory of mind from studies of autism, and as we shall explain, his theory may shed light on the long standing problem how to explain lower perseverance amongst female students. He hypothesizes that human brain functions have developed so as to sustain our species' adaptation to our environment. Humans needed to adapt to the inanimate environment, and hence, we have developed a cognitive skill that Baron-Cohen calls systemizing. Systemizing is a drive to understand laws and rules governing the behaviour of inanimate systems. It is a yearning to analyse and create structured models of such systems. However, for survival our species also needed to adapt to changes in the social environment, and consequently we have developed a skill that Baron-Cohen calls empathizing. Empathizing is a drive to understand other people's thoughts and emotions, imagining how one would think and feel in their situations, allowing us to predict behaviour of people and to respond appropriately to social stimuli. This concept is similar to sub-scales of emotional-social intelligence (Bar-On*,* 2006). Baron-Cohen and his colleagues (Baron-Cohen *et al.,* 2003) suggest that empathizing and systemizing are two cognitive styles people use daily in their reasoning. In addition, on average, they have shown that males tend to be better at systemizing, while females tend to be better at empathizing (Baron-Cohen *et al.,* 2003). Since understanding and predicting patterns of behaviour of physical objects is an important skill in science, not surprisingly Billington *et al.* (2007) discovered that the majority of students choosing to study physical sciences were stronger systemizers than empathizers. Thus, when studying perseverance in sciences we should consider students' cognitive style. Both males and females who are not comfortable when they need to use systemizing cognitive style are probably likely to experience negative emotions while performing tasks in sciences and hence, more likely to withdraw from science studies. Since more women tend to feel uncomfortable when using systemizing cognitive style we speculate that this may explain why they tend to abandon goals of science careers.

Besides the psychological factors which enhance or deter the need to learn, the students attitudes towards sciences, and consequently their motivation to persist in their science studies, are affected by the students prior science socialization and the science culture they have acquired. By science culture we understand knowledge of scientific ideas and an active involvement in the continuous process of exchange and evaluation of these ideas with the goal of building community consensus knowledge (Redish, 1999). Parents, teachers, peers, the media are the most significant providers of science related knowledge, beliefs, habits and attitudes for students (Godin, 1999). Science culture has been shown to impact on students' science attitudes and also on persistence in sciences. At the high school level, Reynolds and Walberg (1992) validated a model in which science culture, alongside motivation, mediates between a home environment variable and outcome variables of science achievement and science attitudes. In this study, science culture originated from teachers, peers and the media. George and Kaplan (1997) developed a model in which such factors as: science activities, library/museum visits, participation in science experiments and home science resources were seen to mediate between parental (family structure, parent education) and instructional (science facilities, teacher preparedness) variables on the one side and the outcome, science attitudes. A recent study (Larose, Guay, Senécal, Harvey, Drouin & Delisle, 2006) examined the persistence of engineering students at Laval University and found that students' science culture was the factor that explained about 3% of the variance in persistence of university science and engineering students. Science culture was measured as the frequency of science activities (*e.g.,* reading scientific journals, visiting science museums, engaging in conversations about science discoveries (*e.g.,* genome project)) and general science knowledge (*e.g.,* knowledge of how lasers function). In this study (2006), the development of science culture was traced to influences of the student's family, teachers and peers. However, most of these studies use definitions which may not distinguish between science culture and science attitudes. Moreover, the definitions used in these studies are inconsistent with each other.

Science education researchers have made an effort to develop consistent definitions of students' attitudes and beliefs about sciences. In this quest, they have developed survey instruments that probe attitudes, beliefs and epistemological frames held by students in introductory physics courses (Redish, Saul & Steinberg, 1998; Halloun & Hestenes, 1998; Elby, 2000; Adams, Perkins, Podolefsky, Dubson, Finkelstein & Wieman, 2006). These instruments are designed to distinguish the beliefs of *experts* from the beliefs of *novices.* For instance, a professional physicist sees physics as a coherent framework of concepts which describe nature and is established by experiment. A novice sees physics as isolated pieces of information that are handed down by authority, must be memorized and have no connection to the real world. Several studies have shown that students' attitudes and beliefs are shaped by students' classroom experiences (Bransford, Brown & Cocking, 1999; Seymour & Hewitt, 1997; Hammer, 2000; Redish, 2003). Alas, students' science attitudes and beliefs have been reported to deteriorate, *i.e.*, become less expert and more novice, after instruction in traditionally taught introductory physics classes (Redish, Saul & Steinebrg, 1998; Perkins, Adams, Pollock, Finkelstein & Wieman, 2004). On the other hand, students' attitudes slightly improved in a large introductory physics course which simultaneously implemented several research-based practices (*e.g.,* Peer Instruction with student response system in lecture was introduced by Mazur (1997)), teaching assistant tutorials, personalized computer assignments (Pollock, 2004; Adams *et al.,* 2004)). In the latter study, pre-instruction students' attitudes positively correlated (r=.21, p=.0008) with normalized gains (Hake, 1998) in conceptual understanding. Moreover, in this study pre-instruction attitudes were shown to impact on persistence. Students who persisted in taking physics courses had 14% higher scores on science attitudes than those who abandoned taking physics courses. Unfortunately, we note that most of the instruments used in the above studies were not tested for internal consistency or external validity.

Although psychological factors and attitudes were shown to impact on perseverance in STEM programs, one research focus is learning environments in science classrooms because, as educators, we know that the classroom is the main arena within which teachers can influence their students, indeed it may be the only arena within which they interact (Tinto, 1997; Pintrich, 2003). A literature review indicates that students' perseverance and achievement are indeed related to learning environments in science classrooms. According to Seymour and Hewitt (1997), more than one third of undergraduate students who leave university majors in science/engineering cite poor teaching as the primary reason. Antiquated pedagogies drive many talented students away from enrollment in university science/engineering programs (Tobias, 1991; Duchesne, Bègin, Boisvert, Riopel, Deraiche, Fiset, Quellet, Fortin, Demers & Couillard, 2001). The pedagogical approach used by a majority of instructors, driven by pressures to cover science/mathematics course curricula, "emphasize quantity over quality, and are all a mile wide and an inch deep" according to G. Nelson, Director of Project 2061 (2001) and may be "full of inert material" according to Peter Lax, the Past President of the American Mathematical society (Uhl, 2000).

Chen, Taylor and Aldridge (1997) have shown that learning environments are results of teachers' intentions, which in turn are primarily guided by teachers' conceptions of teaching and learning. Teachers' conceptions of teaching in higher education can be viewed as a continuum, ranging from student-centred/learning-oriented to teacher-centred/content-oriented (*e.g.,* Kember, 1997), resulting in different teaching acts, different expectations of student actions, and different types of assessment used. For example, teachers conceptualizing teaching as teacher-centred/content-oriented define the curriculum by what they see as the standard knowledge of the discipline and see students as recipients of knowledge. The pressure of standards from above and pressure of "amotivated" students from below lead teachers to adopt controlling practices (Pelletier, *et al.*, 2002*).* Consequently, the focus of science classes is frequently not on development of science culture (Arons, 1997), but rather on the transmission of facts. The process by which experts build commonly held scientific understanding, *i.e.*, proposing, debating and evaluating ideas, may provide a template for creating learning environments in which the largest possible fraction of students can attain expert beliefs, habits and knowledge. But such process takes up a lot of class time and instructors whose beliefs about teaching are teacher centred, resort to lectures in order to cover the curriculum. In our previous study we found that only 35% of science and mathematics instructors in CEGEPs view teaching as student centred. As expected, these teachers were more likely to create a learning environment supportive of student autonomy, and structure their learning environment from a constructivist perspective on learning (Rosenfield *et al.,* 2005). It is possible that these teachers also promoted the development of science culture more effectively than their colleagues who focussed on the transmission of knowledge.

To summarize, the review of research indicates that students' achievement and perseverance are related to their motivation, self-efficacy beliefs and academic emotions. Students who are intrinsically motivated to study sciences are more likely to be high achievers in sciences and persist in science studies. Similarly, those students who perceive themselves to be competent in tasks facing them in their courses of their academic work, are more likely to be successful academically and more persistent in their studies. Lastly, students who frequently experience enjoyment and who do not experience anxiety while studying sciences are the ones who are likely to experience success and who are less likely to abandon their goals in having science careers. These student characteristics may be derived from parental support for autonomy, competence and science acculturation. They may also stem from the learning environments. In learning environments which are supportive of student autonomy, competence and relatedness and which are promoting science acculturation, student intrinsic motivation, self-efficacy beliefs and emotional well being is likely to be enhanced. In other words, teacher support plays an important role during students' academic career and may or may not positively influence students' decisions concerning a career in sciences. In addition, student cognitive style may be another determining factor that leads to increased intrinsic motivation, self-efficacy and positive emotional experiences. Thus, we are hypothesizing that there is a causal structural model that may explain variances in student achievement and perseverance. This model includes independent variables: parental support; teacher support; and, cognitive style. The mediating variables in this model are self-efficacy; motivation; and, academic emotions. The outcome variables are achievement and perseverance. The model is shown in Figure 1 below:

Theoretical Overview (cont.)

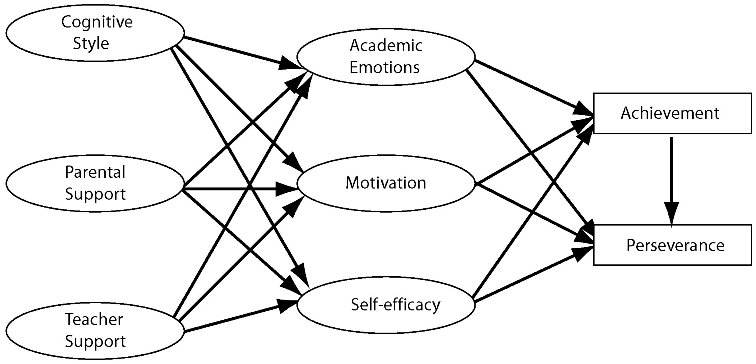

Figure 1

Methodology

Sample: Participants were recruited from two populations: students who enrolled in one of the four public Anglophone CEGEPs in Montreal the Fall 2007 and Swedish students who attended twelfth grade in high schools in Linköping and Stockholm.
Criteria of eligibility: To be eligible to participate in this study,

- a Quebec students admitted into the CEGEP science programs in the Fall of 2007;
- b Quebec students admitted into the Session d'Accueil in the Fall of 2007 and into the science program in the Spring of 2008.
- c Swedish students enrolled in advanced mathematics and science courses in the last year of high school in Sweden during the school year 2007-2008.

Students included in this sample were students who were eighteen to twenty year old during the course of this study. Note that the participants were drawn from populations residing in urban areas of the greater Montreal region or cities in Sweden (Linköping and Stockholm). This population includes students whose mother tongue is English and who are likely to have attended high school in the English sector. It also includes students whose mother tongue is either French or another language, and who are likely to have attended high school in the French sector. The Swedish population was mostly Swedish speaking. All eligible participants signed a consent form required by the ethics boards of the participating institutions.

Data collection**:** With the consent of students, demographic, achievement and enrollment data were acquired from MELS' database SOCRAT or from the Ministry of Education in Sweden. Surveys administered in classes were also sources of data collected in this study. The first survey was administered in the first two weeks of classes in the Fall semester 2007 in Quebec. Due to delays in the translation of the first questionnaire, the data were collected in October 2007 in Sweden. The second questionnaire was administered in the Spring of 2008. Since Swedish students were to enroll in the university programs in the Fall of 2008, the Swedish version of the second questionnaire included an item querying their intentions to pursue university studies in either STEM or health programs. The third questionnaire was administered to Quebec students in the spring of 2009 to obtain the information as to which program they have applied to on March 1, 2009 or to which program they intend to apply if they anticipate to graduate from CEGEP later than in the spring of 2009.

The data were collected from 2916 students in five institutions. We distinguish four Quebec colleges as different institutions but we combine all Swedish students into one institution in our study The Table M1. shows the labels for each of the institutions.

Table M1. Label of the Institutions

Institution	Champlain College	Dawson College	John Abbott College	Vanier College	Swedish high schools
Label	1	2	3	4	5

The graph below shows the number of students from different institutions who participated in at least one of the surveys.

Distribution by institution:

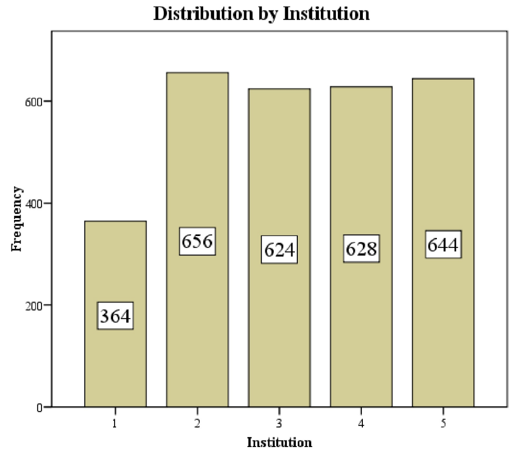

Figure M1

Some respondents amongst CEGEP students enrolled into college in semesters other than the Fall of 2007. In addition, some CEGEP respondents were enrolled in programs other than sciences. Some students who participated in the surveys in Sweden also did not fit the eligibility criteria because they were already enrolled in some courses at university. All students who did not fit the criteria for eligibility were removed from the list of participants. Thus, the sample size became N=2184 and the graphs below shows the distribution of eligible participants by country and across five institutions.

Distribution by country and institution:

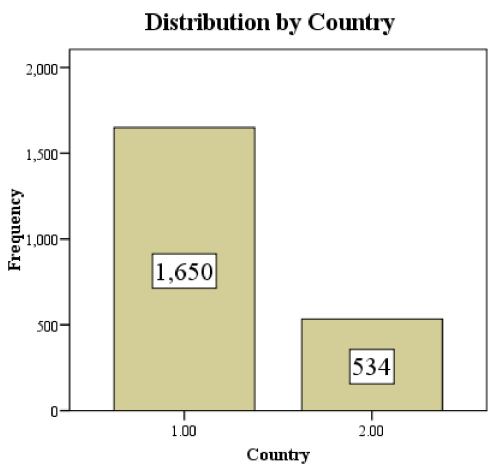

Figure M2

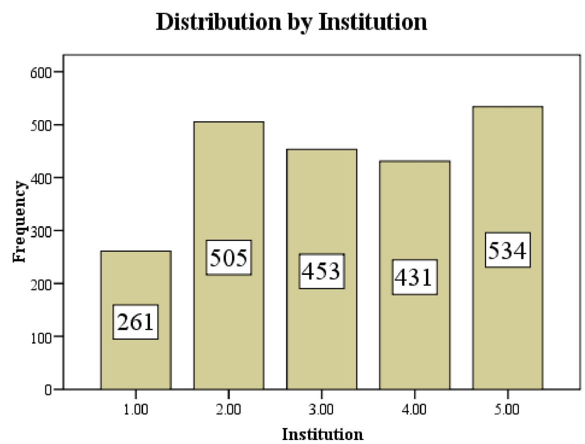

Figure M3

The following table shows the distribution of female and male students amongst the eligible participants:

Table M1. Gender Distribution Amongst the Eligible Participants

			Country		Total
			Quebec	Sweden	1
Gender	Female	Count	801	247	1048
		% within Gender	76.40%	23.60%	100.00%
		% within Country	48.50%	46.30%	48.00%
		% of Total	36.70%	11.30%	48.00%
	Male	Count	849	287	1136
		% within Gender	74.70%	25.30%	100.00%
		% within Country	51.50%	53.70%	52.00%
		% of Total	38.90%	13.10%	52.00%
Total		Count	1650	534	2184
		% within Gender	75.50%	24.50%	100.00%
		% within Country	100.00%	100.00%	100.00%
		% of Total	75.50%	24.50%	100.00%

Variables: In the course of this study we have either adapted validated instruments or we have developed our own instruments. In the latter case, we have often been inspired by existing measures but our instruments are not just an adaptation. Whether a scale is an adaptation or a new instrument, the tests of internal consistency via alpha Cronbach and reliability tests via Confirmatory Factor Analysis was always carried out. Although complete versions of all the surveys are to be found in the appendices of this report, we present samples of items in this section so that a reader can easily understand what attribute any particular scale measures. We proceed from the description of outcome variables to mediating variables and eventually, describe the independent variables.

Outcome variables

Student academic achievement: Since we are dealing with two different school systems we had to reconcile the grading systems into a common measure. In Quebec colleges, the achievement is reported in percentages achieved in each course. In Sweden, the letter grades for each course are reported. Courses in Quebec and in Sweden may have a different content. Subject experts on our team studied the curriculum of advanced courses in Swedish high schools and came to a conclusion that two advanced courses in mathematics essentially resemble the content of the Calculus course 201 NYA. The advanced courses in chemistry and in physics taken by students in Swedish high schools have a content similar to general chemistry 202 NYA and mechanics course 203 NYA. Thus, we base the measure of achievement on students' performance in the three courses that are usually taken by science students in their first semester in CEGEP and four advanced courses takes by Swedish students. To overcome the hurdle of different grading schemas in the two countries, we have first converted the letter grades in the Swedish sample to a numerical scale: Fail=1; PASS=2; PASS WITH DISTINCTION=3; and, PASS WITH GREAT DISTINCTION=4. Then, we have computed the z-scores for each course and labelled the variables as ZCHEM, ZMATH and ZPHYS. Note that in case of Swedish students, ZMATH is an average of the z-zcores in the two advanced courses in mathematics. Finally, achievement is computed as an average of ZCHEM, ZMATH and ZPHYS.

Perseverance: Students responded to a question in one of the surveys: *What is the likelihood that you will continue to study in a science/engineering program at a University within the next two* *years?* The responses ranged from 1=Very unlikely; 2=Unlikely; 3=Likely; and, 4=Very likely. The data was collected in the second questionnaire in Sweden when students were about to graduate from high school. We have asked the same question in Quebec in the spring of 2009 when our cohort was about to graduate from CEGEP. We couldn't to reach all participants who were still enrolled in the science program. Some participants have decided to change program before the data collection. In this study, we assumed that the perseverance of these students is 1 (Very unlikely). That is we have assumed that the likelihood of their enrollment in STEM studies is very low. Thus, we were able to increase the number of participants for whom we have data on perseverance.

Mediating variables

Self-efficacy in mathematics and sciences: To assess students' self-efficacy we have selected five items from a scale that we have used in our previous studies (Dedic, Rosenfield, Alalouf & Klasa, 2004; Rosenfield, *et al.,* 2005). Note that this scale was adapted from two sources: the self-efficacy scale of the Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia, and McKeachie, 1991) and the Mathematics-Related Beliefs' Questionnaire, developed by Op't Eynde and De Corte (2003). All items (*e.g., I am confident that I will be able to correctly solve problems in mathematics and science courses*) refer to students' beliefs concerning their performance in mathematics and science studies because these beliefs are domain specific (Pajares & Miller, 1995).

Self-determined motivation: Self-determined motivation was measured using twenty items adapted from the Academic Motivation Scale (AMS) developed by Vallerand, Pelletier, Blais, Brière *et al.* (1992). The AMS is a scale developed to assess academic motivation within the framework of SDT (Deci & Ryan, 1985). The AMS assesses the three main types of motivation, as described in SDT. All items follow this preamble: *The following questions concern reasons why you are enrolled (or intend to enrol in the future) in the science program.* The four items measuring intrinsic motivation refer to enjoyment in learning science (*e.g., Because I enjoy learning new things in science.*). There are altogether twelve items measuring extrinsic motivation (identified, introjected and external regulation). The four items measuring identified motivation refer to the usefulness of studying sciences in achieving personal goals (*e.g., Because this will help me to study other subjects that I like.*). The next four items that assess students' introjected motivation refer to the shame of not being able to succeed in sciences (*e.g., Because I would be embarrassed if I did not succeed in the science program.*). External regulation is also assessed by four items which refer to external rewards in terms of an admission into top rated programs at university (e.g., *Because good grades in science courses are essential for admission to the best programs at University.*). The last four items measuring student amotivation refer to their lack of interest in sciences (*e.g., I can't see why I am studying in the science program because I really don't care about the sciences.*).

Academic emotions: The twelve items assessing academic emotions are adapted from the Academic Emotion Questionnaire (AEQ). Each emotional scale of the AEQ consists of four components: affective (*e.g., I enjoy the challenge of learning physics.*); cognitive (*e.g., I enjoy the challenge of learning physics*.); motivational (e.g., *I study physics more extensively than is necessary because doing so is fun for me.*); and, physiological (*e.g., When I study physics, I am in a good mood.*) sub scale. The review of literature led us to include the following emotional scales: anxiety, enjoyment and boredom. The latter one has been identified by Pekrun *et al.,* (2002) as an emotion often experienced by bright students who feel that they lack challenge in school. It is also experienced by students who are overwhelmed by challenges faced in school.

Emotional experiences are also domain specific. The same student may experience enjoyment while doing a chemistry task but experience a great anxiety when working on a task in mathematics. Thus, over the course of this study we have examined student emotional states in all four disciplines in sciences (biology, chemistry, physics and mathematics).

Independent variables

Parental support: Ratelle *et al.,* (2005) and Larose *et al.,* (2006) who studied the impact of parental support on achievement and perseverance, have adapted their scales from two sources (Paulson, Marchant & Rothlisberg, 1994; Robinson, Mandleco, Frost Olsen, Bancroft-Andrews, McNeally & Nelson, 1995). We have examined the two original sources as well as Perception of Parents Scale that is available at SDT website and items used to assess parental support of autonomy (*e.g., My parents tell me how to run my life.*) and parental support for competence (*e.g., My parents are proud of me and my accomplishments.*) were selected from one of these questionnaires. The impact of parental support for science acculturation on student perseverance was examined by Larose *et al.,* (2005). The authors of this study did not examine internal consistency of the scale. In addition to items used by Larose and his collaborators (2005), we have also examined scales assessing attitudes towards science as formulated in VASS (Halloun *et al.,* 1998) and in CLASS (Adams *et al.,* 2006) in this context. These three instruments inspired us to formulate a five item scale assessing parental support for science acculturation. We intended to capture acts that portray sciences as an exciting endeavour (*e.g., my parents excitedly discussed new scientific discoveries.*) or acts that actively engage a child (*e.g., my parents and I had debates about science.*)

Teacher support: In our previous study (Rosenfield, *et al.*, 2005) we have adapted items from the Perceptions of Science Classes Survey (PSCS) developed by Kardash and Wallace (2001) and we assessed the internal consistency of this scale in the above study. The problem is that this scale is not rooted in any learning theory. However, many items refer to teaching acts that are likely to be encountered in science and mathematics class rooms at a post-secondary level. This fact makes this scale a useful tool. In this study, we have decided to develop a scale that assesses five dimensions of perceptions of learning environment: autonomy; competence; relatedness; interest in sciences and acculturation into science community. The following principle guided the development: Items for assessing the five dimensions must focus on student perceptions of teacher actions and student perceptions of actions expected of them by the teacher. In addition, all items must reflect teaching acts that are likely to be encountered in the context of post-secondary science/mathematics courses. This indirect approach was used for two reasons. First, it is probably impossible to have students understand precisely what is meant by "autonomy-supporting" or "competence-supporting" based on a short paragraph of explanation. Second, and more importantly, since our overall objective was to provide constructive feedback to teachers to aid them in improving their teaching practice, our questions to students must focus on their perceptions of teacher actions, and their understanding concerning teacher expectations of them, so that the feedback will relate to teacher actions in the classroom, and hence be immediately useful for teachers.

The first three sub scales refer to dimensions derived from the SDT (Deci & Ryan, 2000): teacher support for autonomy (*e.g., My science teacher often taught us several ways of solving the same problem, giving us options to choose when solving problems ourselves.*); teacher support for competence (*e.g., My science teacher made me feel that making mistakes is a normal part of learning.*); and teacher support for relatedness (*e.g., I felt that my science teacher cared about me as a person.*) Items in these three sub scales were adapted from two sources: a scale used in our study (Dedic, *et al.*, 2006) and Basic Psychological Needs (http://www.psych.rochester.edu/SDT/measures/needs.html).

It is certain that most mathematics and science instructors aim to share the knowledge of their subject with their students. Most of them also aim to raise students' interest in their discipline by sharing their passion for their subject. They may be the first mathematicians or scientists that students encounter in their lives. These instructors may become role models for their students who are likely to share with their students the science culture. The two other sub scales refer to students' perceptions of the latter two dimensions of teaching. We have been inspired by VASS (Halloun *et al.,* 1998) and CLASS (Adams *et al.,* 2006) in the formulation of four items of teacher support of interest in sciences (*e.g., My teacher made me feel that doing science is just a lot of work with no excitement.*). The previous example is negatively worded item. Science and mathematics in school is often presented as a set of known theories and concepts. The search for novel perspectives, explorations of uncharted terrains and controversies among leading scientists constitute an integral part of science culture that is usually absent in a science class room. Consequently, to assess teacher support for science culture we have included items such as *My teacher made us debate and take sides on controversial issues (e.g., genetically engineered food, global warming, funding of space exploration)*.

Cognitive style: To assess systemizing and empathizing cognitive style Baron-Cohen and his collaborators have developed a 75-item survey called the Systemizing Quotient and a 60-item survey called the Empathizing Quotient (Baron-Cohen *et al.*, 2003). All items refer to every day activities and tasks and preference for engaging in those activities. We noted that many of items, particularly in the Systemizing Quotient refer to activities and tasks that are likely to be encountered in United Kingdom. We either eliminated or rephrased those items so that items referred to activities and tasks that are likely to be encountered in the cultural contest in Quebec and in Sweden. We have pared down the surveys to 20 items for each of systemizing and empathizing scales and pilot tested this new scale on a small sample of 247 students in the Fall of 2007. Our aim was to further reduce the number of items. An exploratory factor analysis was carried out identifying two factors (systemizing and empathizing). The number of items in the systemizing scale was reduced to twelve and similarly, the number of items in the empathizing scale was reduced to five. As we have said above, items in systemizing scale refer to tasks that people who are driven to analyse systems find easy to accomplish (*e.g., I find it easy to understand instruction manuals for putting things together.*). Items in empathizing scale refer to tasks that people who prefer to to socialize find easy to accomplish (*e.g., I can rapidly and intuitively tune into how someone else feels.*).

Aptitude: A 10 item Aptitude for Science test (http://www.psychtests.com) that resembles Raven's Advanced Progressive Matrices was used to assess cognitive ability. It was administered, one year later than the survey, to 105 volunteers drawn from amongst the Quebec participants.

Demographics: We have also collected data on gender, socioeconomic status, number of hours per week that student employed as part-timers, parents' education and parents' education in scientific domains.

Results

We will present the results of this research in four sections: *Validation*; *Descriptive Statistics and Correlations*; *Comparison Between Canadian and Swedish Populations*; and, *Gender Differences*.

Validation

Academic Emotion: The reliability of each of the three sub-scales of academic emotions (boredom, anxiety and enjoyment) was tested using the α-Cronbach model of internal consistency and Confirmatory Factor Analysis (CFA). EQS software (Bentler, 1995) was used to carry out the CFA. The results of the CFA indicate that each sub-scale is internally consistent (boredom: α=.808; anxiety: α=.723; and enjoyment: α=.791). In addition, CFA was used to validate a three factor model. Three indices for goodness of fit are reported: the comparative fit index (CFI)=.953; Satorra-Bentler Scaled Chi-square ($SB\chi^2$)/df = 388.7804/51=7.608; and, Root Mean-square Error of Approximation (RMSEA)=.058, with the 90% confidence interval of RMSEA being [.053, .064]. The first and last indices indicate a good fit, one that is well within recommended values (CFI >.900 (Bentler, 1992) or CFI close to .950 (Hu & Bentler, 1999); RMSEA<.080). The middle value, Satorra-Bentler Scaled Chi-square exceeds the recommended value of 3, but the value is still within the accepted norms.

The standardized solution is presented below:

Table V1: Validated Factorial Model of Academic Emotions

	Boredom				Anxiety				Enjoyment			
Item	1	2	3	4	1	2	3	4	1	2	3	4
Factor Loading	0.569	0.76	0.725	0.828	0.556	0.633	0.69	0.63	0.695	0.72	0.616	0.758
Error	0.822	0.65	0.689	0.561	0.831	0.774	0.724	0.776	0.719	0.694	0.788	0.653
R^2	0.324	0.577	0.525	0.685	0.309	0.4	0.476	0.397	0.483	0.518	0.379	0.574

The minimum factor loading value is .556, indicating that these sub-scales explain variance in the data well. Thus, we conclude that the three sub-scales of academic emotion reliably measure the emotional experiences of students while they are learning.

Parental Support: The results of testing for internal consistency of the parental support sub-scales show internal consistency for all three sub-scales (parental support for autonomy: α=.767; parental support for competence: α=.743; and, parental support for interest in sciences and science acculturation: α=.800). CFA was used to validate a three factor model, with fit indices (CFI=.937 and RMSEA=.060, 90% confidence interval of RMSEA being [.055, .066]) indicating a good fit with the data. In addition, ($SB\chi^2$)/df=414/51=8.118 is within the accepted norms.

The standardized solution is presented below:

Table V2: Validated Factorial Model of Parental Support of

	Autonomy			Competence				Science Acculturation				
Item	1	2	3	1	2	3	4	1	2	3	4	5
Factor Loading	0.671	0.676	0.708	0.653	0.675	0.608	0.68	0.677	0.516	0.772	0.739	0.595
Error	0.741	0.737	0.706	0.758	0.737	0.794	0.733	0.736	0.857	0.635	0.673	0.804
R^2	0.45	0.457	0.501	0.426	0.456	0.37	0.463	0.458	0.266	0.596	0.546	0.354

The minimum factor loading is .516, indicating that these sub-scales explain the variance in the data well. Thus, we conclude that these three sub-scales of parental support reliably measure students' perceptions of the encouragement their parents gave.

Teacher Support: The four sub-scales of student perception of teacher support were tested for internal consistency (teacher support for interest in sciences and science acculturation: α=.801; teacher support for autonomy: α=.754; teacher support for competence: α=.814; and, teacher support for relatedness: α=.840) and the results indicate that each of the sub-scales is internally consistent. The indices of goodness of fit confirmed a four factorial model (CFI=.939; RMSEA=.059 (90% confidence interval of RMSEA [.056, .063]). Further, $(SB\chi^2)/df=892/129=6.915$ is well within the accepted norm.

The standardized solution is presented below:

Table V3: Validated Factorial Model of Teacher Support

Scale	Item	Factor Loading	Error	R^2
Autonomy	1	0.739	0.617	0.701
	2	0.617	0.787	0.713
	3	0.701	0.713	0.492
	4	0.57	0.822	0.325
Competence	1	0.778	0.629	0.605
	2	0.66	0.757	0.436
	3	0.768	0.641	0.59
	4	0.681	0.732	0.464
Relatedness	1	0.82	0.572	0.673
	2	0.791	0.612	0.626
	3	0.804	0.595	0.647
	4	0.61	0.792	0.373
Science Acculturation	1	0.527	0.697	0.677
	2	0.697	0.717	0.736
	3	0.677	0.736	0.459
	4	0.667	0.745	0.444
	5	0.603	0.798	0.364
	6	0.648	0.762	0.42

The minimum factor loading is .527, indicating that the sub-scales explain variance in the data well. Thus, we conclude that the four sub-scales of teacher support reliably measure students' perceptions of the learning environment they have experienced in class.

Motivation and Self-efficacy: We tested the five sub-scales assessing motivation, as well as a scale assessing student self-efficacy beliefs, for internal consistency. We are satisfied that all scales (external regulation: α=.752; intrinsic motivation: α=.876; identified motivation: α=.753; amotivation: α=.889; introjected motivation: α=.723; and, self-efficacy: α=.789) are internally consistent. CFA tested a six factor model. Indices indicated a good fit of the data (CFI=.940; RMSEA=.045 with 90% confidence interval of RMSEA being [.042,.047]). In addition, $(SB\chi^2)/df=1102/237=4.650$ is well within the accepted norms.

The standardized solution is presented below:

Table V4: Validated Factorial Model of Motivation and Self-efficacy

Scale	Item	Factor Loading	Error	R2
External Regulation	1	0.535	0.845	0.286
	2	0.767	0.641	0.589
	3	0.751	0.66	0.564
	4	0.583	0.813	0.339
Intrinsic Motivation	1	0.796	0.606	0.633
	2	0.823	0.568	0.677
	3	0.872	0.489	0.761
	4	0.722	0.692	0.522
Identified Motivation	1	0.706	0.708	0.499
	2	0.719	0.695	0.517
	3	0.473	0.881	0.224
	4	0.75	0.662	0.562
Amotivation	1	0.82	0.573	0.672
	2	0.819	0.573	0.671
	3	0.833	0.554	0.693
	4	0.807	0.591	0.651
Introjected Motivation	1	0.735	0.678	0.54
	2	0.574	0.819	0.33
	3	0.764	0.645	0.584
	4	0.486	0.874	0.236
Self-efficacy	1	0.7	0.714	0.49
	2	0.701	0.713	0.491
	3	0.712	0.702	0.507
	4	0.698	0.716	0.487

All factor loadings exceed .473. This means that the variance in the data is well explained by this factorial model. Thus, we conclude that the scales were good measures in the assessment of students' motivation to study sciences and of their self-efficacy beliefs about their competence to study sciences.

Cognitive Style: Two sub-scales (systemizing and empathizing) were derived from a very large questionnaire (75 items for systemizing and 60 items for empathizing). Since we could not administer such a large questionnaire, we have pilot tested a shorter version (12 items for systemizing and 5 items for empathizing). The pilot test results indicate good internal consistency. Consequently, we have used the shorter version in this study. Testing for internal consistency using the larger data set collected for this sample (as compared to our pilot test), we found that three items in the systemizing scale were not consistent with other items in the same scale. Removing those three items we found that the α-Cronbach for the systemizing scale rose to an acceptable level (α=.703). The five items assessing the empathizing cognitive style are internally consistent (α=.719). We performed CFA with a two factor model (nine consistent items for the systemizing scale and five items for empathizing scale) on this data set. The model did not fit the data (CFI=.836). The factor loadings of several systemizing items were below the recommended minimum factor loading of .400. Ad hoc modifications of the model led to a two factor model that fits the data. This model includes four items for the systemizing scale and all five items for the empathizing scale. The indices of goodness of fit (CFI=.928 and RMSEA=.056 with the 90% confidence interval of RMSEA being [.050,.066]) meet the usual requirements. However, there is a problem in that the four item scale for systemizing has an unacceptable internal consistency (α=.660). Considering the above results, we are aware that the condensed systemizing scale is not a reliable measure of this cognitive style. Thus, we decided to use the nine-item scale that is internally consistent as assessed by α-Cronbach in subsequent analysis and we will interpret results involving this scale in a cautious manner.

Descriptive Statistics and Correlations

The means and standard deviations of all variables are shown in the tables and graphs below. Correlations between Outcome Variables on the one hand and Independent Variables and Mediating Variables on the other hand, as well as correlations between Independent Variables and Mediating Variables are also shown in tables. Note that all of these values were computed for the whole sample.

Independent Variables

Cognitive Style: Given that responses on both of these two sub-scales range from 1 (Strongly Disagree) to 4 (Strongly Agree), the distribution graphs and means indicate that student responses were somewhat shifted to the right on both sub-scales.

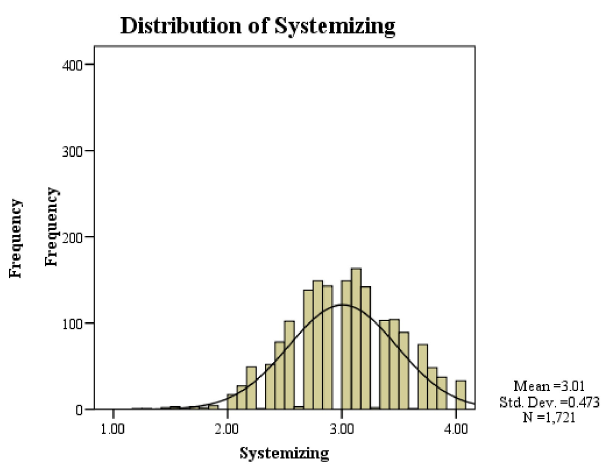

Figure DS1

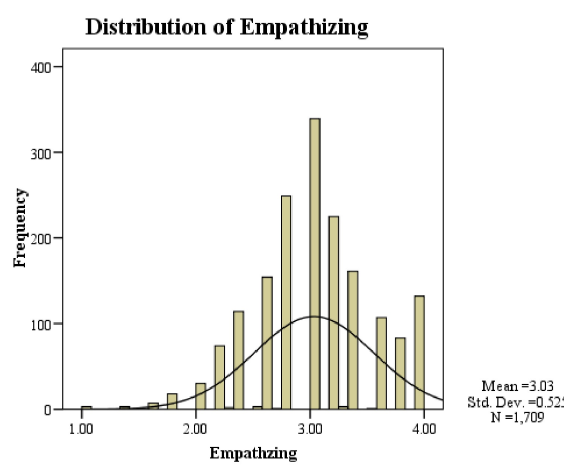

Figure DS2

Examining table DS1 below, we note that although the correlations between systemizing and perseverance, and empathizing and achievement, are statistically significant, both correlations are quite small in absolute value. This indicates that the independent variable of cognitive style does not exert a strong direct impact on either of the two outcome variables. However, we note the strong correlation between our two outcome measures, achievement and perseverance, which quite naturally was anticipated. There is also a weak correlation between the two sub-scales of cognitive style, empathizing and systemizing. This may be related to a personal observation: when we first discovered the literature on cognitive style, and began formulating our instrument by reducing the number of questions, we asked for volunteers from amongst the faculty to complete the full original questionnaire. Noticeably several male faculty members scored very high on systemizing and very low on empathizing, while several female faculty members scored high on systemizing but also quite high on empathizing.

Table DS1. Correlations between Achievement/Perseverance and Cognitive Style

(Pear. Corr, Sig., N)	achievement	perseverance	systemizing
achievement	1, , 2140		
perseverance	.518**, .000, 1588	1, , 1622	
systemizing	0.024, .323, 1702	.181**, .000, 1355	1, , 1721
empathizing	-.058*, .017, 1690	-.028, .305, 1344	.238**, .000, 1709

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Parental Support: Examining the graphs and means shown below for the distributions of the three Parental Support sub-scales (Parental Support for Autonomy, Parental Support for Competence and Parental Support for Science Acculturation) we note immediately that the distributions for the first two sub-scales are skewed to the right, with means both above 3, while the distribution for the third sub-scale is skewed to the left, with a mean just barely above 2. That is, students generally agreed that their parents supported their autonomy and competence, but they generally disagreed that their parents acculturated them to science.

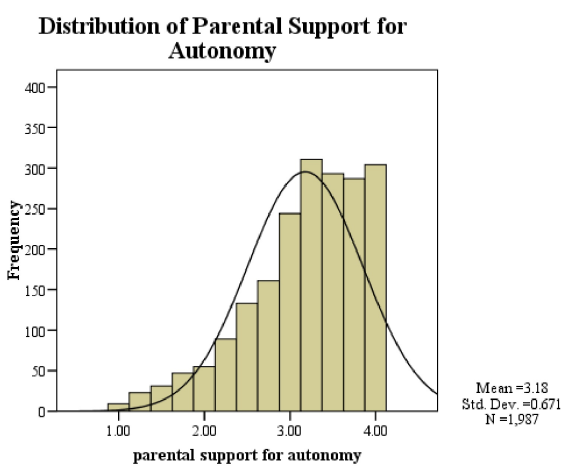

Figure DS3

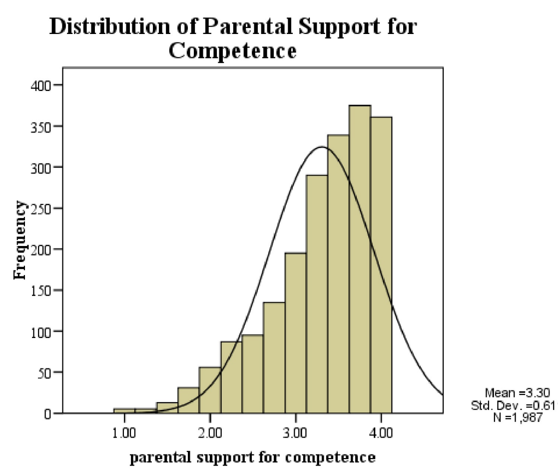

Figure DS4

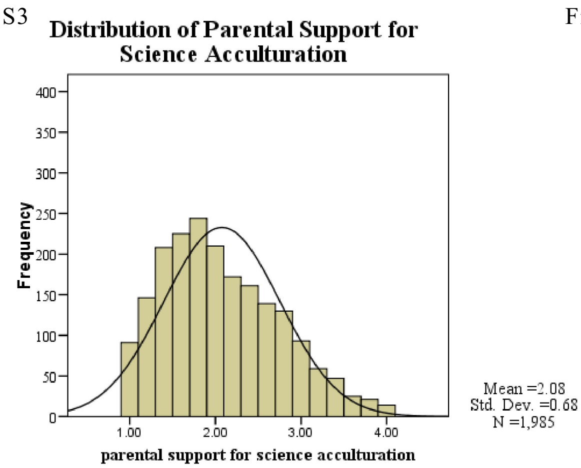

Figure DS5

Examining table DS2 below, once again we note that although the correlations between the three Parental Support sub-scales and achievement, as well as the correlations between two of the Parental Support sub-scales and perseverance, are statistically significant, all five correlations are quite small in absolute value. This indicates that the independent variable of Parental Support does not exert a strong direct impact on either of the two outcome variables. The strong correlation between the two outcome variables was noted earlier. As would be anticipated, there is a strong correlation between Parental Support for Autonomy and Parental Support for Competence.

Table DS2. Correlations between Achievement/Perseverance and Parental Support

(Pear. Corr, Sig., N)	achievement	perseverance	autonomy	competence
achievement	1, , 2140			
perseverance	.518**, .000, 1588	1, , 1622		
autonomy	.055**, .016, 1952	0.044, .090, 1457	1, , 1987	
competence	.164**, .000, 1952	.106**, .000, 1457	.665**, .000, 1987	1, , 1987
science acculturation	.074**, .001, 1950	.081**, .002, 1455	.094**, .000, 1985	.125**, .000, 1985

** Correlation is significant at the 0.01 level (2-tailed).

Teacher Support: Examining the graphs and means shown below for the distributions of the four Teacher Support sub-scales (Teacher Support for Autonomy, Teacher Support for Competence, Teacher Support for Science Acculturation and Teacher Support for Relatedness) we note that the distributions for four sub-scales are skewed to the right, with means just below 3, and similar standard deviations. That is, students generally agreed that their teachers supported their autonomy, competence, acculturation to science and relatedness. It is interesting to contrast these results to those seen for Parental Support, where the sub-scale for Science Acculturation was skewed to the left. That is, in general, teachers seem to be doing a better job than parents, as it were, at acculturating students to science.

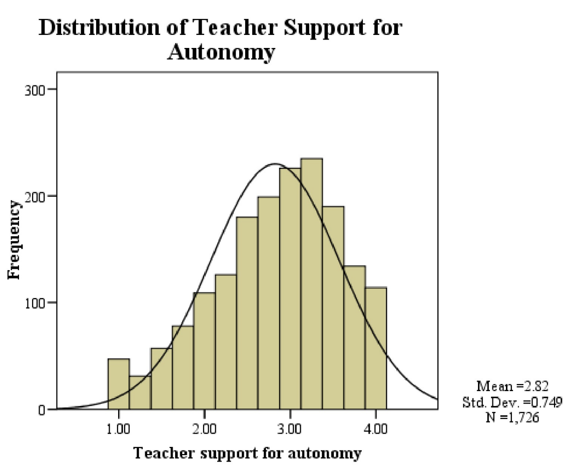

Figure DS6

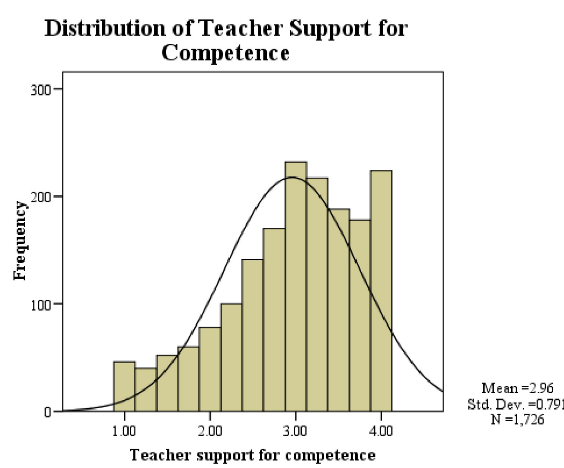

Figure DS7

Results (cont.)

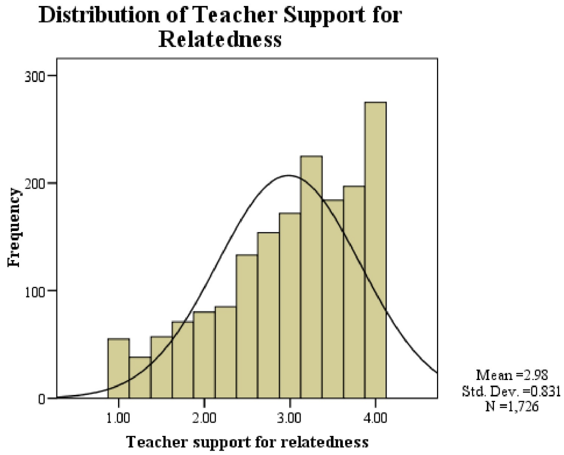

Figure DS8

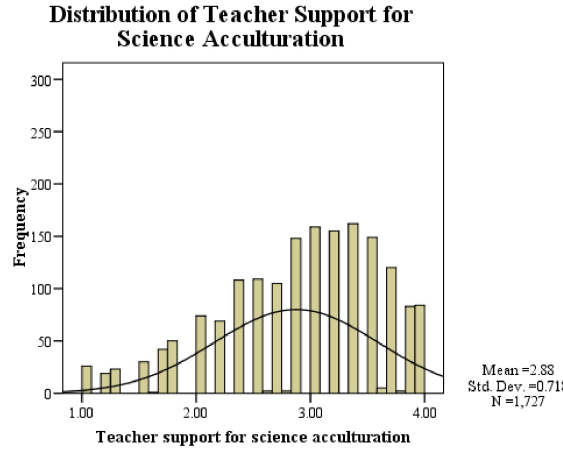

Figure DS9

Examining table DS3 below, we note that although the correlations between the four Teacher Support sub-scales on the one hand, and achievement and perseverance on the other hand, are all statistically significant, all of these correlations are small in absolute value. This indicates that the independent variable of Teacher Support does not exert a strong direct impact on either of the two outcome variables. We do note a weak correlation between Teacher Support for Relatedness and Achievement, and even weaker correlations between Achievement and the other three Teacher Support sub-scales, indicating, not surprisingly, that teacher support does have some impact on student achievement. Aside from the already noted strong correlation between Achievement and Perseverance, we note that there are strong correlations between all four sub-scales of Teacher Support. This would indicate that teachers whom students perceive as supportive of any of science acculturation, autonomy, competence or relatedness, tend to also be perceived as supportive in the other areas.

Table DS3. Correlations between Achievement/Perseverance and Teacher Support for:

(Pear. Corr, Sig., N)	achievement	perseverance	autonomy	competence	relatedness
achievement	1, , 2140				
perseverance	.518**, .000, 1588	1, , 1622			
autonomy	.186**, .000, 1707	.125**, .000, 1358	1, , 1727		
competence	.188**, .000, 1707	.140**, .000, 1358	.736**, .000, 1726	1, , 1726	
relatedness	.198**, .000, 1707	.160**, .000, 1358	.692**, .000, 1726	.821**, .000, 1726	1, , 1726
science acculturation	.182**, .000, 1708	.173**, .000, 1359	.722**, .000, 1726	.672**, .000, 1726	.692**, .000, 1726

** Correlation is significant at the 0.01 level 2-tailed.

Mediating Variables

Academic Emotion: What is most interesting to observe (see graphs below) is the difference in the shapes of the distributions of the three sub-scales, with the negative emotions of Boredom and Anxiety being skewed to the right and the positive emotion of Enjoyment being skewed to the left. That is, students generally reported that they disagreed that they were bored or anxious, but they were more neutral about experiencing enjoyment.

Results (cont.)

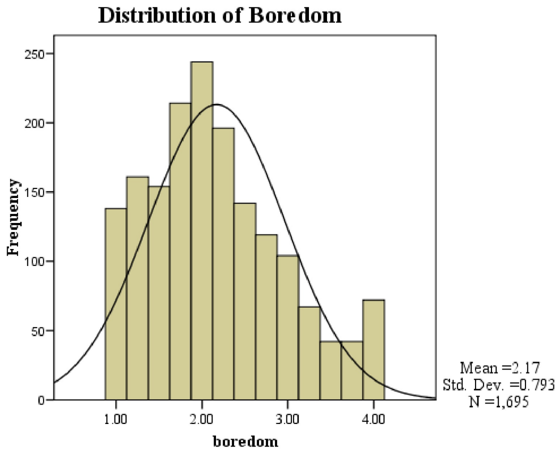

Figure DS10

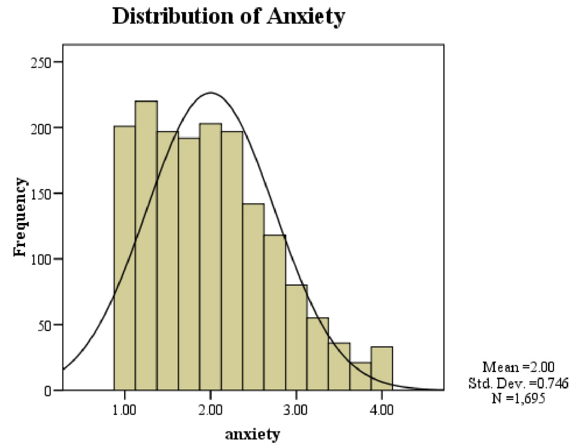

Figure DS11

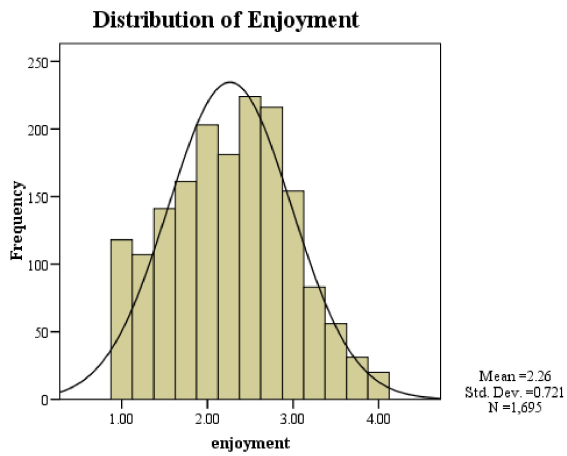

Figure DS12

We note the weak correlations between the sub-scales of Academic Emotions and both of the outcome variables, Achievement and Perseverance. This indicates some direct impact of Academic Emotions on subsequent Achievement and Perseverance. The strong or moderate correlations between the three sub-scales of Academic Emotions indicate that these emotions are tightly bound to each other.

Table DS4. Correlations between Achievement/Perseverance and Academic Emotions

(Pear. Corr, Sig., N)	achievement	perseverance	boredom	anxiety
achievement	1, ,2140			
perseverance	.518**, .000, 1588	1, , 1622		
boredom	-.193**, .000, 1676	-.243**, .000, 1342	1, , 1695	
anxiety	-.218**, .000, 1676	-.241**, .000, 1342	.628**, .000, 1695	1, , 1695
enjoyment	.229**, .000, 1676	.239**, .000, 1342	-.700**, .000, 1695	-.494**, .000, 1695

** Correlation is significant at the 0.01 level (2-tailed).

Motivation and Self-efficacy: We note that in the graphs below we can see that the means of four of the five sub-scales of motivation are a bit to the right of half-way on the 1 (Strongly Disagree) to 4 (Strongly Agree) scale, and the distributions are slightly skewed to the right. That is, on average students tend to agree more or less with the questions concerning motivation. The one exception is the sub-scale concerning Amotiviation, where the mean is 1.60, and the distribution is skewed to the left. That is, on average the students Strongly Disagree/Disagree to questions concerning their being Amotivated. The mean of the final scale, Self-Efficacy, is 3.09 and the distribution is skewed to the right. That is, on average students have reasonably strong feelings of self-efficacy.

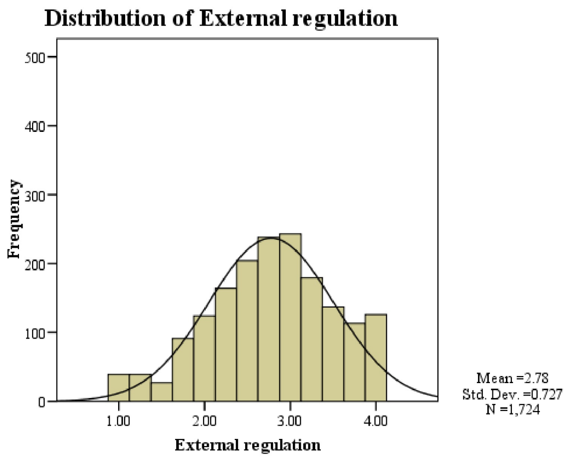

Figure DS13

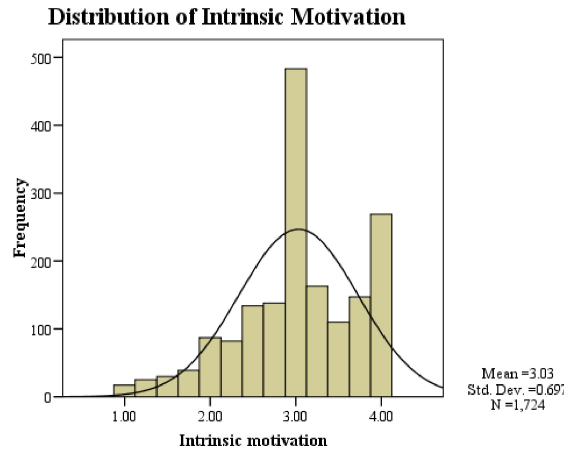

Figure DS14

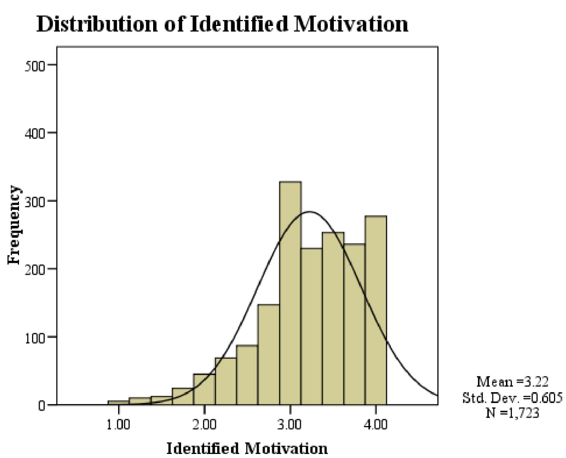

Figure DS15

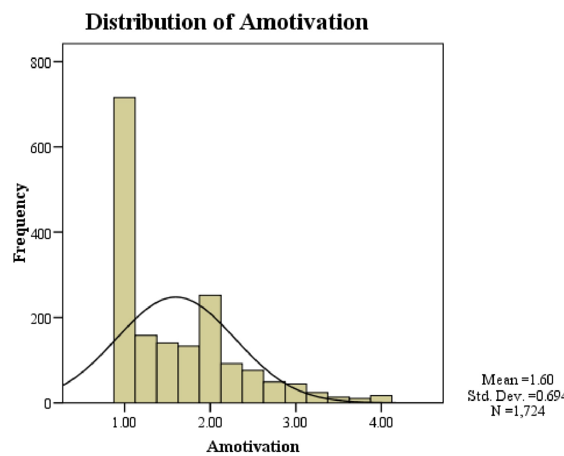

Figure DS16

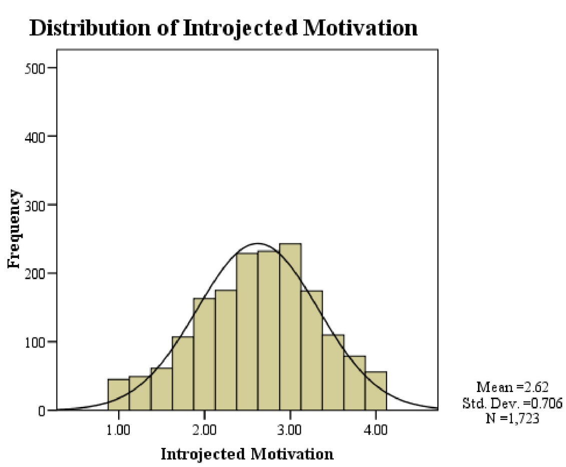

Figure DS17

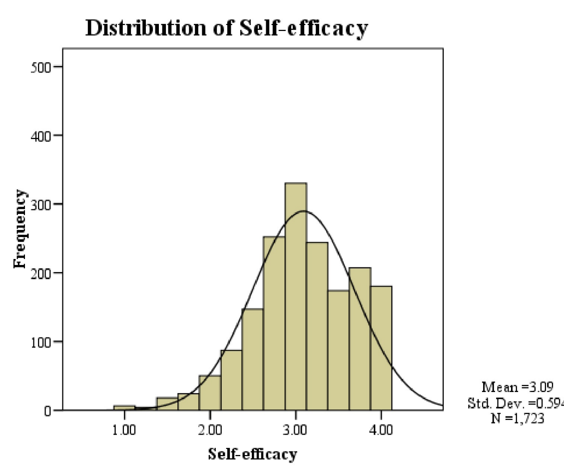

Figure DS18

In table DS5 below we note weak correlations between Achievement and Intrinsic Motivation and Amotivation. This is an indication of some, if not strong, direct impact of these Motivation sub-scales on Achievement. The moderate correlation between Self-efficacy and Achievement indicates a direct link between those two variables. We also note that three of the four sub-scales of Motivation are moderately correlated with Self-efficacy, indicating a link between these mediating variables. Finally, there are strong (or one moderate) correlations between several of the sub-scales of Motivation, all in the anticipated directions.

Table DS5. Correlations between Achievement and Motivation and Self-efficacy

(Pear. Corr, Sig., N)	ach	extr	intr	iden	amot	intrj
ach	1, , 2140					
extr	0.02, .406, 1705	1, , 1724				
intr	.202**, .000, 1705	.053*, .028, 1724	1, , 1724			
iden	.145**, .000, 1704	.305**, .000, 1723	.558**, .000, 1723	1, , 1723		
amot	-.229**, .000, 1705	-.036, .138, 1724	-.591**, .000, 1724	-.530**, .000, 1723	1, , 1724	
intrj	-.029, .235, 1704	.507**, .000, 1723	.177**, .000, 1723	.260**, .000, 1722	-0.011, .643, 1723	1, , 1723
sef	.351**, .000, 1704	.164**, .000, 1723	.478**, .000, 1723	.383**, .000, 1722	-.450**, .000, 1723	135**, .000, 1722

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

ach=Achievement; extr=External regulation; intr=Intrinsic motivation; iden=Identified motivation; amot=Amotivation; intrj=Introjected motivation; and, sef=Self-efficacy

In table DS6 below we note moderate correlations between Perseverance and three of the sub-scales of Motivation, as well as a weak correlation between Perseverance and Self-efficacy. These correlations indicate a moderate link between these mediating variables and Perseverance. The remaining highlighted correlations also appeared in table DS6 and were discussed above.

Table DS6. Correlations between Perseverance and Motivation and Self-efficacy

(Pear. Corr, Sig., N)	pers	extr	intr	iden	amot	intrj
pers	1, , 1622					
extr	.072**, .008, 1357	1, , 1724				
intr	.316**, .000, 1357	.053*, .028, 1724	1, , 1724			
iden	.317**, .000, 1356	.305**, .000, 1723	.558**, .000, 1723	1, , 1723		
amot	-.350**, .000, 1357	-.036, .138, 1724	-.591**, .000, 1724	-.530**, .000, 1723	1, , 1724	
intrj	.049, .071, 1356	.507**, .000, 1723	.177**, .000, 1723	.260**, .000, 1722	-.011, .643, 1723	1, , 1723
sef	.260**, .000, 1356	.164**, .000, 1723	.478**, .000, 1723	.383**, .000, 1722	-.450**, .000, 1723	.135**, .000, 1722

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

pers=Perseverance; extr=External regulation; intr=Intrinsic motivation; iden=Identified motivation; amot=Amotivation; intrj=Introjected motivation; and, sef=Self-efficacy

Outcome Variables

The means and standard deviations of achievement and perseverance are displayed in table DS7 below.

Table DS7

	N	Mean (SD)	Skewness	Std. Error	Kurtosis	Std. Error
achievement	2140	-.0193 (.92277)	-0.695	0.053	0.326	0.106
perseverance	1622	2.71 (1.273)	-0.286	0.061	-1.607	0.121

Given the different grading systems in Quebec and in Sweden, we used z-scores to minimize those differences, and hence equitably assess student achievement. For this reason the mean of achievement is close to zero. Perseverance was assessed on a scale from 1 (very unlikely to continue with science studies at a university) to 4 (very likely to continue science studies at a university). The mean of 2.71 indicates that, on average, students are likely to continue science studies. However, this statistical result alone does not really tell the whole story. As the graph below indicates, the distribution of perseverance has very low kurtosis, and is bimodal, with the modes occurring at the edges. That is, there is a large number of students who are very likely to continue science studies at a university and a fairly large number of students who are very unlikely to follow a similar career path. Note that there is a large number of missing values due to the fact that in the Canadian sample the perseverance data were gathered when we attempted to contact students one year after the original data were collected. It is evident that we have not been able to reach all students who initially participated in this study.

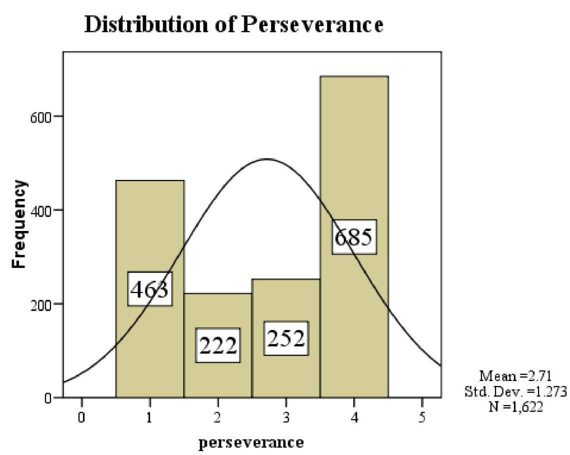

Figure DS19

More Correlations: Correlations between Independent Variables and Mediating Variables

In the several correlation tables seen above we have noted the absence of even weak correlation between the Independent Variables (Cognitive Style, Parental Support and Teacher Support) and the Outcome Variables (Achievement and Perseverance), and commented as to how this indicated not much of a direct link between the two sets of variables. We also noted correlations ranging from weak through moderate to strong between various Mediating Variables (Academic Emotions, Motivation and Self-efficacy) and the Outcome Variables (Achievement and Perseverance). What remains to be examined, seen in table DS8 below, are the correlations between the Independent Variables (Cognitive Style, Parental Support and Teacher Support) and the Mediating Variables (Academic Emotions, Motivation and Self-efficacy) that will explain why we have termed Academic Emotions, Motivation and Self-efficacy as “Mediating”. We note that sub-scales of both Cognitive Style and Teacher Support are weakly or moderately correlated with sub-scales of Academic Emotions, Motivation and Self-efficacy. Parental Support for Science Acculturation is the only sub-scale of Parental Support with even weak correlation to a sub-scale of Academic Emotions and a sub-scale of Motivation. These correlations between Independent and Mediating Variables, and the ones between the Mediating Variables and the Outcome Variables, provided the first hints for the structural model that is discussed in a separate chapter, and of course the source of the term "Mediating".

Table DS8: Correlations between Independent and Mediating Variables

Independent \ Mediating		Academic Emotions			Motivation					Self-efficacy
		bor	anx	enj	extr	intr	iden	amot	intrj	
Parents	autonomy	-.064*	-.107**	-0.035	-.076**	.094**	.086**	-.166**	-.077**	.100**
	competence	-.077**	-.106**	-0.006	-0.044	.139**	.098**	-.178**	-.069**	.144**
	science a.	-.134**	-.139**	.200**	.072**	.223**	.121**	-.157**	0.012	.146**
Teachers	autonomy	-.248**	-.186**	.284**	0.026	.289**	.208**	-.217**	.090**	.281**
	competence	-.204**	-.200**	.216**	0.015	.230**	.186**	-.212**	.057*	.243**
	relatedness	-.183**	-.188**	.193**	-0.011	.217**	.138**	-.214**	.050*	.215**
	science a.	-.283**	-.217**	.280**	-0.021	.321**	.175**	-.260**	0.044	.244**
C. Style	systemizing	-.287**	-.333**	.291**	.074**	.348**	.266**	-.332**	0.031	.350**
	empathizing	-0.03	-.054*	-0.005	.060*	.066**	.126**	-.107**	0.039	.128**

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

bor=Boredom; anx=Anxiety; enj=Enjoyment; extr=External regulation; intr=Intrinsic motivation; iden=Identified motivation; amot=Amotivation; intrj=Introjected motivation; and, science a.=Science acculturation

Comparison Between Quebec and Swedish Populations

Note once again that we used z-scores to assess achievement because of difficulties in comparing two very different assessment systems. In doing so we have assumed that the mean of achievement was the same for the two populations. Thus, in this section we focus on a comparison of the means of Perseverance of Quebec and Swedish students. ANOVA results indicate that Swedish students (mean of Perseverance = 3.080) are significantly more likely to persevere into science studies at a university than their Quebec peers (mean of Perseverance=2.600, $F(1,1620)=42.011$, $p<.001$). Assuming that there might be cultural differences between Quebec and Swedish students, we have also contrasted students' perceptions of Parental Support and Teacher Support, their Motivation and Self-efficacy as well as their Cognitive Style. As Table C1 below indicates, we have determined that while Quebec and Swedish parents do not differ significantly in terms of Parental Support for Competence, Swedish parents are significantly more supportive of students' Autonomy and Science Acculturation. On the other hand, Swedish teachers are perceived as being significantly less supportive of students' Autonomy than their Quebec counterparts, while they are perceived as not being significantly different from Quebec teachers in terms of support for Competence, Relatedness and Science Acculturation. Note that there were no significant differences found in the Cognitive Style of Quebec and Swedish students.

Table C1. Comparison of Perceptions of Parental Support and Teacher Support

	Population	N	Mean	SD	
Parental Support for Autonomy	Quebec	1542	3.137	0.688	$F(1,1985)=24.909$, $p<.001$
	Sweden	445	3.316	0.588	
Parental Support for Science Acculturation	Quebec	1540	2.036	0.664	$F(1,1983)=23.366$, $p<.001$
	Sweden	445	2.212	0.717	
Teacher Support for Autonomy	Quebec	1343	2.886	0.746	$F(1,1724)=44.410$, $p<.001$
	Sweden	383	2.600	0.716	

There are also significant differences between Quebec and Sweden students' Motivation and Self-efficacy. In general, Quebec students are more motivated to study sciences, as readily seen in Table C2. below.

Table C2. Comparison of Students' Motivation and Self-efficacy

	Population	N	Mean	SD	
External Regulation	Quebec	1342	2.825	0.705	$F(1,1722)=26.587$, $p<.001$
	Sweden	382	2.609	0.777	
Intrinsic Motivation	Quebec	1342	3.078	0.64	$F(1,1722)=28.589$, $p<.001$
	Sweden	382	2.864	0.846	
Identified Motivation	Quebec	1341	3.296	0.549	$F(1,1721)=91.358$, $p<.001$
	Sweden	382	2.969	0.716	
Introjected Motivation	Quebec	1341	2.710	0.672	$F(1,1721)=102.503$, $p<.001$
	Sweden	382	2.307	0.732	
Self-efficacy	Quebec	1341	3.158	0.538	$F(1,1721)=81.335$, $p<.001$
	Sweden	382	2.854	0.71	

We also examined whether relationships between Perseverance on the one hand, and Parental Support, Teacher Support, Cognitive Style, Academic Emotions, Motivation and Self-efficacy on the other hand, are different for the two populations. Table C3. below shows the coefficients of correlation of all of these variables with Perseverance. We note that Perseverance does not really correlate with Parental or Teacher Support in the Canadian population. In contrast, Perseverance correlates weakly with Parental and Teacher Support for Science Acculturation in the Swedish population. In addition, Perseverance moderately correlates with Systemizing Cognitive Style in the Swedish population, but not in the Quebec population. When we examined the correlations between Perseverance and Academic Emotions, we found similar patterns in both populations, *e.g.,* Boredom and Anxiety correlate negatively, while Enjoyment correlates positively with Perseverance. All correlations between Academic Emotions and Perseverance are weak in the Quebec population, while Boredom and Enjoyment correlate moderately with Perseverance amongst the Swedes. As for the Motivational sub-scales, we observe that External Regulation and Introjected Motivation do not correlate with Perseverance in either of the two populations. Intrinsic and Identified Motivation correlate weakly with Perseverance in the Quebec population but correlate strongly with Perseverance in the Swedish population. Amotivation correlates negatively with Perseverance in both populations, but the magnitude of the coefficient of correlation differs. Self-efficacy correlates positively with Perseverance in both populations, but again the magnitude of the coefficient of correlation is different. In all three cases, the correlation is stronger in the Swedish population.

Table C3. Differences in Relationships: Correlations with Perseverance

	Correlation			Correlation	
Variable \ Population	Quebec	Sweden	Variable \ Population	Quebec	Sweden
Parental support for autonomy	0.022	0.053	Boredom	-.225**	-.338**
Parental support for competence	.091**	0.095	Anxiety	-.236**	-.258**
Parental support for science acculturation	0.04	.201**	Enjoyment	.220**	.359**
Teacher support for autonomy	.136**	.146**	External regulation	0.038	.215**
Teacher support for competence	.135**	.187**	Intrinsic motivation	.270**	.507**
Teacher support for relatedness	.154**	.180**	Identified motivation	.282**	.530**
Teacher support for science acculturation	.167**	.213**	Amotivation	-.314**	-.472**
Systemizing	.126**	.346**	Introjected motivation	0.051	.117*
Empathizing	-0.037	-0.01	Self-efficacy	.261**	.369**

Gender Differences

We have examined gender differences in Achievement and Perseverance. ANOVA results indicate that female students' academic performance (mean of Achievement = -.045) is not significantly different from the academic performance of male students (mean of Achievement =.004, $F(1,2138)=1.472$, $p=.225$). On the other hand, male students are significantly more likely to persevere (mean of Perseverance=2.817) in science studies at a university than their female peers (mean of Perseverance=2.604, $F(1,1620)=11.437$, $p=.001$). The graph below shows the distribution of Perseverance. This graph highlights the fact that many more males are **certain** to continue with science studies at a university than their female peers.

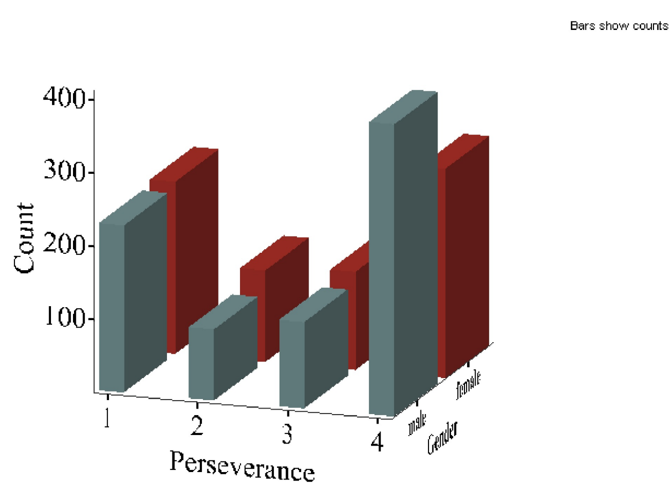

Figure G1

We also examined gender differences in students' perceptions of Parental Support, Teacher Support and Cognitive Style. Table G1. (below) shows only those variables that are significantly different. Female students perceive their parents as being more supportive of their competence. Importantly, female students are significantly less likely to be systemizers than their male peers. Note that the "persevering males" or "persevering females" are those students who stated that they were "Very Likely" to continue in science studies at a university, while their "not persevering" peers are those students who stated that they were "Very Unlikely" to continue in science studies at a university. The size of the *F* value indicates the strength of the differences in Systemizing. In contrast, while females are significantly more likely to be empathizers than their male peers, the size of the *F* value is much reduced.

Table G1. Comparison of Perceptions of Parental Support and Cognitive Style

		N	Mean	SD	
Parental Support for Competence	all females	962	3.360	0.607	$F(1,1985)=15.433$, $p<.001$
	all males	1025	3.253	0.61	
Systemizing	all females	828	2.826	0.426	$F(1,1719)=271.691$, $p<.001$
	all males	893	3.176	0.452	
	persevering females	272	2.88	0.44	$F(1,651)=117.261$, $p<.001$
	persevering males	381	3.255	0.439	
	not persevering females	126	2.763	0.418	$F(1,247)=31.835$, $p<.001$
	not persevering males	123	3.076	0.458	
Empathizing	all females	820	3.084	0.501	$F(1,1707)=14.040$, $p<.001$
	all males	889	2.989	0.543	

In table G1 above we saw that there were significant difference between the means of Systemizing and Empathizing for male and female students. However, in the case of Systemizing there is also a visible difference in the distributions of this variable. (Note: The statistical software package, SPSS, which was used to generate all statistics and graphs in this report does not allow the user to control the number of bars appearing on the *x*-axis in histograms. As a result, the reader should not allow themselves to be fooled by SPSS created visual differences in height and width of bars when comparing such graphs. Nevertheless, a careful observer can see real differences in the shapes of distributions.) We note that in figures G2 and G3 below, the male distribution is skewed to the right while the female distribution is shaped more symmetrically.

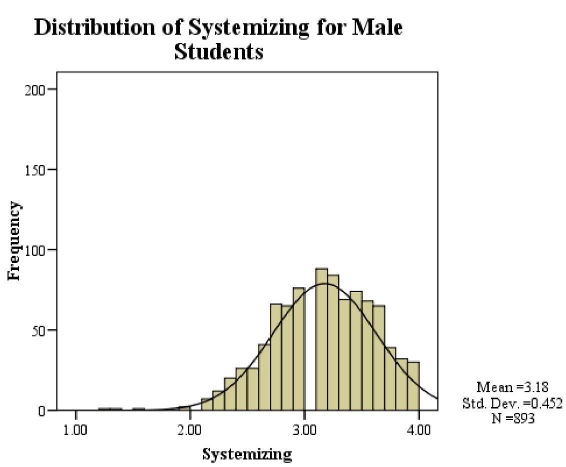

Figure G2

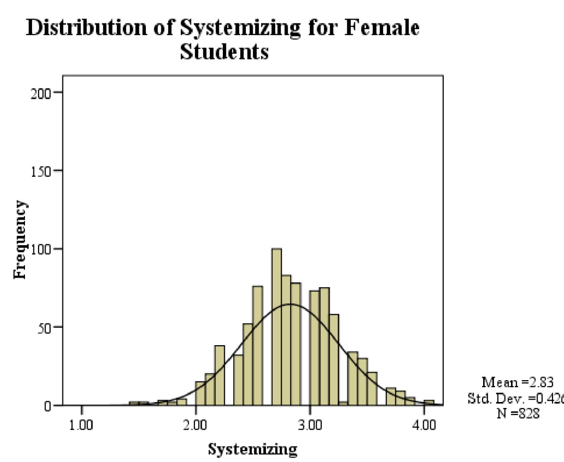

Figure G3

Note further how when we restrict the population to only those students who were "Very Likely" to persevere, as in figures G4 and G5 below, the difference in the distributions seems even more pronounced. In part these differences may be due to the fact that the majority of male students either agree or agree strongly on items in the Systemizing sub-scale, while amongst female students there is a sizable group who disagree.

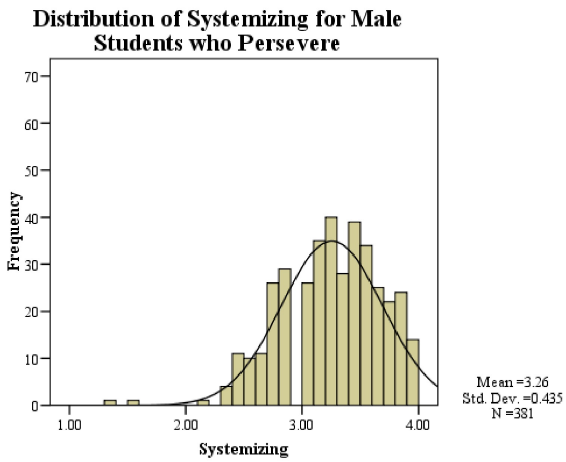

Figure G4

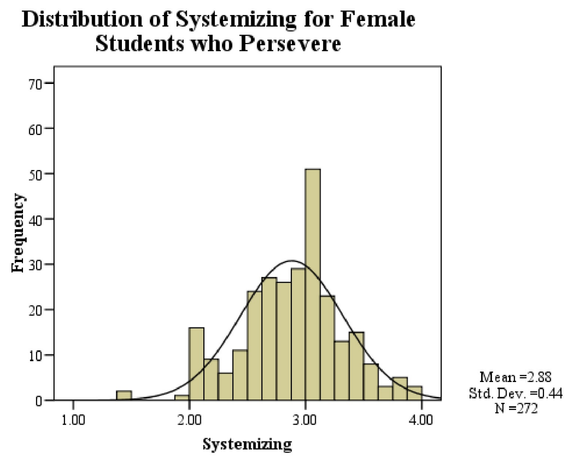

Figure G5

In the case of the variable Empathising, there is no such difference visible in the distributions.

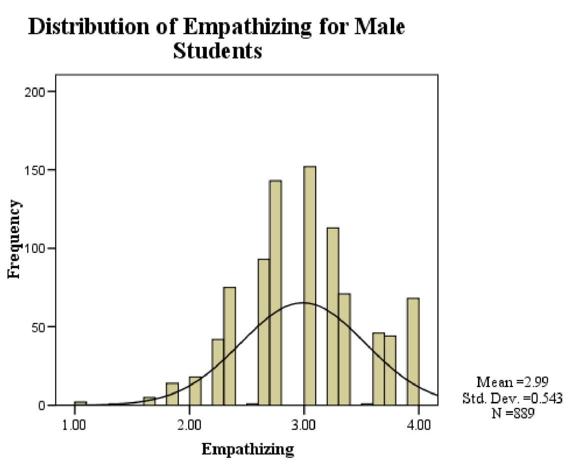

Figure G6

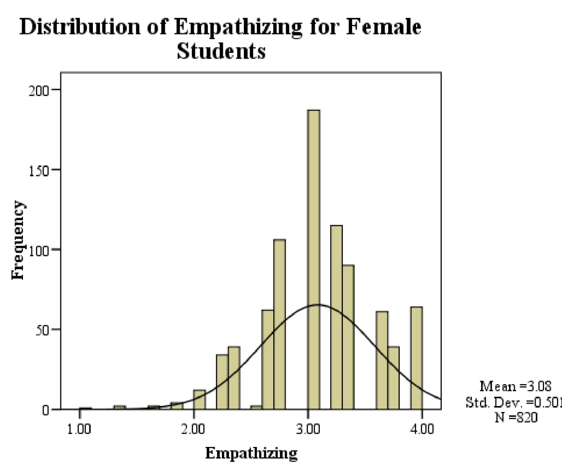

Figure G7

In table G2. below we list the correlations between Perseverance on the one hand, and Parental Support, Teacher Support, Cognitive Style, Academic Emotion, Motivation and Self-efficacy on the other hand. Amongst the Independent Variables, the only two correlations that are worth reporting are weak correlations, for males only, between Teacher Support for Science Acculturation and Perseverance as well as between Systemizing and Perseverance. The weak negative correlations between Perseverance and two Academic Emotion sub-scales are stronger for males than for females, indicating that Boredom and Anxiety have a stronger impact on males than on females. The pattern of correlations between Perseverance and the Motivation sub-scales is more complex. The weak correlation between Perseverance and Enjoyment is positive for both males and females, but slightly stronger for males. The correlation between Perseverance and Intrinsic motivation is moderate for females but only weak for males. The correlations between

Perseverance on the one hand, and Identified and Amotivation on the other hand, is moderate for both males and females. Finally, the correlation between Perseverance and Self-efficacy is weak for both males and females.

Table G2. Differences in Relationships: Correlations with Perseverance

Variable		Correlations: female	Correlations: male	Variable		Correlations: female	Correlations: male
Parental Support for	Autonomy	0.054	0.046	Academic Emotions	Boredom	-.208**	-.257**
	Competence	.114**	.118**		Anxiety	-.191**	-.264**
	Science Acculturation	.084*	.077*	Motivation	Enjoyment	.215**	.236**
Teacher Support for	Autonomy	.168**	.188**		External Regulation	0.048	.076*
	Competence	.124**	.132**		Intrinsic	.353**	.288**
	Relatedness	.104**	.175**		Identified	.313**	.333**
	Science Acculturation	.123**	.202**		Amotivation	-.359**	-.349**
Cognitive Style	Systemizing	.115**	.195**		Introjected	0.054	0.056
	Empathizing	-0.066	0.02	Self-efficacy		.240**	.260**

The results summarized in the section above are mostly descriptive, and examine two-way relationships between the various variables measured in this study. In the last few chapters below we present our first attempts at studying multivariate relationships by using Structural Equation Modelling (SEM). We are currently testing more complex models, and the results of that work will be submitted for publication when completed.

Discussion and Conclusions

In this section the results that have been reported in the section above are discussed, following the same organizing principle that was used in **Results**.

Validation

In the course of this research we have adapted many well-known scales. These adaptations have taken two forms: to make the scale more accurately reflect the context of mathematics and science education; to reduce the number of items per scale. We note that the validation process leads us to conclude that the scales that we eventually used retained their internal consistency and were confirmed using CFA. We should point out that in the case of the Systemizing sub-scale of Cognitive Style we reduced the number of items from 75 to 9, a dramatic reduction in scale size. This reduced scale has satisfactory internal consistency, but does not have as good psychometric properties as the other instruments used in this study. We intend to continue refining this scale. In addition, we developed two new scales: Parental Support for Science Acculturation; Teacher Support for Science Acculturation. Both scales proved to be internally consistent and were confirmed using CFA. Consequently we are confident that the data collected in this research are meaningful.

Independent Variables

Systemizing: The average value of Systemizing within this population is 3.01, which lies above the neutral point of 2.5 on this scale. This agrees with the result of Billington *et al*. (2007), who found that the majority of STEM students are Systemizers. We note that these authors were examining a population of students who were already attending a university. In our case, both in Quebec and Sweden, the students are not yet attending a university, and as we note elsewhere, many of them are unlikely to be STEM students at a university. This would tend to both lower the average Systemizing score and possibly inflate the Empathizing score.

It is important to note that the results on Systemizing for Quebec and Sweden were virtually identical (Quebec mean = 3.003, SD = .458; Swedish mean = 3.022, SD = .523). We also note that the results for Empathizing are also virtually identical (Quebec mean = 3.029, SD = .516; Swedish mean = 3.054, SD = .556). These results support the notion of Baron-Cohen that Cognitive Style is a basic characteristic of human brain function, and that any national cultural differences in Cognitive Style are minuscule compared to differences between professions.

A third result concerning Cognitive Style that is worth discussing is the differences in scores on both sub-scales across gender. That is, when we compare the distribution of Systemizing in males (mean = 3.176, SD = 0.452) to that in females (mean = 2.826, SD = 0.426), we note that the distributions are remarkably dissimilar in shape, with the one for males significantly shifted to the right ($F(1,1719) = 271.691$, $p < .001$) and skewed. That is, a higher percentage of the males in our sample are high systemizers compared to their female peers. Of course, when we compare the distribution of Empathizing in males (mean = 2.989, SD = 0.543) to that in females (mean = 3.084, SD = 0.501), we note that this time both distributions are skewed, in fact remarkably similar in shape, but here the distribution for females is significantly shifted to the right ($F(1,1707) = 14.040$, $p < .001$), albeit much less shifted than was the case for Systemizing. Interestingly, when we examined only those students who are “Very Likely” to attend a university STEM program, the visible difference between the distributions grows larger, with the distribution for males being stacked up at the right edge, where the distribution for females is still roughly symmetric ($F(1,651)=117.261$, $p<.001$). Note that the F value is smaller in large part because the sample size decreased due to the restriction imposed by choice of persevering students.

Empathizing does not seem to correlate with any other variable that we have measured. However, Systemizing correlates weakly with Perseverance, explaining approximately 3% of variance in Perseverance. Systemizing has a stronger impact on the Academic Emotions of students, explaining approximately 10% of variance. We would speculate that students who are used to using this cognitive style in their everyday life feel more at ease in science classrooms, where the tasks often involve discovering patterns and laws that govern the world of inanimate objects. Consequently, it is likely that they enjoy themselves more, feel less anxiety and are less bored than their peers who are more comfortable with empathizing. One of the reasons that the correlation between Systemizing and Boredom cannot be much higher is that both high and low Systemizers are likely to experience boredom, but for very different reasons. High Systemizers are bored when the task they face is not sufficiently challenging, where low Systemizers are bored because the very nature of the task that they face is uncomfortable. One would anticipate that high Systemizers would tend to enjoy themselves in science classrooms, more so than their low systemizing peers. However, enjoyment is dependent upon many other variables as well. Thus, the univariate approach of examining correlations fails us to some extent. In future work that is planned but not yet carried out we will use multivariate approaches that may be more successful in mapping the relationships between these variables.

Systemizers are probably used to performing the types of tasks faced in science classrooms, having done so from their childhood. As a result, they are much more likely than their non-systemizing peers to have confidence in their ability to perform such tasks, leading to higher feelings of self-efficacy. This then would explain the moderate correlation between Systemizing and Self-efficacy, that explains about 12% of the variation in Self-efficacy.

Parental Support: Parental support for autonomy and competence correlate moderately, meaning that parents who support their children's independence are also likely be increasing their children's belief in their own competence. We noted that Swedish parents are more supportive in both of these areas. Note that parental support for autonomy and competence is a general notion, inherent in good parenting. Thus, it is not particularly surprising that these sub-scales are not related to Support for Science Acculturation. We note that Parental Support does not correlate with Achievement and Perseverance. This is in contrast to the results of Larose *et al*., (2006), who found that Parental Support for Science Acculturation explained 3% of the variance in the perseverance of engineering students at Laval University. However, we found that Parental Support for Science Acculturation explained 4% of the variance in Enjoyment and 5% of the variance in Intrinsic Motivation. Some of this difference in finding may be related to the differences in ages of our population and that of Larose. While Larose did not measure our mediating variables, it is possible that Enjoyment and Intrinsic Motivation play a larger role in the perseverance of University students, hence paradoxically strengthening the influence of parents on student perseverance as they move from CEGEP to university. This is an interesting notion that will require further investigation.

Teacher Support: All of the Teacher Support sub-scales have high correlation with each other, explaining 45% or more of the variation in each other. We interpret this as suggesting that teachers who support (or don't support) one of the four aspects measured, tend strongly to support (or not support) the other aspects as well. From the student perspective, examining the distributions of the four sub-scales, we note that in Competence and Relatedness, the distributions were skewed to the right. In other words, many more students perceive their teachers as being very supportive of their competence and relatedness. In the case of Autonomy and Science Acculturation, fewer students perceive their teachers as being very supportive of these aspects. In the case of Autonomy, this lessening of "very supportive" is even more pronounced amongst Swedish teachers as opposed to their Quebec counterparts. Autonomy and Science Acculturation are important because they correlate with students Intrinsic Motivation and Self-efficacy. In addition, since Parental Support for Science Acculturation is low, their science teachers may be the most important venue through which students acquire some attachment to science culture. Surprisingly, we see that Teacher Support does not even correlate weakly with Achievement and Perseverance. This means that Teacher Support does not have a direct impact on Achievement and Perseverance, however, it does have indirect impact through Motivation as we have pointed out above.

Mediating Variables: While it is fortunate that students generally disagree that they are bored or anxious, unfortunately they also disagree that they enjoy science studies. Boredom, Anxiety and Enjoyment all correlate with Achievement and Perseverance. Thus, low Enjoyment has a direct impact on Achievement and Perseverance.

We note also that the distributions of Intrinsic Motivation and Identified Motivation are skewed to the right, while the distribution of Amotivation is very skewed to the left. This tells us that there are a large number of students who are telling us that they are studying science because they like doing so, or because they believe it to be good for them. Intrinsic Motivation is weakly positively correlated to Achievement, but both Intrinsic and Identified Motivation are moderately correlated to Perseverance. That is, highly intrinsically motivated students are more likely to be high achievers and to persevere, while students who score highly on Identified Motivation are generally more likely to persevere, but not necessarily to be high achievers. Over half of the population is strongly disagreeing that they are amotivated. This finding is probably related to the fact that these students are either in a transition year in Quebec, switching from high school to CEGEP, where they have chosen to study science, or in the last year of high school in Sweden, where they have chosen to take advanced courses preparing them for science studies at a university. It is very unlikely that highly amotivated students in either location would have made these choices.

Self-efficacy has a moderate correlation with Achievement and a weak correlation with Perseverance. We note that female students have significantly lower Self-efficacy than their male counterparts. Other studies have reported similar findings of lower Self-efficacy in females in science and mathematics. However, the correlation of Self-efficacy with Achievement and with Perseverance is similar for male and female students. Thus, the lower Self-efficacy of females may partially explain their lower Perseverance.

Unfortunately due to the differences between grading systems in Quebec and Sweden we were forced to assume that the mean grade in the two populations was the same so that we could create a variable called Achievement using z-scores, and then assume that one standard deviation above the mean has the same meaning in each population. These assumptions do not explain away the result that in both populations female students had the same Achievement as male students. Although Achievement strongly correlates with Perseverance, explaining more that 25% of the variance, it does not explain why Perseverance amongst females is significantly lower than that of their male counterparts. In figure G1 in the Results section above (page 38) we note that the visible difference between the female and male distributions for Perseverance is that the males have a much larger clump of students who are “Very Likely” to continue on in science studies at a university. We also note that at this stage when we asked the students about their university plans, very few students, male or female, fell into the “Unlikely” or “Likely” categories, with most falling into “Very Unlikely” or “Very Likely”. That is, by and large most students had made up their minds at this point. This means that although the variable Perseverance is based on statements by students concerning future intentions, by and large those intentions appear to be solid.

Bibliography

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D. & Wieman, C. E. (2006). A new instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey. *Physics Review Special Topics - Physics Education Research*, 2, 010101-1-010101-14.

Aldridge, J., Taylor, P., & Chen, C.-C. (1997). *Development, Validation and use of the Beliefs About Science and School Science Questionnaire*. Paper presented at the National Association for Research in Science Teaching, Chicago, IL.

Arons, A. (1993). *A Guide to Introductory Physics Teaching.* New York: John Wiley and Sons, Inc..

Astin, A. & Astin, H. (1993). *Undergraduate science education: The impact of different college environments and the educational pipeline in the colleges*. Los Angeles, CA:Higher Educational Research Institute, U.C.L.A.

Baillargeon, G., Demers, M., Ducharme, P., Foucault, D., Lavigne, J., Lespérance, A., Lavallée, S., Ristic, B., Sylvain, G. & Vigneault, A. (2001). *Education Indicators, 2001 edition*. Québec City: Ministère de l'Éducation, Gouvernement du Québec.

Bandura, A. (1986). *Social Foundation of Thought and Action: A Social Cognitive Theory.* Englewood Cliffs, N.J.: Prentice-Hall.

Bandura, A. (1997). *The Self-efficacy: The Exercis of Control.* New York Freeman Press.
Bar-On, R. (2006). The Bar-On model of emotional-social intelligence (ESI). *Psicothema,* 18, suppl., 13-25.

Baron-Cohen, S. (2002). The Extreme Brain Theory of Autism. *Trends in Cognitive Sciences*, 6(6), 248-254.

Black, A. E. & Deci, E. L. (2000). The Effects of Instructors' Autonomy Support and Students' Autonomous Motivation on Learning Organic Chemistry: Self-Determination Perspective. *Science Education, 84*, 6, 740-766.

Bransford, J. D., Brown A. L. & Cocking, R. R. (1999). *How people learn: brain, mind, experience, and school.* Nat. Acad. Press., 346 p.

Commission d'évaluation de l'enseignement collégial (2004). *L'évaluation des plans d'aide à la réussite des collèges.* Rapport sythèse, Québec, Gouvernement du Québec.

Daempfle, P. A. (2003). An analysis of the high attrition rates among first year college science, math and engineering majors. *Journal of College Student Retention, 5*, 1, 37-52.

Davis, F. & Steiger, A. (1996). *Gender and Persistence in the Sciences*. A final report submitted to PAREA, Gouvernement du Québec.
Deci, E., & Ryan, R. (1985). *Intrinsic Motivation and Self-determination in human Behavior.* New York: Plenum.

Deci, E., Koestner, R., & Ryan, R. M. (1999). A Metaanalysis Review of Experiments Examining the Effects of Extrinsic Rewards on Intrinsic Motivation. *Psychological Bulletin, 125,* 627-668.

Deci, E., Koestner, R., & Ryan, R. M. (2001). Extrinsic Rewards and Intrinsic Motivation in Education: Reconsidered Once Again. *Review of Educational Research, 71,* 1*,* 1-27.

Deci, E., & Ryan, R.M. (2000). The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Inquiry, 11,* 4, 227-268.

Dedic, H., Rosenfield, S., Alalouf, E. & Klasa, J. (2004). *Calculus and Computer-supported Collaborative Learning*. Final report submitted to PAREA. ISBN 2-9211024-64-0

Dedic, H., Rosenfield, S., Simon, R., Ivanov, I., & Rosenfield, E. (2006). *A Motivational Model of Post-Secondary Science Student: Achievement and Persistence*. A paper submitted to the annual meeting of American Educational Association, Chicago, USA.

Dedic, H. Rosenfield, S. & Abrami, P. C. (in preparation) Factors Influencing Students' Persistence in Sciences.

Duchesne, L., Bégin, M., Boisvert, C., Riopel, P., Deraiche, M., Fiset, L., Quellet, P., Fortin, A., Demers M. & Couillard,, V. (2001). *Québec Policy on Science and Innovation: Knowledge to Change the World.* Québec City : Ministère de la Science et de la Technologie, ISBN: 2-550-380059-2.

Elby, A. (2001). Helping physics students learn about learning. *American Journal of Physics, 69,* 1-14.

Fédération des cégeps, (1999). *La réussite et la diplomation au collégial: des chiffres et des engagements.* Montreal, Fédération des cégeps, 114 p.

Filak, V. F., & Sheldon, K. M. (2003). Student Psychological Need Satisfaction and College Teacher-Course Evaluation. *Educational Psychology, 23(3)*, 235-247.

Furrer, C. & Skinner, E. (2003). Sense of Relatedness as a Factor in Children's Academic Engagement and Performance. *Journal of Educational Psychology,* 95, 148-162.

George, R. & Kaplan, D. (1997). A Structural Model of Parent and Teacher Influences on Science Attitudes of Eight Graders: Evidence from NELS: 88. *Science Education,* 82, 93-108.

Godin, B. (1999). *Les usages sociaux de la culture scientifique.* Québec: Presses de l'Université Laval.

Hake, R. R. (1998). Interactive-engagement vs. traditional methods: A six-thousand-students survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66,* 1, 64-74.

Halloun, I., Hestenes, D. (1998). Interpreting VASS Dimensions and Profiles for Physics Students. *Science and Education, 7,* 6, 553-577.

Hammer, D. (2000). Student Resources for Learning Introductory Physics. *American Journal of Physics,* 68, S52-S59.

Kardash, C. A. & Wallace, M. L. (2001). The perceptions of science classes Survey: What undergraduate science reform efforts really need to address*, Journal of Educational Psychology*, *93,1*, 199-210.

Kember, D. (1997). A reconceptualisation of the research into university academics' conceptions of teaching. *Learning and Instruction*, 7(3), 255-275.

Klem, A. M. & Connell, J. P. (2004). Relationships Matter: Linking Teacher Support to Student Engagement and Achievement. *Journal of School Health*, *74,* 7, 262-273.

Kubanek, A. M. & Waller, M. (1996). *Confidence in Science: Interpersonal and Institutional Differences.* Rapport de recherche, Montreal, John Abbott College.

Larose, S., Guay, F., Senécal, C., Harvey, M., Drouin, E. & Delisle, M.-N. (2006). *Le rôle de la culture, motivation et socialisation scientifiques.* Rapport de recherche. Québec. Université de Laval.

Levesque, C., Zuehlke, A. N., Stanek, L. R. & Ryan, R. M. (2004). Autonomy and Competence in German and American University Students: A Comparative Study Based on Self-Determination Theory. *Journal of Educational Psychology, 96,* 1, 68-84.

Mazur, E. (1997). *Peer Instruction: A User's Manual.* Prentice-Hall, Upper Saddle River, NJ.

Meyer, D., Turner, J. (2002) Discovering Emotion in Classroom Motivation Research. *Educational Psychologist* 37:2, 107-114

Nelson, G. (2001). Choosing Content That's Worth Knowing. *Educational Leadership, 59* (2), 12-16.

Op't Eynde, P. & De Corte, E. (2003). *Students' mathematics-related belief systems: Design and analysis of a questionnaire*. Paper presented at the Annual Meeting of the American Educational Research Association: Chicago, IL.

Pajares, F. & Miller, M. D. (1995). Mathematics Self-efficacy and Mathematics Performance: The Need for Specificity of Assessment. *Journal of Counseling Psychology, 42(2)*, 1-9.

Pajares, F. (1996). Self-efficacy Beliefs in Academic Settings. *Review of Educational Research*, 66, 543-578.

Pajares, F. (2002). Gender and Perceived Self-efficacy in Self-regulated Learning. *Theory Into Practice*, *41(2),* 116-125.

Parker, L. H., Rennie, L. J. & Harding, J. (1995). Gender Equity. In B. J. Fraser & H. J. Walberg (Eds.), *Improving Science Education*. (pp. 186-210), Chicago: National Society For The Study of Education.

Paulson, S. E., Marchant, G. J. & Rothlisberg, B. A. (1994). *Constructs underlying students' perceptions of parents, teachers, and schools.* Paper presented at the Midwestern Educational Research Association, Chicago.

Pekrun, R., Goetz, T., Titz, W. & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational Psychologist, 37*(2), 91-105.

Pelletier, L. G., Seguin-Levesque, C., & Legualt, L. (2002). Pressure From Above and Pressure From Below as Determinants of Teachers' Motivation and Teaching Behaviours. *Journal of Educational Psychology, 94(1)*, 186-196.

Perkins, K. K., Adams, W. K., Pollock, S. J., Finkelstein N. D. & Wieman, C. E. (2004). Correlating Student Beliefs With Student Learning Using the Colorado Learning Attitudes about Science Survey. http://cosmos.colorado.edu/CLASS/Perkins_PERC_revisedfinal.pdf Accessed February, 28, 2010.

Pintrich, P. R., Smith D. A. F., Garcia, T. & McKeachie, W. J. (1991). *A Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ).* Ann Arbor, MI: National Center for Research to Improve Postsecondary Teaching and Learning.

Pintrich, P. R. (2003). A Motivational Science Perspective on the Role of Student Motivation in Learning and Teaching Contexts. *Journal of Educational Psychology, 95(4)*, 667-686.

Pollock, S. (2004). No Single Cause: Learning Gains, Student Attitudes, and the Impacts of Multiple Effective Reforms. http://www.colorado.edu/physics/EducationIssues/pollock/pollock_PERC_sum04_draft.pdf Accessed February,28, 2010.

Pritchard, M. E., & Wilson, G. (2003). Using emotional and social factors to predict student success. *Journal of College Student Development, 44,* 18-27.

Ratelle, C. F., Guay, F., Larose, S. & Senécal, C. (2004). Family Corelates of Trajectories of Academic Motivation during a School Transition: A Series of Parametric Group-based Approach. *Journal of Educational Psychology, 96,* 4, 743-754.

Ratelle, C. F., Larose, S., Guay, F. & Senécal, C. (2005). Perceptions of Parental Involvement and Support as Predictors of College Students Persistence in Science Curriculum. *Journal of Family Psychology, 19*, 2, 286-293.

Redish, E. F., Saul, J. M., & Steinberg, R. N. (1998). Student expectations in introductory physics. *American Journal of Physics, 66*, 212-224.

Redish, E. F. (1999). Millikan Lecture 1998: Building a Science of Teaching Physics. *American Journal of Physics*, *67*, 7, 562-573.

Redish, E. F. (2003). *Teaching Physics with Physics Suite.* John Wiley & Sons, 232 p.

Reynolds, A. J. & Walberg, H. J. (1992). A Structural Model of Science Achievement and Attitude: An Extension of High School. *Journal of Educational Psychology,* 84, 371-382.

Robinson, C. C., Mandleco, B. L., Frost Olsen, S., Bancroft-Andrews, C., McNeally, M. K. & Nelson, L. (1995). *Authoritative, authoritarian, and permissive parenting practices. Psychometric support for a new measure.* Paper preseented at the Biennial Meeting of the Society for Research in Child Development, Indianopolis, IN.

Rosenfield, S., Dedic, H., Dickie, L. O., Rosenfield, E., Aulls, M., Koestner, R., Krishtalka, A., Milkman, K. & Abrami, P. (2005, October). *Étude des facteurs aptes à influencer la réussite et la rétention dans les programmes de sciences aux cégeps anglophones.* Rapport de recherche, (FQRSC Action Concertée Grant 2003-PRS-89553.). Montréal: Vanier College.

Roy, J. Mainguy, N., Gauthier, M. & Giroux, L. (2005). *Étude comparée sur la réussite scolaire en milieu collégial selon une approch d'écologie sociale*. Rapport de recherche. Cegep de Sainte-Foy, Québec, ISBN: 2-921299-59-3

Ryan, R. M. (1982). Control and Information in the Intrapersonal Sphere: An Extension of Cognitive Evaluation Theory. *Journal of Personality and Social Psychology, 43,* 450-461.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology,* 25, 54-67.

Schunk, D. H., & Pajares, F., (2001). *The Development of Academic Self-efficacy.* In Wigfield, A., & Eccles, J., (Eds) *Development of Achievement Motivation.* San Diego: Academic Press, USA.

Sheldon, K. M., Elliot, A. J., Kim, Y. & Kasser, T. (2001). What's satisfying about satisfying events? Comparing ten candidate psychological needs. *Journal of Personality and Social Psychology, 80,* 325-339.

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences.* Boulder, CO: Westview Press.

Tinto, V. (1997). Classrooms as communities: Exploring the educational character of student persistence. *Journal of Higher Education*, *68(6)*, 599-623.

Tobias, S. (1990). *They're Not Dumb, They're Different*. Tucson, AZ. Research Corporation.

Uhl, J. (2000). Following Descartes' advice and teaching to the gut. AMS/MAA Joint Mathematics Meetings, Washington, DC.

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Brière, N. M., Senécal, C. B. & Vallières, E. F. (1992). The Academic Motivation Scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and Psychological Measurement*, *52*, 1003-1019.

Vansteenkiste, M., Simons, J., Lens, W., Sheldon, K. M. & Deci, E. L. (2004). Motivating Learning, Performance, and Persistence: The Synergistic Effects of Intrinsic Goal Contents and Autonomy-Supportive Contexts. *Journal of Personality and Social Psychology, 87,* 2, 246-260.

Wieman, C. E. (2007). *A new model for post-secondary education, the Optimized University*. http://www.cwsei.ubc.ca/about/BCCampus2020_Wieman_think_piece.pdf Accessed March 1, 2010.

Appendix A

Model of How Cognitive Style Impacts Differentially by Gender on Achievement and Perseverance in STEM Studies.[1]

by

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Abstract

There is both a gender gap and a decline in enrollment in STEM studies in most Western countries. To better understand this phenomenon we have investigated relationships between cognitive style, learning anxiety, intrinsic motivation and self-efficacy, and achievement and perseverance in mathematics and science courses. Research suggests that systemizing is one of the two major cognitive styles people use in their reasoning. Systemizing is defined as the yearning to analyse systems. Québec and Swedish students (N = 980) participated in this study. Using SEM, our model shows that students with low scores on systemizing, a disproportionate number of whom are female, are likely to experience higher anxiety and lower intrinsic motivation, and hence lower perseverance than their high systemizing peers. Reversing the STEM studies gender gap and the overall decline in STEM studies may require pedagogy for learning science that has been designed specifically to aid low systemizers.

Introduction

Evidence indicates that enrollment in science/technology/engineering/mathematics (STEM) studies is declining in North America and Europe (OECD, 2006), presenting a serious problem. Barack Obama has pointed out that success in educating more scientists and engineers, the next generation of innovators, is necessary to drive a successful US economy in this century. In addition, there has been a persistent gender gap in the pursuit of STEM studies (*e.g.*, NSF, 2004), despite women being the majority of university students in the western world. There is evidence that any gender gap in mathematics and science achievement may already have disappeared or even reversed (Xiu & Shauman, 2003; Rosenfield, S., Dedic, H., Dickie, L. O., Rosenfield, E., Aulls, M., Koestner, R., Krishtalka, A., Milkman, K. & Abrami, P. , 2005). Nevertheless, studying the role gender plays in the choice of STEM studies and subsequent careers requires investigation for two reasons: “the persistence of gender inequality in the labor force ?”; “concern in the US about the supply of science labor ?” (Xie and Shauman, 2003).

Investigations into the causes of, and potential remedies for, this decline in STEM enrollment have been pursued in several directions over many years. The instructional design common to most STEM classes was seen as the problem (*e.g.*, Tobias, 1990; Seymour & Hewitt, 1997), but despite instructional reform efforts the decline continued. Motivation towards STEM studies, or the lack thereof, is another area of study (*e.g.*, Larose, Ratelle, Guay, Senecal & Harvey, 2006; Black & Deci, 2000). Some studies indicate that choosing not to study science or pursue a science career may be the result of social pressure, *e.g*., stereotype of science as a male domain (Delisle, Guay, Senecal & Larose, in press). Dr. Lawrence H. Summers, now Director of the National Economic Council, waded into the issue of the gender gap claiming that not enough females fell into the top .01 % of ability to be able to pursue careers in science at the highest level, a remark which led to his leaving his post at Harvard. While multiple studies show gender ability gaps (*e.g.,* Benbow, Lubinski, Shea & Eftekhari-Sanjani, 2000), both on standardized tests and school achievement, other studies show either no gap or even a reversal of the achievement gap (*e.g.*, Catsambis, 2005). These contradictory results make an ability based explanation for the gender gap in perseverance less reasonable. Billington, Baron-Cohen and Wheelwright (2007) discovered that STEM students score higher than students in the social sciences on a measure assessing use of systemizing cognitive style, Systemizing Quotient (Baron-Cohen, Richler, Bisarya, Gurunathan & Wheelwright, 2003), providing a novel possible explanation for the persistent gender gap in STEM studies. Our objective was to investigate whether, and if so, how, cognitive style impacts on any gender differences in achievement and perseverance in STEM studies.

Theoretical Framework

This study relies on the theory of mind as presented by Baron-Cohen (2002). Human brain functions have developed so as to sustain our species adaptation to our environment. Humans needed to adapt to the inanimate environment, and hence, we have developed a cognitive skill that Baron-Cohen calls systemizing. Systemizing is a drive to understand laws and rules governing behaviours of inanimate systems. It is a yearning to analyse and create structured models of such systems. However, for survival our species also needed to adapt to changes in the social environment, and consequently developed a skill that Baron-Cohen calls empathizing. Empathizing is a drive to understand other people's thoughts and emotions, imagining how one would think and feel in their situation, allowing us to predict behaviours of people and to respond appropriately to social stimuli. This concept is similar to subscales of emotional-social intelligence (Bar-On, 2006). Recent research suggests that empathizing and systemizing are two cognitive styles people use daily in their reasoning (Baron-Cohen *et al.,* 2003). In addition, on average, males tend to be better at systemizing while females tend to be better at empathizing (Baron-Cohen *et al.,* 2003). Since understanding and predicting patterns of behaviour of physical objects is an important skill in science, not surprisingly Billington *et al.* (2007) discovered that the majority of students choosing to study physical sciences were stronger systemizers than empathizers. Thus, a logical variable to consider when investigating gender differences in perseverance or achievement in science studies is systemizing.

It is important to note that systemizing is not a measure of cognitive ability (intelligence), but rather a measure of how people seem to interact with the world. Probably we have all observed people who are strong systemizers, and at the same time have observed a wide range of cognitive abilities in these people. We note that cognitive scientists have consistently shown that there are gender differences in cognitive abilities (Kimura, 1999). For example, Kimura (2002) has shown that men outperform women in abstract spatial reasoning, particularly in mental rotation tasks. These particular skills are vital for success in higher level mathematics and science courses. On the other hand, women outperform men in computational tasks, which may explain why elementary and junior high females outperform their male peers in school mathematics. Note that cognitive ability is a variable that has not been examined in recent studies of achievement and perseverance in STEM programs. Controversies has surrounded IQ testing and there has been evidence of cultural, racial bias in IQ tests (Eysenck, 1971; Mensh & Mensh, 1991), so that educational researchers seem to avoid the issue investigating any relationship between intelligence and achievement. However, Dr John Raven (1936) developed a test to deal with issues of bias, called Raven's Advanced Progressive Matrices, that is a culturally independent measure of abstract reasoning. Because of the nature of the questions on this test, questions that focus on pattern seeking, Raven's Progressive Matrices are useful in measuring an ability that is of particular importance in mathematics and science. It has been shown that scores on this test positively correlate with indicators of achievement in mathematics and languages (*e.g.,* Morrow, 1979). Since systemizers self-select for STEM, and cognitive ability, as measured by tests such as Raven's Progressive Matrices, correlates with achievement in mathematics, it is important to investigate any possible links between systemizing scores and cognitive ability scores.

Cognitive ability is not the only variable that correlates positively with achievement. Student achievement is also strongly correlated with motivation, study skills, goals, self-efficacy beliefs, *etc*. Thus, when investigating the impact of gender differences in systemizing on student achievement and perseverance, such variables need to be considered.

To explore the impact of motivational variables, we adopted the tenets of self-determination theory (Ryan & Deci, 2000) and of Bandura's (1997) social cognitive theory. If the research question is whether systemizing impacts on student achievement and perseverance in mathematics and sciences (chemistry and physics), then these theories would suggest that the impact would be mediated by other variables, such as intrinsic motivation and self-efficacy. For example, if high systemizers are high achievers, perhaps it is because they are highly intrinsically motivated. Intrinsic motivation implies engagement in learning because of personal interest and enjoyment in doing it (Ryan & Deci, 2000). Academic self-efficacy may also mediate the impact of systemizing on achievement because it concerns students' self-perceived capability of achieving explicit academic goals and specific results (Bandura, 1997). Perceived self-efficacy for mastering academic tasks has been shown to predict academic achievement (Pajares, 1996). Hafner (2008) has shown that self-efficacy is the key variable mediating between mathematics anxiety and achievement. In addition, academic emotions have been linked to achievement in science (Goetz, Preckel, Pekrun & Hall*,* 2006). In particular, anxiety correlates negatively with student intrinsic motivation and achievement (Pekrun, Goetz, Titz & Perry, 2002). Thus, for example, low systemizers may experience high anxiety while they are studying, which may lead to low achievement, and may also lead them to abandon STEM. Thus, the objective of this study is to formulate a model determining how systemizing relates to achievement and perseverance, through mediating variables, self-efficacy, intrinsic motivation and learning anxiety, and we hypothesize a positive impact of systemizing.

Figure 1. below shows a hypothetical model that we tested in this study.

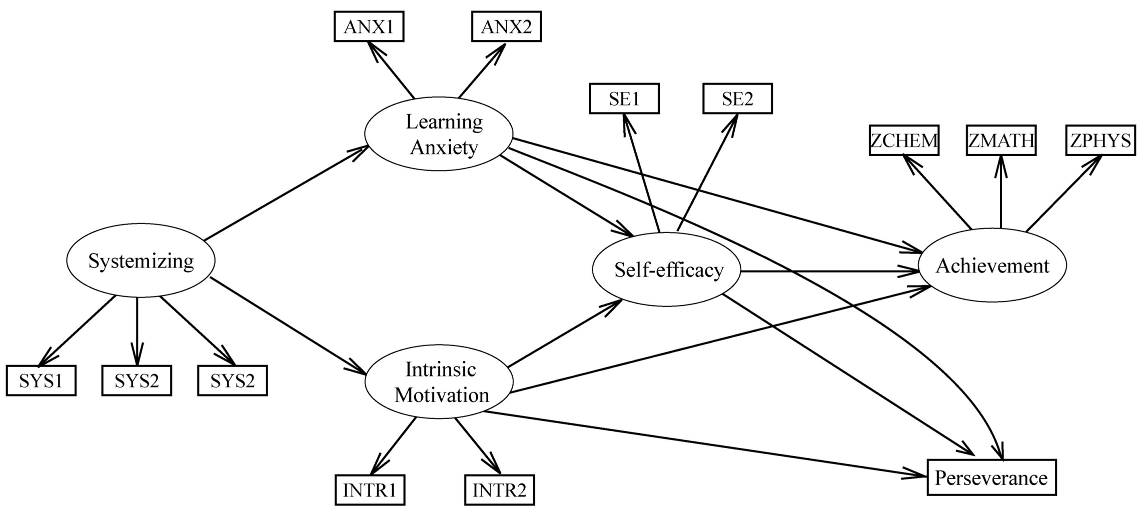

Figure 1

Methodology

A population of 18 year old students from Sweden and Québec, headed towards university STEM studies, was represented by 980 students (25.2% Swedish females; 29.2% Swedish males; 21.8% Québec females; 23.8% Québec males). Swedish students were in their last high school year. Québec students were in their first year of a two-year CEGEP science program. Surveys, administered late in the year, assessed: systemizing, 9-item scale adapted from the Systemizing Quotient (Baron-Cohen *et al.*, 2003); self-efficacy, 6-item scale adapted from the MSLQ (Pintrich *et al.*, 1991); intrinsic motivation, 4-item scale adapted from the AMS (Vallerand *et al*., 1992); learning anxiety, 4-item scale adapted from the AEQ (Pekrun *et al.*, 2002). Note that systemizing was measured by questions pertaining to everyday activities (*e.g.*, *I am fascinated by how machines work.* Answers: 1. Strongly disagree 2. Disagree 3. Agree 4. Strongly agree), not STEM study activities.

Perseverance was assessed by one item in the survey, assessing the likelihood (scale: very unlikely - unlikely - likely - very likely) of choosing science, technology, engineering or mathematics programs at university. Achievement data were obtained from participating institutions' records. To overcome differences between the grading system of Swedish schools and that of Québec CEGEPs, we converted achievement data to z-scores, assuming that average achievement was the same in both countries.

A 10 item Aptitude for Science test (http://www.psychtests.com) that highly correlates (Jerabek, 2009) with Raven's Advanced Progressive Matrices was used to assess cognitive ability. It was administered, one year later than the survey, to 105 volunteers drawn from amongst the CEGEP participants.

Structural Equation Modelling (SEM) (Byrne, 2006) was used to test the hypothesised model concerning how systemizing relates to achievement and perseverance in science, and to assess gender and cultural differences. (This paper only reports on gender differences. Cultural differences will be discussed in a forthcoming paper.) Prior to analysis, the data were tested for multivariate outliers using Mahalanobis distance (Tabachnik and Fiddell, 2000). Thirty-two cases were removed from analysis, either having a very large Mahalanobis distance or making a large contribution to multivariate kurtosis (Bentler, 1995).

Results

Table 1. below indicates significant differences between means for females and males on the independent variable systemizing, with males scoring higher than females. While there were no significant differences between the intrinsic motivation of females and males, females were significantly more anxious than males. Males were significantly more self-efficacious than females. While there was no gender difference in the dependent variable achievement, males were significantly more persistent than females.

Appendix A

Descriptive Statistics & Results of ANOVA				
	Female (457)	Male (515)	F(1,971)	Sig.
Variable	MEAN (SD)	MEAN (SD)		
Systemizing	2.864 (.400)	3.178 (.441)	134.344	< .001
Learning Anxiety	2.258 (.755)	1.817 (.669)	93.209	< .001
Intrinsic Motivation	2.912 (.746)	2.927 (.794)	.030	0.860
Self-efficacy	2.889 (.636)	3.053 (.653)	15.631	< .001
Perseverance	2.930 (.722)	3.284 (.689)	60.964	< .001
Achievement	.035 (.810)	.065 (.846)	.330	0.570

Table 1.

Not only were the means of systemizing different by gender, but the distributions of systemizing differed, skewed at opposite ends of the axis. To measure gender differences in the distribution of systemizing, systemizing was categorized into low, medium (±½SD from the Mean) and high scores, and cross-tabulated versus Gender. We computed the Pearson Chi-Square (2, 972) = 114.752, Sig. (2-sided) < .001, which indicates the significance of the differences by gender in the distributions of systemizing, with the data shown in Table 2 below.

Cross-tabulation of Categorized Systemizing versus Gender				
Systemizing		Female	Male	Total
Low	Count	204	105	309
	% within Low	66.0%	34.0%	100.0%
	% within Gender	44.6%	20.4%	31.8%
	% of Total	21.0%	10.8%	31.8%
Medium	Count	187	186	373
	% within Medium	50.1%	49.9%	100.0%
	% within Gender	40.9%	36.1%	38.4%
	% of Total	19.2%	19.1%	38.4%
High	Count	66	224	290
	% within High	22.8%	77.2%	100.0%
	% within Gender	14.4%	43.5%	29.8%
	% of Total	6.8%	23.0%	29.8%
Total	Count	457	515	972
	% within Systemizing	47.0%	53.0%	100.0%
	% within Gender	100.0%	100.0%	100.0%
	% of Total	47.0%	53.0%	100.0%

Table 2.

The results of an ANOVA, shown in Table 3. below, indicate no significant differences between males and females in cognitive abilities. Further, as anticipated, there was no correlation between systemizing (cognitive style) and cognitive ability. Also, as seen in Morrow (1979), cognitive ability correlates significantly with achievement (r = .278**).

ANOVA of Aptitude for Science by Gender				
Gender	N	Mean (SD)	F (1, 103)	Sig.
Female	50	5.620 (1.369)		
Male	55	6.180 (1.634)	3.61	0.06
Total	105	5.910 (1.532)		

Table 3.

SEM confirmed the hypothesized model. Mardia coefficients of multivariate kurtosis were relatively elevated in both groups, so the Robust method of estimation was used. The result indicates a good fit (CFI = .956, RMSEA = .063 (.055, .071), Satorra-Bentler scaled Chi-Square/df = 319.08/112 = 2.85). LM and Wald tests indicated that one of the constraints needed to be released to improve fit. Constraints on the equality of path coefficients were imposed and the LM test indicated no significant differences between path coefficients for males and females.

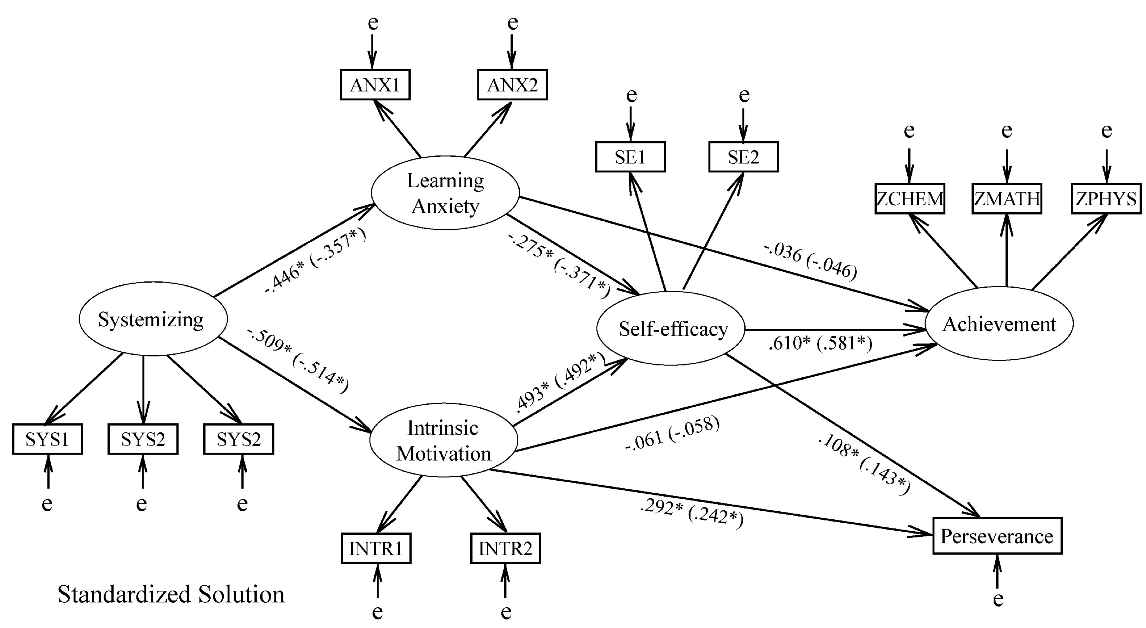

Figure 2

Discussion

This study has revealed significant differences by gender in the means of systemizing, learning anxiety, self-efficacy and perseverance. However, the differences in self-efficacy means, while statistically significant, are relatively small, being less than one third of one pooled standard deviation. These differences, with males evidencing higher feelings of self-efficacy than their female counterparts, are well known in the literature (*e.g,*. Dedic, Rosenfield, Simon, Ivanov & Rosenfield, 2009).

The model developed in this study demonstrated no gender differences in relationships between variables, corroborating results of a number of studies which demonstrated gender differences in the means of variables, but no gender differences in relationships (*e.g.,* Simpkins, Davis-Kean & Eccles, 2006). However, males outperform females on systemizing, a corroboration of the findings of Baron-Cohen *et al.,* (2003). Table 2 illustrates gender differences in the distribution of systemizing: the two distributions are skewed in opposite directions, so that there are many more females low on systemizing with many more males high on systemizing. Being a low systemizer likely influences choices of young girls for out-of-school activities away from those involving mathematics and science. As Simpkins *et al.,* (2006) showed, these early childhood experiences guide choices of academic trajectory later on. In all likelihood, high systemizers incorporate use of this cognitive style into both school and play from early childhood, while low systemizers probably shun activities, both in school and play, that would give them practice at recognizing patterns. Hence, when studying mathematics and science the low systemizers are more likely to experience a high cognitive load (Sweller, 2006), and hence, increased learning anxiety. In addition, high systemizers were likely to enjoy playing with inanimate objects and figuring out how systems work in their childhood. When they grew up, this habit probably led to their high intrinsic motivation towards STEM.

Our model corroborates the findings of Hafner (2008) that self-efficacy beliefs are the key indicator of student achievement. Further, the model indicates that learning anxiety and intrinsic motivation together strongly influence self-efficacy, explaining roughly 30% of the variance in self-efficacy. This model also indicates that self-efficacy explains 50% of the variance in achievement, yet there is no significant difference between the means of male and female achievement.

However, despite equivalent achievement scores, there is a significant difference between the means of male and female perseverance. We speculate that females compensate for low systemizing with a higher level of study skills, but the extra effort and anxiety thereby induced during learning eventually takes its toll in their perseverance. Strong links between systemizing and learning anxiety and intrinsic motivation, and then from these to self-efficacy, and finally from self-efficacy to perseverance, indicate that low-systemizing students are likely to abandon pursuit of science studies, and more of these are female than male. We should note that unlike the case with achievement, intrinsic motivation not only links to perseverance through self-efficacy, but also there is a direct link.

Importantly, we also demonstrated that aptitude for science (cognitive ability) does not correlate with systemizing (cognitive style), so lack of perseverance is not about ability, but rather about being comfortable and proficient at systemizing tasks inherent in studying science. Although cognitive style in Baron-Cohen's theory of mind (2002) is presented as a trait, Gredlein and Bjorkhead (2005) demonstrated that interventions in small children's play can increase use of systemizing. Thus, increasing students' interest in science careers and closing the gender gap may require intervention in young children's play, or as Sweller (2006) suggests, developing instructional designs that decrease the cognitive load of low systemizers, thereby increasing comfort and proficiency in searching for patterns. Low systemizers at the CEGEP level may need more time practising/learning any given topic in order to develop their skills and increase their comfort level. Further, the tasks set for such students need to be more intrinsically appealing to them, in order to raise the motivation of these students. However, over 50% of instructors still believe that the single most important responsibility they have is to cover all material, something they find easiest to accomplish by lecturing (Rosenfield *et al*, 2005).

Conclusion

The scientific importance of this study is threefold: 1. a variable, systemizing, not previously studied, has been shown to impact on both achievement and perseverance in science studies; 2. the model indicates how the impact of systemizing is mediated by learning anxiety, intrinsic motivation and self-efficacy; 3. offers a new perspective on the important problem of halting declining enrolment and closing the gender gap in STEM studies in Québec, and elsewhere.

The authors wish to gratefully acknowledge the kind assistance provided through discussions with the leader of the FQRSC Régroupment and Equipe grants, Dr. P. Abrami, and in the gathering of data and helpful suggestions of the other PAREA grant team members, Ivan Ivanov, Murray Bronet, Eva Rosenfield and Joel Trudeau.

Bibliography

Bandura, A. (1997). *The Self-efficacy: The Exercise of Control.* New York Freeman Press.

Baron-Cohen, S. (2002). The Extreme Brain Theory of Autism. *Trends in Cognitive Sciences*, 6(6), 248-254.

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N. & Wheelwright, S. (2003). The systemizing quotient: an investigation of adults with Asperger syndrome or high-functioning autism, and normal sex differences. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 358, 361-374.

Bar-On, R. (2006). The Bar-On model of emotional-social intelligence (ESI). *Psicothema,* 18, suppl., 13-25.

Benbow, C. P., Lubinski, D., Shea D. L. & Eftekhari-Sanjani, H. (2000). Sex Differences in Mathematical Reasoning Ability at Age 13: Their Status 20 Years Later. *Psychological Science*, 2, 6, 474-480.

Bentler, P. M. (1995). *EQS 6 Structural Equations Program Manual*. Multivariate Software, Inc. Encino, CA.

Black, A. E. & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination perspective. *Science Education, 84*, 6, 740-766.

Billington, J., Baron-Cohen, S. & Wheelwright, S. (2006). Cognitive style predicts entry into physical sciences and humanities: Questionnaire and performance tests of empathy and systemizing. *Learning and Individual Differences*, 17, 260-268.

Byrne, B. M. (2006). *Structural equation modeling with EQS and EQS/Windows: Basic concepts, application and programming*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Catsambis, S. (2005). The gender gap in mathematics: Merely a step function? In A. M. Gallagher & J. C. Kaufman (Eds.), *Gender differences in mathematics* (pp. 220-245). Cambridge, UK: Cambridge University Press.

Delisle, M.-N., Guay, F., Senecal, C. & Larose, S. (in press). Predicting Stereotype Endorsement and Academic Motivation in Women in Science Programs: A Longitudinal Model. *Learning and Individual Differences*.

Eysenck, H. J. (1971). *The IQ Argument. Race, Intelligence and Education.* The Library Press, New York, N.Y.

Goetz, T., Preckel, F., Pekrun, R. & Hall, N. C. (2007). Emotional experiences during test taking: Does cognitive ability make a difference? *Learning and Individual Differences*, 17, 1, 3-16.

Gredlein, J. M. & Bjorkhead, D. F. (2005). Sex Differences in Young Children Use of Tools in a Problem-Solving Task: The Role of Object Oriented Play. *Human Nature - Biosocial Perspective*, 16, 211-232.

Hafner, E. W. (2008). *The relationship between math anxiety, math self-efficacy, and achievement among a sample of eighth grade students.* Dissertation Abstracts International Section A: Humanities and Social Sciences. Vol 69(2-A), pp. 503

Kimura, D. (1999). *Sex and Cognition*. Cambridge, MA: MIT Press

Kimura, D. (2002). Sex Hormones Influence Human Cognitive Pattern. *Neuroendocrinology Letters Special Issue*, Suppl. 4, 23, 67-77.

Mensh, E. & Mensh, H. (1991). *IQ Mythology*. Carbondale and Edwardsville, Southern Illinois University Press.

National Science Foundation: Division of Science Resources Statistics (2004). *Education, Women, Minorities, and Persons with Disabilities in Science and Engineering.* NSF 04-317, Arlington, VA. Retrieved July 13, 2009, from http://www.nsf.gov/statistics/wmpd/pdf/nsf04317.pdf

OECD (2006). *Evolution of Student Interest in Science and Technology Studies.* Policy Report. Global Science Forum: Organisation for Economic Co-operation and Development

Pajares, F. (1996). Self-efficacy Beliefs in Academic Settings. *Review of Educational Research*, 66, 543-578.

Pekrun, R., Goetz, T., Titz, W. & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational Psychologist, 37*(2), 91-105.

Pintrich, P. R., Smith D. A. F., Garcia, T. & McKeachie, W. J. (1991). *A Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ).* Ann Arbor, MI: National Center for Research to Improve Postsecondary Teaching and Learning.

Ratelle, C. F., Guay, F., Larose, S. & Senecal, C. (2004). Family Correlates of Trajectories of of Academic Motivation During: A Semiparametric Group-Based Approach. *Journal of Educational Psychology*, 96(4), 745-754.

Rosenfield, S., Dedic, H., Dickie, L. O., Rosenfield, E., Aulls, M., Koestner, R., Krishtalka, A., Milkman, K. & Abrami, P. (2005). *Étude des facteurs aptes à influencer la réussite et la rétention dans les programmes de sciences aux cégeps anglophones.* Rapport de recherche, (FQRSC Action Concertée Grant 2003-PRS-89553). Montréal: Collège Vanier.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology,* 25, 54-67.

Seymour, E. & Hewitt, N. 1997. *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview.

Simpkins, S. D., Davis-Kean, P. E. & Eccles, J. C. (2006). Math and Science Motivation: Longitudinal Examination of the Links between Choices and Beliefs. *Developmental Psychology,* 40, 1, 70-83.

Sweller, J. (2006). Discussion of 'Emerging Topics in Cognitive Load Research: Using Learner and Information Characteristics in the Design of Powerful Learning Environments. *Applied Cogmitive Psychology*, 20, 353-357.

Tabachnik, B. G. & Fidel, L. S. (2001). *Using multivariate statistics*. 4th ed. Boston; London: Allyn and Bacon.

Tobias, S. (1990). *They're not dumb, they're different: Stalking the second tier. An occasional paper on neglected problems in science education*. Tucson, AR: Research Corporation.

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Brière, N. M., Senécal, C. B. & Vallières, E. F. (1992). The Academic Motivation Scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and Psychological Measurement*, *52*, 1003-1019.

Xie, Y. & Shauman, K. A. (2003). *Women in Science: Career Processes and Outcomes.* p.p. 3-4, Cambridge, MA: Harvard University Press.

Cognitive Style and Science Achievement of Canadian and Swedish College Level Students.[2]

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Key words: Cognitive style, Science Education, Anxiety, Intrinsic Motivation, Achievement

Introduction

Evidence indicates that enrollment in Science, Technology, Engineering and Mathematics (STEM) studies is declining in North America and Europe (OECD, 2006), presenting a serious problem. Success in educating more scientists and engineers, the next generation of innovators, is a necessary component in driving a successful economy in this century. Investigations into the cause of, and potential remedies for, this decline, have been pursued in several directions over many years. The instructional design most commonly used in STEM classes was seen as the problem (*e.g.*, Tobias, 1990; Seymour & Hewitt, 1997), but despite instructional reform efforts over the past two decades, the decline continues. Motivation towards STEM studies, or the lack thereof, is another area of study (*e.g.*, Ratelle, Guay, Larose, & Senecal, 2004; Black & Deci, 2000) engage in by those seeking to explain why students decide to abandon science studies, as well as to help instructors design classroom environments that would stimulate student motivation.

Researchers studying autism have found evidence that empathising and systemising are two major cognitive styles people use in their reasoning (Baron Cohen, 2002; Lawson, Baron Cohen & Wheelwright, 2004). Systemising cognitive style is defined as the yearning to analyse systems of physical objects and create structured models. Since understanding and predicting patterns is a necessary skill in science, not surprisingly Billington *et al.* (2007) found that the majority of students choosing to study physical sciences were systemisers, that is, they were scoring higher on systemising cognitive style than on empathising cognitive style.

This study investigates relationships between systemising cognitive style, academic emotions, academic motivation, self-efficacy and achievement in mathematics and science courses. The research question is whether systemising cognitive style impacts on student achievement in mathematics and sciences (chemistry and physics), and whether such impact is mediated by other variables. Perhaps systemisers are higher achievers because they are intrinsically motivated. Intrinsic motivation implies engagement in learning because of personal interest and enjoyment in doing it (Ryan & Deci, 2000). Academic emotions have been linked to cognitive ability and achievement (Goetz *et al.*, 2006). In particular, anxiety correlates negatively with student intrinsic motivation and achievement (Pekrun *et al.*, 2002). Consequently, systemisers may be less likely to experience learning anxiety. Academic self-efficacy may also mediate the impact of systemising cognitive style on achievement because it concerns students' self-perceived capability of achieving explicit academic goals and specific results (Bandura, 1997). Perceived self-efficacy for mastering academic tasks predicts academic achievement (Pajares, 1996). In Hafner (2008), self-efficacy is the key variable mediating between mathematics anxiety and achievement.

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[2]This paper was presented at the Annual meeting of European Educational Research Association in Vienna, October 2009.

Thus, we hypothesized that a systemising cognitive style has a positive impact on achievement in science courses, mediated by anxiety, intrinsic motivation and academic self-efficacy. We studied whether there are cultural differences (Quebec vs. Sweden) in the relationships amongst these variables.

Methodology

A population of 18 year old Swedish/Quebec students, headed towards university science, mathematics or engineering, were represented by 980 students (25.2% Swedish females, 29.2% Swedish males, 21.8% Quebec females and 23.8% Quebec males). Swedish students were in their last year of high school. Quebec students were in their first year of a two-year junior college program. It should be noted that the student population in junior colleges in Quebec consists of native Quebecers of French, English or other European country descent, as well as first and second generation immigrants. Some ethnic groups maintain strong cultural ties to their original communities, while other groups tend to adapt to and share the cultural values of mainstream Quebecers. Thus, the Swedish population is probably more culturally homogeneous than the population of Quebec junior colleges.

Surveys, administered late in the school year, assessed: systemizing cognitive style, 10 item scale adapted from the Systemizing Quotient (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003); self efficacy, 6 item scale adapted from MSLQ (Pintrich *et al.*, 1991); intrinsic motivation, 4 item scale adapted from AMS (Vallerand *et al.*, 1992); anxiety, 4 item scale adapted from AEQ (Pekrun *et al.*, 2002). Achievement data were obtained from participating institutions' records. A confirmatory factor analysis (CFA) was carried out to assess whether the scales used in this study are satisfactory. In addition, the sample was assessed for univariate and/or multivariate outliers. Furthermore, Missing Value Analysis (MVA) using SPSS was caried out to replace randomly missing values. Then, ANOVA was used to assess the differences between the means. An SEM procedure (Byrne, 2006) was used to test a theoretical model concerning how systemising cognitive style relates to achievement in science, and to assess cultural differences.

Results

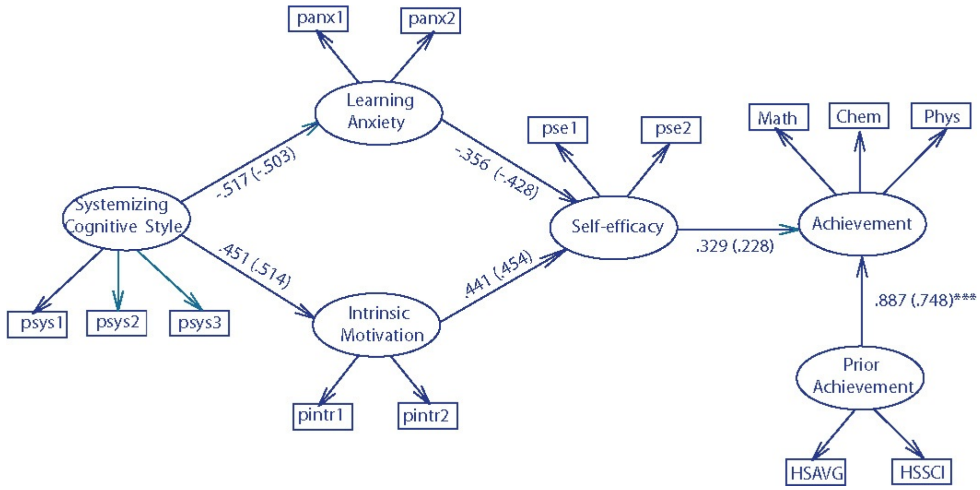
The results of the CFA (CFI=.968, χ^2/df=2.73, RMSEA=.060) validated all scales. No univariate or multivariate outliers were removed from the sample. The results of ANOVA are shown in Table 1 below.

Table 1 Means of motivational variables and systemising cognitive style

Populations	Swedish	Quebec
Variables	Mean(SD)	Mean(SD)
Learning Anxiety***	1.95(.76)	2.10(.71)
Self-efficacy***	2.83(.72)	3.10(.50)
Intrinsic Motivation***	2.82(.85)	3.00(.64)
Systemising	3.02(.48)	3.04(.42)

There are significant differences ($p<.001$) between the means of learning anxiety, self-efficacy and intrinsic motivation for Quebec versus Swedish students. Interestingly, there are no significant differences between the systemising cognitive style scores.

The structural equation modelling procedure followed the algorithm suggested by Byrne (2006). The configural model was tested first, and then constraints were imposed on the first order factors. The LM test indicated that there were no significant differences between the factor loadings of the two samples (Swedes & Quebecers). Subsequently constraints were imposed on second order factors. The resulting model had favourable indices of validity (CFI=.941, χ^2/df=3.77, RMSEA=.076). The LM test indicated that there were significant differences, Sweden versus Quebec, between the path coefficients connecting prior achievement and achievement. The model below indicates the path coefficients, with values in round brackets being those related to the Quebec students.



Discussion

It was found that there are statistically significant differences between the means of learning anxiety, self-efficacy and intrinsic motivation. However, the size of the standard deviations for those variables, suggests strongly that these differences are not meaningful. Furthermore, we note that Swedish students continued to attend school in the same system while Quebec students were in transition between a high school and a junior college. It is conceivable that what small differences between the means were seen can be attributed to such differences between the situations of the two populations. For example, the learning anxiety amongst Quebecers may be heightened by the fact that these students, unlike their Swedish counterparts, are facing a novel environment. In contrast, Quebec students having just made a very important decision concerning their future careers may feel more confident about their competence, as well as feel more intrinsically motivated to pursue science careers. The means of the systemising cognitive style did not differ. This last result implies that systemising cognitive style is not a function of culture, but rather a function of the brain architecture as Baron-Cohen (2002) suggests.

The best fitting structural model indicates that systemising influences the achievement of students indirectly: students high in systemising experienced less anxiety, and had higher intrinsic motivation; low anxiety and robust intrinsic motivation resulted in higher academic self-efficacy in science; higher self-efficacy significantly impacted academic performance. Nonetheless, prior academic achievement remains the strongest predictor of future academic performance. The causal structure of this model is invariant across the two very different populations that we have examined. Testing for group differences revealed just one significantly different link between latent variables: Swedes' (versus Quebecers') prior achievement and achievement. We believe that this difference can also be attributed to the fact that Swedish students were continuing to attend the same school, and were probably taught by teachers in their advanced science classes that they were familiar with from previous school years. In contrast, Quebec students have "moved on" from high school to junior college, and in the new setting the pedagogy and grading practices are likely to be quite different. Note that the correlation between prior achievement and achievement is still very high in both populations, but in the Swedish population the path coefficient may be higher due to the fact that the same teachers, or close colleagues, were assessing the achievement of the students.

Given that approximately one third of the student population appears to have a low (½ a SD below the mean) score on systemising cognitive style, we propose that if these students are to succeed in the sciences, they will need a learning environment in which instructors repeatedly model how to search for patterns, and in which instructors make an large effort to stimulate intrinsic motivation.

Conclusion

In this research we have shown that systemising cognitive style plays an important role in student intrinsic motivation. Systemising cognitive style is also closely related to experiences of learning anxiety. Since both of these variables have been shown to influence students' academic performance, we conclude that systemising cognitive style is an important factor to be considered in studies of achievement and perseverance in STEM studies. In the course of this research we have validated a short form of SQ (Baron Cohen *et al.*, 2003) that may be used in future research. Furthermore, we have shown how systemising cognitive style impacts on students' performance, and that the same model applies in the two very different cultural settings that we have examined. It should be interesting to investigate whether the same model would also operate amongst 18-year olds attending schools in developing countries, since these countries currently are not experiencing the same decline in the number of STEM graduates as the developed countries that do. Since females are more likely to have a low score on systemising cognitive style than males (Lawson *et al.*, 2004), we intend to use this data set to explore whether there are significant gender differences in path coefficients of this model. In addition, we will explore how systemising cognitive style impacts on perseverance.

Bibliography

Bandura, A. (1997). *The Self-efficacy: The Exercise of Control.* New York Freeman Press.

Baron-Cohen, S. (2002). The Extreme Brain Theory of Autism. *Trends in Cognitive Sciences*, 6(6), 248-254.

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N. & Wheelwright, S. (2003). The systemizing quotient: an investigation of adults with Asperger syndrome or high-functioning autism, and normal sex differences. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 358, 361-374.

Black, A. E. & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination perspective. *Science Education, 84*, 6, 740-766.

Billington, J., Baron-Cohen, S. & Wheelwright, S. (2006). Cognitive style predicts entry into physical sciences and humanities: Questionnaire and performance tests of empathy and systemizing. *Learning and Individual Differences*, 17, 260-268.

Byrne, B. M. (2006). *Structural equation modeling with EQS and EQS/Windows: Basic concepts, application and programming*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Goetz, T., Preckel, F., Pekrun, R. & Hall, N. C. (2007). Emotional experiences during test taking: Does cognitive ability make a difference? *Learning and Individual Differences*, 17, 1, 3-16.

Hafner, E. W. (2008). *The relationship between math anxiety, math self-efficacy, and achievement among a sample of eighth grade students.* Dissertation Abstracts International Section A: Humanities and Social Sciences. Vol 69(2-A), 2008, pp. 503

Lawson, J., Baron-Cohen, S. & Wheelwright, S. (2006). Empathising and Systemising in Adults with and without Asperger Syndrome. *Journal of Autism and Developmental Psychology*, 54,3, 302-310.

OECD (2006). *Evolution of Student Interest in Science and Technology Studies.* Policy Report. Global Science Forum: Organisation for Economic Co-operation and Development

Pajares, F. (1996). Self-efficacy Beliefs in Academic Settings. *Review of Educational Research*, 66, 543-578.

Pekrun, R., Goetz, T., Titz, W. & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational Psychologist, 37*(2), 91-105.

Pintrich, P. R., Smith D. A. F., Garcia, T. & McKeachie, W. J. (1991). *A Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ).* Ann Arbor, MI: National Center for Research to Improve Postsecondary Teaching and Learning.

Ratelle, C. F., Guay, F., Larose, S. & Senecal, C. (2004). Family Correlates of Trajectories of of Academic Motivation During: A Semiparametric Group-Based Approach. *Journal of Educational Psychology*, 96(4), 745-754.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology,* 25, 54-67.

Seymour, E. & Hewitt, N. 1997. *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview.

Tobias, S. (1990). *They're not dumb, they're different: Stalking the second tier. An occasional paper on neglected problems in science education*. Tucson, AR: Research Corporation.

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Brière, N. M., Senécal, C. B. & Vallières, E. F. (1992). The Academic Motivation Scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and Psychological Measurement*, *52*, 1003-1019.

Appendix C

Model of How Cognitive Style Impacts Differentially by Gender on Achievement and Perseverance in SMET Studies.[3]

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Abstract

A gender gap and decline in enrollment in SMET studies occurs in most Western countries. To better understand this phenomenon we have investigated relationships between cognitive style, anxiety, motivation and self-efficacy, and achievement and perseverance in mathematics/science courses. Research suggests that systemising is one of the two major cognitive styles people use in their reasoning. Systemising is defined as the yearning to analyse systems. Canadian and Swedish students (N = 980) participated in this study. Using SEM, our model shows that students scoring low on systemising (who tend to be female) are likely to experience higher anxiety and lower self-efficacy, and then lower perseverance. Reversing the gap and the decline may require pedagogy that helps low systemisers to learn science.

Introduction

Evidence indicates that enrollment in science/mathematics/engineering/technology (SMET) studies is declining in North America and Europe (OECD, 2006), presenting a serious problem. Barack Obama has pointed out that success in educating more scientists/engineers, the next generation of innovators, is necessary to drive a successful US economy in this century. Investigations into the cause of and potential remedies for this decline have been pursued in several directions over many years. The instructional design common to SMET classes was seen as the problem (*e.g.*, Tobias, 1990; Seymour & Hewitt, 1997), but despite instructional reform efforts the decline continues. Motivation towards SMET studies, or the lack thereof, is another area of study (*e.g.*, Larose, Ratelle, Guay, Senecal & Harvey, 2006; Black & Deci, 2000). In addition, there is a persistent gender gap in the pursuit of SMET studies (*e.g.*, NSF, 2004), despite women being the majority of university students in the western world. Thus, studying the role gender plays in the choice of SMET studies/careers needs investigation for two reasons: "the persistence of gender inequality in the labor force …"; "concern in the US about the supply of science labor …" (Xie and Shauman, 2003). Some studies indicate that choosing not to study science or pursue a science career may be the result of social pressure, *e.g*., stereotype of science as a male domain (Delisle, Guay, Senecal & Larose, in press). Dr. Lawrence H. Summers, now Director of the National Economic Council, waded into the issue of the gender gap claiming that not enough females fell into the top .01 % of ability to be able to pursue careers in science at the highest level, a remark which led to his leaving his post at Harvard. While multiple studies show gender ability gaps (*e.g.,* Benbow, Lubinski, Shea & Eftekhari-Sanjani, 2000), both on standardized tests and school achievement, other studies show either no gap or even a reversal of the gap (*e.g.*, Catsambis, 2005). Contradictory results make an ability based explanation for the

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[3]This paper will be presented at the annual meeting of the American Educational Research Association in Denver, U.S.A. in May, 2010.

gender gap less reasonable. Billington, Baron-Cohen and Wheelwright (2007) discovered that SMET students score higher than students in the social sciences on a measure assessing use of systemising cognitive style (SQ) (Baron-Cohen, Richler, Bisarya, Gurunathan & Wheelwright, 2003), providing a novel possible explanation for the persistent gender gap in SMET studies. Our objective was to investigate whether, and if so, how, cognitive style impacts on achievement and perseverance in SMET studies.

Theoretical Framework

This study relies on the theory of mind as presented by Baron-Cohen (2002). Human brain functions have developed so as to sustain our species adaptation to our environment. Humans needed to adapt to the inanimate environment, and hence, we have developed a cognitive skill that Baron-Cohen calls systemising. Systemising is a drive to understand laws and rules governing behaviours of inanimate systems. It is a yearning to analyse and create structured models of such systems. However, for survival our species also needed to adapt to changes in social environment, and consequently developed a skill that Baron-Cohen calls empathising. Empathising is a drive to understand other people's thoughts and emotions, imagining how one would think and feel in their situation, allowing us to predict behaviours of people and to respond appropriately to social stimuli. This concept is similar to subscales of emotional-social intelligence (Bar-On*,* 2006). Recent research suggests that empathising and systemising are two cognitive styles people use daily in their reasoning (Baron-Cohen *et al.,* 2003). In addition, on average, males tend to be better at systemising while females tend to be better at empathising (Baron-Cohen *et al.,* 2003). Since understanding and predicting patterns of behaviour of physical objects is an important skill in science, not surprisingly Billington *et al.* (2007) discovered that the majority of students choosing to study physical sciences were stronger systemisers than empathisers. Thus, a logical variable to consider when investigating gender differences in perseverance or achievement in science studies is SQ.

It is important to note that SQ is not a measure of cognitive ability (intelligence). Recent studies still indicate that males outperform females in certain cognitive abilities. For example, Kimura (1999) noted that in mathematical/mechanical reasoning males score higher than female peers. However, studies show that any gender gap in achievement in mathematics/science courses has disappeared (*e.g.*, Xiu and Shauman, 2003). Since cognitive ability positively correlates with achievement, how do we explain this? The answer probably lies in the fact that student achievement is also strongly correlated to other variables, *e.g.,* motivation, study skills, goals, self-efficacy beliefs, *etc*. Thus, when investigating the impact of gender differences in SQ on student achievement, such variables need to be considered.

To explore the impact of motivational variables, we adopted the tenets of self-determination theory (Ryan & Deci, 2000) and of Bandura's (1997) social cognitive theory. If the research question is whether SQ impacts on student achievement in mathematics and sciences (chemistry/physics), then these theories would suggest that the impact would be mediated by other variables, such as intrinsic motivation and self-efficacy. Perhaps systemisers are higher achievers because they are intrinsically motivated. Intrinsic motivation implies engagement in learning because of personal interest and enjoyment in doing it (Ryan & Deci, 2000). Academic self-efficacy may also mediate the impact of SQ on achievement because it concerns students' self-perceived capability of achieving explicit academic goals and specific results (Bandura, 1997). Perceived self-efficacy for mastering academic tasks predicts academic achievement (Pajares, 1996). Also, academic emotions have been linked to achievement in science (Goetz, Preckel, Pekrun & Hall*,* 2006). In particular, anxiety correlates negatively with student intrinsic motivation and achievement (Pekrun, Goetz, Titz & Perry, 2002). In Hafner (2008), self-efficacy is the key variable mediating between mathematics anxiety and achievement. Thus, systemisers may be less likely to experience learning anxiety.

We hypothesized a positive impact of an SQ on achievement and perseverance in science studies, mediated by learning anxiety, intrinsic motivation and academic self-efficacy. Figure 1. below shows a hypothetical model that we tested in this study.

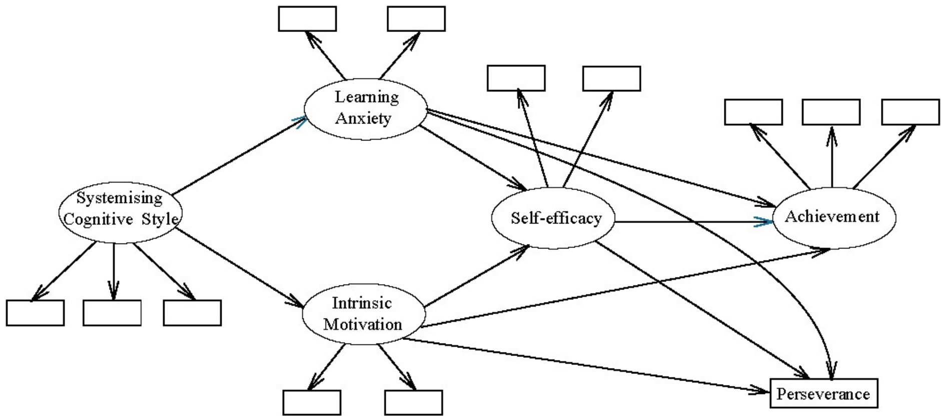

Figure 1.

Methodology

A population of 18 year old Swedish/Canadian students, headed towards university SMET studies, was represented by 980 students (25.2% Swedish females; 29.2% Swedish males; 21.8% Canadian females; 23.8% Canadian males). Swedish students were in their last high school year. Canadian students were in their first year of a two-year junior college program. Surveys, administered late in the year, assessed: systemizing cognitive style, 9-item scale adapted from the Systemizing Quotient (Baron-Cohen *et al.*, 2003); self-efficacy, 6-item scale adapted from MSLQ (Pintrich *et al.*, 1991); intrinsic motivation, 4-item scale adapted from AMS (Vallerand *et al.*, 1992); learning anxiety, 4-item scale adapted from AEQ (Pekrun *et al.*, 2002). Note that systemizing was measured by questions pertaining to everyday activities (*e.g.*, I am fascinated by how machines work. 1. Strongly disagree 2. Disagree 3. Agree 4. Strongly agree), not SMET study activities.

Perseverance was assessed by one item in the survey, assessing the likelihood (scale: very unlikely - unlikely - likely - very likely) of choosing science/mathematics/engineering programs at university. Achievement data were obtained from participating institutions' records. To overcome differences between the grading system of Swedish schools and that of Canadian colleges, we converted achievement data to z-scores, assuming that average achievement was the same in both countries.

A 10 item Aptitude for Science test (http://www.psychtests.com) that resembles Raven's Advanced Progressive Matrices was used to assess cognitive ability. It was administered, one year later than the survey, to 105 volunteers drawn from amongst the Canadian participants.

An SEM procedure (Byrne, 2006) was used to test the hypothesised model concerning how SQ relates to achievement and perseverance in science, and to assess gender and cultural differences. (This paper only reports on gender differences. Cultural differences will be discussed at ECER, 2009.) Prior to analysis, the data were tested for multivariate outliers using Mahalanobis distance (Tabachnik and Fiddell, 2000). Thirty-two cases were removed from analysis, either having a very large Mahalanobis distance or making a large contribution to multivariate kurtosis (Bentler, 1995).

Results

Table 1. below indicates significant differences between means for females and males on the independent variable systemising, with males scoring higher than females. While there were no significant differences between the intrinsic motivation of females and males, females were significantly more anxious than males. Males were significantly more self-efficacious than females. While there was no gender difference in the dependent variable achievement, males were significantly more persistent than females.

Descriptive Statistics & Results of Anova				
	Female (457)	Male (515)	F(1,971)	Sig.
Variable	MEAN (SD)	MEAN (SD)		
SQ	2.864 (.400)	3.178 (.441)	134.344	.000
Learning Anxiety	2.258 (.755)	1.817 (.669)	93.209	.000
Intrinsic Motivation	2.912 (.746)	2.927 (.794)	.030	.862
Self-efficacy	2.889 (.636)	3.053 (.653)	15.631	.000
Perseverance	2.930 (.722)	3.284 (.689)	60.964	.000
Achievement	.035 (.810)	.065 (.846)	.330	.566

Table 1.

Not only were the means of systemising different by gender, but the distributions of systemising differed, skewed at opposite ends of the axis. Table 2. below illustrates these differences. Systemising was categorized into low, medium (±½SD from the Mean) and high scores, and cross-tabulated versus Gender. The Pearson Chi-Square (2, 972) = 114.752, Sig. (2-sided) < .001 indicates the significance of these differences.

Cross-tabulation of Categorized Systemising versus Gender				
Systemising		Female	Male	Total
Low	Count	204	105	309
	% within Low	66.0%	34.0%	100.0%
	% within Gender	44.6%	20.4%	31.8%
	% of Total	21.0%	10.8%	31.8%
Medium	Count	187	186	373
	% within Medium	50.1%	49.9%	100.0%
	% within Gender	40.9%	36.1%	38.4%
	% of Total	19.2%	19.1%	38.4%
High	Count	66	224	290
	% within High	22.8%	77.2%	100.0%
	% within Gender	14.4%	43.5%	29.8%
	% of Total	6.8%	23.0%	29.8%
Total	Count	457	515	972
	% within Systemising	47.0%	53.0%	100.0%
	% within Gender	100.0%	100.0%	100.0%
	% of Total	47.0%	53.0%	100.0%

Table 2.

The results of an ANOVA, in Table 3. below, indicate no significant differences between males and females in cognitive abilities. There was no correlation between systemising (cognitive style) and cognitive ability, however, cognitive ability did correlate significantly with achievement (r = .278**).

ANOVA of Aptitude for Science by Gender				
Gender	N	Mean (SD)	F (1, 103)	Sig.
Female	50	5.620 (1.369)	3.61	.060
Male	55	6.180 (1.634)		
Total	105	5.910 (1.532)		

Table 3.

SEM confirmed the hypothesized model. Mardia coefficients of multivariate kurtosis were relatively elevated in both groups, so the Robust method of estimation was used. The result indicates a good fit (CFI = .956, RMSEA = .063 (.055, .071), Satorra-Bentler scaled Chi-Square/DF = 319.08/112 = 2.85). LM and Wald tests did not indicate that constraints needed to be released or added to improve fit. Constraints on the equality of path coefficients were imposed and the LM test indicated no significant differences between path coefficients for males and females.

Appendix C

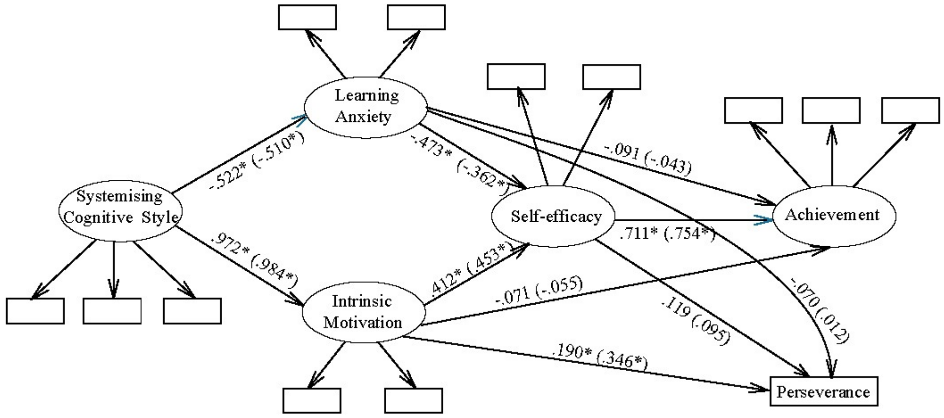

Figure 2

Conclusions

This study demonstrated no gender differences in relationships between variables, corroborating results of a number of studies which demonstrated gender differences in the means of variables, but no gender differences in relationships (*e.g.,* Simpkins, Davis-Kean & Eccles, 2006). However, males outperform females on SQ, a corroboration of the findings of Baron-Cohen *et al.,* (2003). Table 2 illustrates gender differences in the distribution of SQ: the two distributions are skewed in opposite directions, so that there are many more females low on systemising with many more males high on systemising. Being a low systemiser likely influences choices of young girls for out-of-school activities away from those involving mathematics/science. As Simpkins *et al.,* (2006) showed, these early childhood experiences guide choices of academic trajectory later on. In addition, as low systemisers, more females likely experienced a high cognitive load (Sweller, 2006) in mathematics/science classes and hence, increased learning anxiety. As our model demonstrates, this leads to lower self-efficacy beliefs amongst girls. Although self-efficacy beliefs are the key indicator of student achievement in this model, as in the findings of Hafner (2008), there are no significant gender differences in achievement. It is likely that females compensate for low systemizing with a higher level of study skills, but the extra effort and anxiety thereby induced during learning takes its toll in their perseverance. Strong links between systemising and intrinsic motivation and then to perseverance, indicate that low-systemising students are likely to abandon pursuit of science studies.

Importantly, we also demonstrated that aptitude for science (cognitive ability) does not correlate with systemizing (cognitive style), so lack of perseverance is not about ability, but about being comfortable and proficient at systemizing tasks inherent in studying science. Although cognitive style in Baron-Cohen's theory of mind (2002) is presented as a trait, Gredlein and Bjorkhead (2005) demonstrated that interventions in small children's play can increase use of an SQ. Thus, increasing students' interest in science careers and closing the gender gap may require intervention in young children's play, or as Sweller (2006) suggests, developing instructional designs that decrease the cognitive load of low systemisers, thereby increasing comfort and proficiency in searching for patterns.

The scientific importance of this study is threefold: 1. a variable, SQ, not previously studied, has been shown to impact on both achievement and perseverance in science studies; 2. the model indicates how the impact of SQ is mediated by learning anxiety, intrinsic motivation and self-efficacy; 3. offers a new perspective on the important problem of halting declining enrollment and closing the gender gap in SMET studies.

Bibliography

Bandura, A. (1997). *The Self-efficacy: The Exercise of Control.* New York Freeman Press.

Baron-Cohen, S. (2002). The Extreme Brain Theory of Autism. *Trends in Cognitive Sciences*, 6(6), 248-254.

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N. & Wheelwright, S. (2003). The systemizing quotient: an investigation of adults with Asperger syndrome or high-functioning autism, and normal sex differences. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 358, 361-374.

Bar-On, R. (2006). The Bar-On model of emotional-social intelligence (ESI). *Psicothema,* 18, suppl., 13-25.

Benbow, C. P., Lubinski, D., Shea D. L. & Eftekhari-Sanjani, H. (2000). Sex Differences in Mathematical Reasoning Ability at Age 13: Their Status 20 Years Later. *Psychological Science*, 2, 6, 474-480.

Bentler, P. M. (1995). *EQS 6 Structural Equations Program Manual*. Multivariate Software, Inc. Encino, CA.

Black, A. E. & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination perspective. *Science Education, 84*, 6, 740-766.

Billington, J., Baron-Cohen, S. & Wheelwright, S. (2006). Cognitive style predicts entry into physical sciences and humanities: Questionnaire and performance tests of empathy and systemizing. *Learning and Individual Differences*, 17, 260-268.

Byrne, B. M. (2006). *Structural equation modeling with EQS and EQS/Windows: Basic concepts, application and programming*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Catsambis, S. (2005). The gender gap in mathematics: Merely a step function? In A. M. Gallagher & J. C. Kaufman (Eds.), *Gender differences in mathematics* (pp. 220-245). Cambridge, UK: Cambridge University Press.

Delisle, M.-N., Guay, F., Senecal, C. & Larose, S. (in press). Predicting Stereotype Endorsement and Academic Motivation in Women in Science Programs: A Longitudinal Model. *Learning and Individual Differences*.

Goetz, T., Preckel, F., Pekrun, R. & Hall, N. C. (2007). Emotional experiences during test taking: Does cognitive ability make a difference? *Learning and Individual Differences*, 17, 1, 3-16.

Gredlein, J. M. & Bjorkhead, D. F. (2005). Sex Differences in Young Children Use of Tools in a Problem-Solving Task: The Role of Object Oriented Play. *Human Nature - Biosocial Perspective*, 16, 211-232.

Hafner, E. W. (2008). *The relationship between math anxiety, math self-efficacy, and achievement among a sample of eighth grade students.* Dissertation Abstracts International Section A: Humanities and Social Sciences. Vol 69(2-A), 2008, pp. 503

Kimura, D. (1999). *Sex and Cognition*. Cambridge, MA: MIT Press

Ratelle, C. F., Guay, F., Larose, S. & Senecal, C. (2004). Family Correlates of Trajectories of of Academic Motivation During: A Semiparametric Group-Based Approach. *Journal of Educational Psychology*, 96(4), 745-754.

National Science Foundation: Division of Science Resources Statistics (2004). *Education, Women, Minorities, and Persons with Disabilities in Science and Engineering.* NSF 04-317, Arlington, VA. Retrieved July 13, 2009, from http://www.nsf.gov/statistics/wmpd/pdf/nsf04317.pdf

OECD (2006). *Evolution of Student Interest in Science and Technology Studies.* Policy Report. Global Science Forum: Organisation for Economic Co-operation and Development

Pajares, F. (1996). Self-efficacy Beliefs in Academic Settings. *Review of Educational Research*, 66, 543-578.

Pekrun, R., Goetz, T., Titz, W. & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational Psychologist, 37*(2), 91-105.

Pintrich, P. R., Smith D. A. F., Garcia, T. & McKeachie, W. J. (1991). *A Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ).* Ann Arbor, MI: National Center for Research to Improve Postsecondary Teaching and Learning.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology,* 25, 54-67.

Seymour, E. & Hewitt, N. 1997. *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview.

Simpkins, S. D., Davis-Kean, P. E. & Eccles, J. C. (2006). Math and Science Motivation: Longitudinal Examination of the Links between Choices and Beliefs. *Developmental Psychology,* 40, 1, 70-83.

Sweller, J. (2006). Discussion of 'Emerging Topics in Cognitive Load Research: Using Learner and Information Characteristics in the Design of Powerful Learning Environments. *Applied Cogmitive Psychology*, 20, 353-357.

Tabachnik, B. G. & Fidel, L. S. (2001). *Using multivariate statistics*. 4th ed. Boston; London: Allyn and Bacon.

Tobias, S. (1990). *They're not dumb, they're different: Stalking the second tier. An occasional paper on neglected problems in science education*. Tucson, AR: Research Corporation.

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Brière, N. M., Senécal, C. B. & Vallières, E. F. (1992). The Academic Motivation Scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and Psychological Measurement*, *52*, 1003-1019.

Xie, Y. & Shauman, K. A. (2003). *Women in Science: Career Processes and Outcomes.* p.p. 3-4, Cambridge, MA: Harvard University Press.

The first questionnaire (as administered in August/September 2007):

Survey of Student Perceptions of Science Experiences

It is important to understand that there are no right or wrong answers to the questions below. Your answers should reflect what you actually and honestly think. Try not to get stuck on any particular question. Instead, respond with what comes to mind when you read the question.

Please do not make marks on the questionnaire itself.
Use a dark pencil and mark one answer per item on the NCS Answer sheet.

Thank you in advance for your cooperation.

1. Please begin by entering your last name, your first name, and the CÉGEP Identity # that you have been given. Please enter these both in printed letters (in the appropriate spaces) and by colouring the opscan letters with your pencil.

2. Next, in the area labelled IDENTIFICATION NUMBER, please enter your student I.D., both by printing on top and colouring the opscan letters with your pencil.

3. Now proceed to the questions on the next page. As you work through the questionnaire, please be careful to read all instructions.

Appendix D

The following twelve questions refer to emotions you may have felt when studying physics. Before answering those questions, please, recall some typical situations you had experienced. Please use the following scale when responding:

1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree

1. Things I have to do when learning physics are tiresome.
2. I am tense when studying physics.
3. When I study physics, I am in a good mood.
4. Physics is so boring that I get tired just thinking about it.
5. I worry whether physics is much too difficult for me.
6. I enjoy the challenge of learning physics.
7. I feel sick when thinking about doing physics problems.
8. I get so nervous that I have difficulty beginning to study physics.
9. I can't stop daydreaming when I study physics because physics is so dull.
10. It bores me to study physics.
11. I study physics more extensively than is necessary because doing so is fun for me.
12. Physics is so enjoyable that I look forward to learning more physics.

The following twelve questions refer to emotions you may have felt when studying biology or environmental science. Before answering those questions, please, recall some typical situations you had experienced. Please use the following scale when responding: **1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree**

13. I enjoy the challenge of learning biology.
14. It bores me to study biology.
15. I study biology more extensively than is necessary because doing so is fun for me.
16. Biology is so enjoyable that I look forward to learning more biology.
17. I worry whether biology is much too difficult for me.
18. Things I have to do when learning biology are tiresome.
19. I am tense when studying biology.
20. Biology is so boring that I get tired just thinking about it.
21. When I study biology, I am in a good mood.
22. I can't stop daydreaming when I study biology because biology is so dull.
23. I feel sick when thinking about reading for biology.
24. I get so nervous that I have difficulty beginning to study biology.

The following questions concern your perceptions of interactions with your parents. Please use the following scale when responding: **1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree**

25. My parents tell me how to run my life.
26. My parents take my opinions seriously.
27. My parents have high expectations of me because they believe in me.
28. My parents encourage me to decide things for myself.
29. My parents often seem to be disappointed in me.
30. My parents taught me that hard work is the road to competence.
31. My parents insist upon my doing things their way.
32. My parents are proud of me and my accomplishments.
33. My parents encourage me to work hard to get the best marks possible in science.
34. My parents, whenever possible, allow me to make my own choices.
35. My parents often criticize my opinion.
36. My parents always told me that in school I can accomplish anything I want to, if I set my mind to it.

The following questions still concern interactions with your parents. Please respond how often the events described below took place while you were younger: **1. Never 2. Few times 3. Often 4. Very often**
When I was growing up ..
37. my parents explained natural phenomena to me.
38. my parents took me to visit a science museum, aquarium, *etc*.
39. my parents excitedly discussed new scientific discoveries.
40. my parents and I had debates about science.
41. my parents expressed high esteem for the work of scientists.

The following questions concern your perceptions of science classes/teachers. When answering these questions, please, think about one particular class/teacher and tell us which class you are thinking of:
42. **1. Secondary IV math 2. Physical Science 3. Secondary V math 4. Chemistry 5. Physics**

Please use the following scale when responding these questions:
1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree
43. My teacher discussed new scientific discoveries in class.
44. My science teacher was enthusiastic about his/her subject.
45. I felt that my science teacher provided us with choices and options concerning learning the subject.
46. My science teacher communicated his/her confidence in my ability to do well in the course.
47. I felt like my science teacher understood me.
48. My teacher recommended that we watch TV shows about science, *e.g.,* NOVA.
49. My teacher made me feel that science is a dry subject.
50. My science teacher encouraged me to think for myself.
51. My science teacher made me feel that making mistakes is a normal part of learning.
52. I felt that my science teacher cared about me as a person.
53. My teacher made me feel that being a scientist is cool.
54. Demonstrations in science classes made me want to get involved.
55. Science classes stimulated me to think along with my teacher as s/he explained new ideas.
56. My science teacher tried to ensure that students felt confident and competent in the course.
57. My science teacher earned my trust.
58. My teacher made us debate and take sides on controversial issues (*e.g.,* genetically engineered food, global warming, funding of space exploration).
59. My teacher made me feel that doing science is just a lot of work with no excitement.
60. My science teacher often taught us several ways of solving the same problem, giving us options to choose when solving problems ourselves.
61. My science teacher treated my opinions with respect.
62. I didn't feel very good about the way my science teacher talked to me.

The following questions concern your reasons for taking science courses. Please use the following scale when responding to the next question.
1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree
63. The knowledge I gain in science courses is important to me.
64. What I learn in science classes appears useless to me.
65. I don’t really have a specific reason for studying science, it is just important to me.
66. Science courses are a valuable part of my education.

Appendix D

Please answer the following twelve questions either **1. No** or **2. Yes**.
I value science courses because **...**

67. it is required by my chosen program at university.
68. I think that doing science is cool.
69. my parents insist that I take them.
70. my friends are also taking them.
71. scientific ideas are needed to solve the biggest problems in our society.
72. I need them to have a career that pays a lot of money.
73. it allows me to keep my career options open.
74. most jobs require the skills learned in science courses.
75. science is a field highly regarded by society.
76. science gives me the most powerful tools to contribute positively to society.
77. science makes me think deeper of why things are the way they are.
78. I am more capable of doing well in science than in any other field.
79. although I prefer arts I believe sciences are necessary for becoming a well rounded person.

The following six questions concern your beliefs about sciences. Please use the following scale when responding:

1. Disagree **2. Mostly Disagree** **3. Mostly Agree** **4. Agree**

80. The most difficult step when I try to solve a science problem is deciding which information is relevant to the problem and which is not.
81. As scientists learn more, most scientific ideas that we use in technologies today are likely to be proven wrong.
82. Usually, there is only one correct approach to solving a science problem.
83. Equations do not help my understanding of ideas: they are just for doing calculations.
84. Knowledge in science consists of many disconnected topics.
85. It is easier to understand science ideas without mathematics.

The following questions concern reasons why you are enrolled (or intend to enrol in the future) in the science program. Please use the following scale when responding:

1. Strongly disagree **2. Disagree** **3. Agree** **4. Strongly agree**

86. Because without science it would be harder to get into university programs that lead to high paying jobs.
87. Because learning sciences is fun.
88. Because I think that knowledge of sciences will help me in my chosen career.
89. Honestly, I don’t know: I really feel that I am wasting my time in science courses.
90. To prove to myself that I am capable of graduating from the science program.
91. Because succeeding in the science program will help me to be accepted in highly rated universities.
92. Because I enjoy learning new things in science.
93. Because it will eventually help me to get a job in a field that I like.
94. I wonder why I continue to study sciences, I don’t like them.
95. Because I will feel good about myself after I succeed in the science program.
96. Because good grades in science courses are essential for admission to the best programs at University.
97. Because I enjoy learning sciences.
98. Because this will help me to study other subjects that I like.
99. I can’t see why I am studying in the science program because I really don’t care about the sciences.
100. To prove to myself that I am an intelligent person.
101. Because people who have a good knowledge of sciences get ahead of others.
102. Because I will learn interesting things in the science program.
103. Because the more I know about sciences, the more competent I will be in my chosen career.
104. I don’t know what I am doing in the science program.
105. Because I would be embarrassed if I did not succeed in the science program.

The following six questions concern your beliefs about your competence in mathematics and sciences. Please use the following scale when responding: **1. Strongly disagree 2. Disagree 3. Agree 4. Strongly agree**

106. I am unsure that my grades in the science program will be good.
107. I am confident that I will be able to correctly solve problems in mathematics and science courses.
108. I think I will have a good knowledge of concepts in mathematics and sciences when I graduate.
109. I will write exams in science and mathematics courses with much less confidence than exams in other subjects.
110. I will succeed in the science program.
111. I will be able to do even the most difficult problems in mathematics and science textbooks.

The second questionnaire (as administered in Spring 2008):

Survey of Student Perceptions of Science Experiences

It is important to understand that there are no right or wrong answers to the questions below. Your answers should reflect what you actually and honestly think. Try not to get stuck on any particular question. Instead, respond with what comes to mind when you read the question.

Please do not make marks on the questionnaire itself.
Use a dark pencil and mark one answer per item on the NCS Answer sheet.

Thank you in advance for your cooperation.

1. Please begin by entering your last name, and after a space your first name. Please enter these both in printed letters (in the appropriate spaces) and by colouring the opscan letters with your pencil.

2. Next, in the area labelled IDENTIFICATION NUMBER, please enter your student I.D., both by printing on top and colouring the opscan letters with your pencil.

3. Now proceed to the questions on the next page. As you work through the questionnaire, please be careful to read all instructions.

Appendix E

The following twelve questions refer to emotions you may have felt when studying physics at CEGEP last term. Before answering those questions, please, recall some typical situations you had experienced. If you did not take a physics course in the Fall 2007 term, then skip Items 1.- 12. below and go directly to the instructions above Item 13.

Please use the following scale when responding:

1. Disagree **2. Mostly Disagree** **3. Mostly Agree** **4. Agree**

1. Things I have to do when learning physics are tiresome.
2. I am tense when studying physics.
3. When I study physics, I am in a good mood.
4. Physics is so boring that I get tired just thinking about it.
5. I worry whether physics is much too difficult for me.
6. I enjoy the challenge of learning physics.
7. I feel sick when thinking about doing physics problems.
8. I get so nervous that I have difficulty beginning to study physics.
9. I can't stop daydreaming when I study physics because physics is so dull.
10. It bores me to study physics.
11. I study physics more extensively than is necessary because doing so is fun for me.
12. Physics is so enjoyable that I look forward to learning more physics.

The following twelve questions refer to emotions you may have felt when studying chemistry at CEGEP last term. Before answering those questions, please, recall some typical situations you had experienced. If you did not take a chemistry course in the Fall 2007 term, then skip Items 13.- 24. below and go directly to the instructions above Item 25.

Please use the following scale when responding:

1. Disagree **2. Mostly Disagree** **3. Mostly Agree** **4. Agree**

13. I enjoy the challenge of learning chemistry.
14. It bores me to study chemistry.
15. I study chemistry more extensively than is necessary because doing so is fun for me.
16. Chemistry is so enjoyable that I look forward to learning more chemistry.
17. I worry whether chemistry is much too difficult for me.
18. Things I have to do when learning chemistry are tiresome.
19. I am tense when studying chemistry.
20. Chemistry is so boring that I get tired just thinking about it.
21. When I study chemistry, I am in a good mood.
22. I can't stop daydreaming when I study chemistry because chemistry is so dull.
23. I feel sick when thinking about reading for chemistry.
24. I get so nervous that I have difficulty beginning to study chemistry.

The following questions concern your perceptions of science classes/teachers at CEGEP last term. When answering these questions, please, think about one particular class/teacher and tell us which class you are thinking of:

25. **1. Mathematics 2. Chemistry 3. Physics**

N.B. If you chose **1. Mathematics** above, the wording of a few of the following questions may seem odd, but we are confident that you can reinterpret the question to apply to a Mathematics class so please do so.

Please use the following scale when responding:

1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree

26. My teacher discussed new scientific discoveries in class.
27. My science teacher was enthusiastic about his/her subject.
28. I felt that my science teacher provided us with choices and options concerning learning the subject.
29. My science teacher communicated his/her confidence in my ability to do well in the course.
30. I felt like my science teacher understood me.
31. My teacher recommended that we watch TV shows about science, *e.g.,* NOVA.
32. My teacher made me feel that science is a dry subject.
33. My science teacher encouraged me to think for myself.
34. My science teacher made me feel that making mistakes is a normal part of learning.
35. I felt that my science teacher cared about me as a person.

Please use the following scale when responding:

1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree

36. My teacher made me feel that being a scientist is cool.
37. Demonstrations in science classes made me want to get involved.
38. Science classes stimulated me to think along with my teacher as s/he explained new ideas.
39. My science teacher tried to ensure that students felt confident and competent in the course.
40. My science teacher earned my trust.
41. My teacher made us debate and take sides on controversial issues (*e.g.,* genetically engineered food, global warming, funding of space exploration).
42. My teacher made me feel that doing science is just a lot of work with no excitement.
43. My science teacher often taught us several ways of solving the same problem, giving us options to choose when solving problems ourselves.
44. My science teacher treated my opinions with respect.
45. I didn't feel very good about the way my science teacher talked to me.

Appendix E

The following questions concern reasons why you are enrolled (or intend to enrol in the future) in the science program. Please use the following scale when responding:

1. Strongly disagree **2. Disagree** **3. Agree** **4. Strongly agree**

46. Because without science it would be harder to get into university programs that lead to high paying jobs.
47. Because learning sciences is fun.
48. Because I think that knowledge of sciences will help me in my chosen career.
49. Honestly, I don't know: I really feel that I am wasting my time in science courses.
50. To prove to myself that I am capable of graduating from the science program.
51. Because succeeding in the science program will help me to be accepted in highly rated universities.
52. Because I enjoy learning new things in science.
53. Because it will eventually help me to get a job in a field that I like.
54. I wonder why I continue to study sciences, I don't like them.
55. Because I will feel good about myself after I succeed in the science program.
56. Because good grades in science courses are essential for admission to the best programs at University.
57. Because I enjoy learning sciences.
58. Because this will help me to study other subjects that I like.
59. I can't see why I am studying in the science program because I really don't care about the sciences.
60. To prove to myself that I am an intelligent person.
61. Because people who have a good knowledge of sciences get ahead of others.
62. Because I will learn interesting things in the science program.
63. Because the more I know about sciences, the more competent I will be in my chosen career.
64. I don't know what I am doing in the science program.
65. Because I would be embarrassed if I did not succeed in the science program.

The following five questions concern your beliefs about your competence in mathematics and sciences. Please use the following scale when responding:

1. Strongly disagree **2. Disagree** **3. Agree** **4. Strongly agree**

66. I am confident that I will be able to correctly solve problems in mathematics and science courses.
67. I think I will have a good knowledge of concepts in mathematics and sciences when I graduate.
68. I will write exams in science and mathematics courses with much less confidence than exams in other subjects.
69. I will succeed in the science program.
70. I will be able to do even the most difficult problems in mathematics and science textbooks.

The following twelve questions concern your interest into factual, systematic phenomena. Please use the following scale when responding:

1. Strongly disagree **2. Disagree** **3. Agree** **4. Strongly agree**

71. I am not interested in understanding how new technology (*e.g.,* wireless communication) works.
72. I am fascinated by how machines work.
73. I can easily remember large amounts of information about a topic that interests me (*e.g.*, songs, movies, sports teams, books)
74. I do not enjoy games that involve a high degree of strategy (*e.g.,* chess).

Please use the following scale when responding:

1. Strongly disagree **2. Disagree** **3. Agree** **4. Strongly agree**

75. I find it easy to read and understand maps.
76. I do not tend to watch science documentaries on TV or read articles about science or nature.
77. I find it easy to understand instruction manuals for putting things together.
78. I rarely read web pages or articles about new technology.
79. I find it difficult to learn how to use all the features of a new cell-phone.
80. If I were buying a computer, I would want to know the exact details of its technical specifications (*e.g.,* hard drive capacity or processor speed).
81. I find it difficult to interpret a graph if it does not have an accompanying explanation.
82. When I read a news article, I am drawn to tables of information, such as hockey scores or stock market indices.

The following five questions concern your social skills.

Please use the following scale when responding:

1. Strongly disagree **2. Disagree** **3. Agree** **4. Strongly agree**

83. I can pick up quickly if someone says one thing but means another.
84. I am quick to spot when someone in a group is feeling awkward or uncomfortable.
85. I find it difficult to judge if someone else is interested or bored with what I am saying.
86. I can rapidly and intuitively tune into how someone else feels.
87. It is hard for me to tell if someone is masking her/his true emotions.

The following questions ask for basic demographic data.

88. What is the annual income (before taxes) of your family *per person*? If you are no longer supported by your family use your own annual income.

1. less than 10000$/person 2. 10000$ to 20000$/person 3. 20000$ to 30000$/person 4. more than 30000$/person

89. Did you hold a paid job during the last semester?

    1. No 2. less than 12 hrs/week 3. 12 hrs/week to 30 hrs/week 4. more than 30 hrs/week

90. Keeping in mind your parent who has the highest level of education, the highest level of courses that this parent followed were in:

    1. High-school 2. College 3. University 4. Post-graduate studies

91. For the same parent as in the previous question, what is the highest educational level at which she/he took science/mathematics courses?

    1. High-school 2. College 3. University 4. Post-graduate studies

92. Besides the common Canadian/Quebecois cultures that surround us all here in Montreal, what ethno-cultural environment has had an impact on your identity? (Think about holidays that you celebrate, foods that you eat frequently, extended family and friends that you have extensive contact with.)

    1. East Asian 2. South-East Asian 3. South Asian 4. Middle Eastern 5. European 6. African 6. Carribean 7. Latin American 8. Other 9. Quebecois/Canadian/North American only

    East Asia = China, Japan, Korea, Taiwan, Vietnam
    South-East Asia = Burma, Cambodia, Indonesia, Laos, Malaysia, Phillippines, Thailand
    South Asia = Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka

N.B. If you selected **8. Other** above, then please write (in pencil) what that culture is using the bottom margin of the second (back) side of your opscan sheet.

Thank You For Your Participation!

The third questionnaire (as administered in Spring 2009):

Survey of Student Perceptions and Intentions

It is important to understand that there are no right or wrong answers to the questions in Part I below. Your answers should reflect what you actually and honestly think. Try not to dwell on any particular question. Instead, respond with what comes to mind when you read the question. Please try to answer all questions that apply to you.

Please do not make marks on the questionnaire itself.

Use a dark pencil and mark one answer per item on the opscan sheet.

Thank you in advance for your cooperation.

Please begin by entering your last (family) name, your first (given) name, and your CÉGEP Student Number. Please enter these **both** in printed letters (in the appropriate spaces) and by colouring the Opscan letters/numbers with your pencil.

NB: We take the confidentiality of your answers very seriously. We need your name and student number to connect your answers to these questions to the answers you gave us in previous questionnaires.

Now proceed to the questions. As you work through the questionnaire, please be careful to read all instructions.

Part I:

1. Did you apply before March 1, 2009 for admission to study at a University?
   1. Yes 2. No

If you answered 2. (No) for Item 1. above, then skip Items 2. and 3. below and go directly to Item 4.

2. Since you answered yes to Item 1. above, how many distinct programs did you apply to?
   1. One 2. Two 3. Three 4. Four 5. Five 6. Six 7. Seven 8. Eight 9. Nine 10. Ten or more

3. Amongst your applications to University how many are to science/engineering programs?
   (examples: Architecture, Biology, Biochemistry, Chemistry, Computer Science, Dentistry, Earth and Planetary Sciences, Engineering, Geology, Mathematics, Medicine, Nursing, Physiotherapy, Physics)
   1. None 2. Some 3. Most 4. All

If you answered Items 2. and 3. above, then skip Items 4. and 5. below and go directly to Item 6.

4. Do you intend to attend University?
   1. Yes 2. No

If you answered 2. (No) for Item 4. above, then skip Item 5. below and go directly to Item 6.

5. Since you answered yes to Item 4. above, on a list of possible programs that you are thinking of applying to, how many will be science/engineering programs?
   (examples: Architecture, Biology, Biochemistry, Chemistry, Computer Science, Dentistry, Earth and Planetary Sciences, Engineering, Geology, Mathematics, Medicine, Nursing, Physiotherapy, Physics)
   1. None 2. Some 3. Most 4. All

The following twelve questions refer to emotions you may have felt when studying mathematics at CEGEP. Before answering those questions, please, recall some typical situations you had experienced.
Please use the following scale when responding:

1. Disagree **2. Mostly Disagree** **3. Mostly Agree** **4. Agree**

6. Things I have to do when learning mathematics are tiresome.
7. I am tense when studying mathematics.
8. When I study mathematics, I am in a good mood.
9. Mathematics is so boring that I get tired just thinking about it.
10. I worry whether mathematics is much too difficult for me.
11. I enjoy the challenge of learning mathematics.
12. I feel sick when thinking about doing mathematics problems.
13. I get so nervous that I have difficulty beginning to study mathematics.
14. I can't stop daydreaming when I study mathematics because mathematics is so dull.
15. It bores me to study mathematics.
16. I study mathematics more extensively than is necessary because doing so is fun for me.
17. Mathematics is so enjoyable that I look forward to learning more mathematics.

The following twelve questions concern your interest in factual, systematic phenomena.
Please use the following scale when responding:

1. Strongly disagree **2. Disagree** **3. Agree** **4. Strongly agree**

18. When doing household chores (*e.g.*, laundry, dishes, cleaning) it is more important that I follow a particular routine than to finish rapidly.
19. I am fascinated by how machines work.
20. I can easily remember large amounts of information about a topic that interests me (*e.g.*, songs, movies, sports teams, books).
21. When facing a puzzle I use trial and error guessing until I get the answer.
22. I find it easy to read and understand maps.
23. I do not tend to watch science documentaries on TV or read articles about science or nature.
24. I find it easy to understand instruction manuals for putting things together.
25. I rarely read web pages or articles about new technology.
26. I find it difficult to learn how to use all the features of a new cell-phone.
27. If I were buying a computer, I would want to know the exact details of its technical specifications (*e.g.,* hard drive capacity, processor speed, etc).
28. I find it difficult to interpret a graph if it does not have an accompanying paragraph of explanation.
29. I look for patterns in order to help me remember phone numbers.

There are 10 more questions in a separate questionnaire, but they must be answered on the same Opscan sheet. Please do that now. Again, do not write on the questionnaire itself, just on the Opscan sheet.

However, at this point we want to thank you for your cooperation and wish you all the best in your future studies and careers.

Next fall we intend to complete the analysis of data that you gave us over the last two years and we would be very pleased to share our findings with you if you are interested. To obtain a copy of the report, please contact the Principal Investigator for this research project, Dr. Ivan Ivanov at ivanovi@vaniercollege.qc.ca.

Consent form used with questionnaires:

Attracting and Retaining Science Students

Directions to the Student

A team of researchers from Champlain, Dawson, John Abbott and Vanier is investigating the reasons why students choose or do not choose to pursue further studies in science. Since you are in or hope to be in the CEGEP Science Program, we would like you to participate in this research by filling in questionnaires inquiring about your views about science/mathematics education and by allowing the college registrar, the Ministry of Education, Sports and Leisure of Quebec or other Quebec Government Ministries to provide us with information in your file. If you are interested in more information, or the results of this research, please contact the project director, Ivan Ivanov, by telephone at (514) 744-7500-2-7737, or by e-mail at ivanovi@vaniercollege.qc.ca.

I, the undersigned, consent to participate with the assurance that the data will be kept **confidential** and in **no way affect my academic record at CEGEP**. I understand that I have the right to refuse to participate at any time, and that such a refusal would also in no way affect my academic record at CEGEP. Further, I understand that should I decide to participate at this time, I can subsequently change my mind by sending an e-mail to the project director, **Ivan Ivanov**, at **ivanovi@vaniercollege.qc.ca**, informing him of my decision. In such a circumstance, all data that I have contributed will be withdrawn and my decision will also in no way affect my academic record at CEGEP or elsewhere.

DATE: ________________________

PRINT YOUR FIRST NAME: ____
(Given Name)

PRINT YOUR LAST NAME: ____
(Family Name)

STUDENT #: ________________________

SIGNATURE: ____

Pilot test 1.

This test was carried out during the summer session, E'07, at Vanier College. The participants were all students in science and mathematics classes. Their instructors allowed us to administer the questionnaire in their classes. The sample size was N=199. The table below shows the results of the LCFA and α-Cronbach of each scale:

# items	variable	LCFA	Latent Factor	#items	α-Cronbach
12	Academic emotions in physics	Confirmed	boredom	4	0.767
			anxiety	4	0.779
			enjoyment	4	0.753
12	Academic emotions in biology	Confirmed	boredom	4	0.798
			anxiety	4	0.784
			enjoyment	4	0.836
29	parental support of	Confirmed model with 4 factors and 17 items	autonomy	4	0.773
			competence	4	0.772
			competence due effort	4	0.793
			science culture	5	0.786
33	Instructors' support of	Confirmed model with 5 factors and 20 items	science culture	4	0.702
			interest in sciences	4	0.677
			autonomy	4	0.744
			competence	4	0.773
			relatedness	4	0.763

The questionnaire that was tested follows:

Survey of Student Perceptions of Science Experiences

It is important to understand that there are no right or wrong answers to the questions below. Your answers should reflect what you actually and honestly think. Try not to dwell on any particular question. Instead, respond with what comes to mind when you read the question.

Please do not make marks on the questionnaire itself.
Use a dark pencil and mark one answer per item on the NCS Answer sheet.

Thank you in advance for your cooperation.
Please do not enter any identifying information (no name, birth date, student identity number, course or section number etc.) on the NCS Answer sheet. Proceed directly to the questions on the pages below, answering only on the NCS Answer sheet.

Appendix H

The following twelve questions refer to emotions you may have felt when studying physics. Before answering those questions, please, recall some typical situations you had experienced. Please use the following scale when responding:
1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree

1. Things I have to do when learning physics are tedious.
2. I am tense when studying physics.
3. When I study physics, I am in a good mood.
4. Physics is so boring that I get tired just thinking about it.
5. I worry whether physics is much too difficult for me.
6. I enjoy the challenge of learning physics.
7. When thinking about physics, I get queasy.
8. I get so nervous that I have difficulty to begin studying physics.
9. I can't stop daydreaming when I study physics because physics is so dull.
10. It bores me to study physics.
11. I study physics more extensively than is necessary because doing so is fun for me.
12. Physics is so enjoyable that I look forward to learning more physics.

The following twelve questions refer to emotions you may have felt when studying biology. Before answering those questions, please, recall some typical situations you had experienced. Please use the following scale when responding:
1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree

13. I enjoy the challenge of learning biology.
14. It bores me to study biology.
15. I study biology more extensively than is necessary because doing so is fun for me.
16. Biology is so enjoyable that I look forward to learning more biology.
17. I worry whether biology is much too difficult for me.
18. Things I have to do when learning biology are tedious.
19. I am tense when studying biology.
20. Biology is so boring that I get tired just thinking about it.
21. When I study biology, I am in a good mood.
22. I can't stop daydreaming when I study biology because biology is so dull.
23. When thinking about biology, I get queasy.
24. I get so nervous that I have difficulty to begin studying biology.

The following five questions concern your perceptions of interactions with your parents. Please use the following scale when responding: **1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree**

25. My parents tell me how to run my life.
26. My parents, whenever possible, allow me to make my own choices.
27. My parents allow me to solve my problems by myself.
28. My parents encourage me to decide things for myself.
29. My parents insist upon my doing things their way.

The following nine questions concern your perceptions of interactions with your parents. Please use the following scale when responding: **1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree**

30. My parents take my opinions seriously.
31. My parents often seem to be disappointed in me.
32. My parents are proud of me and my accomplishments.
33. My parents often criticize my opinion.
34. My parents trust that I know what I am talking about.
35. My parents have high expectations of me because they believe in me.
36. My parents taught me that hard work is the road to competence.
37. My parents encourage me to work hard to get the best grades possible in science.
38. My parents always told me that if I set my mind to it I can accomplish anything I want to in school.

The following fifteen questions concern your childhood. Please answer either **1. No** or **2. Yes**
When I was young ...
39. my parents gave me books about science, *e.g.,* about dinosaurs, plants.
40. my parents understood that when I took my toys apart, I was trying to figure out how they worked.
41. I played games with my parents that involved counting.
42. my parents encouraged me to observe nature *e.g.,* animals, stars.
43. my parents and I built models.
44. my parents explained natural phenomena to me.
45. my parents and I watched TV shows like those on Discovery channel.
46. we visited science museums, aquariums *etc*.

Please answer either **1. No** or **2. Yes**
and as I became older ...
47. my parents discussed controversial scientific issues such as cloning, nuclear power *etc*., with me.
48. my parents were excited about new scientific discoveries.
49. my parents and I often had debates about science.
50. my parents had high esteem for the work of scientists.
51. my parents had books about science at home.
52. my parents subscribed to science magazines.
53. my parents encouraged me to participate in science fairs.

The following thirty-two questions concern your perceptions of science classes/teachers in general. Please use the following scale when responding: **1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree**
54. My science teacher was enthusiastic about his/her subject.
55. My teacher made me feel that science is a dry subject.
56. My teacher discussed new scientific discoveries in class.
57. My teacher recommended that we watch TV shows about science, *e.g.,* NOVA.
58. Experiments in science classes bored me.
59. My teacher made me feel that being a scientist is cool.
60. My teacher made us debate and take sides on controversial issues (*e.g.,* genetically engineered food, global warming, funding of space exploration).
61. My teacher made me feel that doing science is just a lot of work with no excitement.
62. There were a lot of science books in our school library.

Please use the following scale when responding:
1. Disagree 2. Mostly Disagree 3. Mostly Agree 4. Agree
63. My teacher encouraged us to participate in science fairs.
64. I felt that my science teacher provided choices and options when teaching the subject.
65. My science teacher listened to how I would like to do things.
66. My science teacher tried to understand how I see things before suggesting another way.
67. My science teacher encouraged me to think for myself.
68. Science classes stimulated me to think along with my teacher as s/he explained new ideas.
69. My science teacher often taught us several ways of solving the same problem, giving us options to choose when solving problems ourselves.
70. My science teacher gave up class time to debate issues that students brought up.

Please use the following scale when responding:

1. Disagree **2. Mostly Disagree** **3. Mostly Agree** **4. Agree**

71. My science teacher insisted that we solve problems his/her way.
72. My science teacher conveyed confidence in my ability to do well in the course.
73. My science teacher made me feel that making mistakes is a normal part of learning.
74. My science teacher tried to ensure that students felt confident and competent in the course.
75. When I asked questions my science teacher made me feel stupid.
76. My science teacher treated my opinions with respect.
77. My classmates trusted me as being competent in science.
78. My science teacher encouraged me to share my solutions with my classmates.
79. My science teacher praised my better ideas in front of my peers.

Please use the following scale when responding.

1. Disagree **2. Mostly Disagree** **3. Mostly Agree** **4. Agree**

80. I felt understood by my science teacher.
81. I felt that my science teacher cared about me as a person.
82. My classmates supported me in my science studies.
83. I was able to be open with my science teacher during class.
84. I felt a lot of trust in my science teacher.
85. I didn't feel very good about the way my science teacher talked to me.
86. I felt alienated from other students in my science class.

The following fifteen questions concern your reasons for taking science courses. Please use the following scale when responding to the next question.

1. Disagree **2. Mostly Disagree** **3. Mostly Agree** **4. Agree**

87. The knowledge I gain in science courses is important to me.

Please answer either **1. No** or **2. Yes** for the following eleven questions.
I value science courses because **...**

88. they will lead to my chosen career.
89. they show me how to take better care of my health.
90. they explain how gadgets work.
91. I think that doing science is cool.
92. my parents insist on me taking them.
93. my friends are also taking them.
94. science ideas are needed to solve the biggest problems in our society.
95. they are needed for a career which will make me rich.
96. a career in science will make me famous.
97. it allows me to keep my career options open.
98. **Please write any other reasons in the white space on the top of side 2 of the NCS Answer sheet.**

Please use the following scale when responding.

1. Disagree **2. Mostly Disagree** **3. Mostly Agree** **4. Agree**

99. Mostly, I don’t have a specific reason for studying science, it just is important to me.
100. What I learn in science classes appears useless to me.
101. Although studying sciences might be useful, it is just too much work for me.

Appendix H

The following twelve questions concern your beliefs about science. Please use the following scale when responding:

1. Disagree **2. Mostly Disagree** **3. Mostly Agree** **4. Agree**

102. The most difficult step when I try to solve a science problem is to decide which information is relevant to the problem and which is not.
103. Knowledge in science consists of many disconnected topics.
104. As scientists learn more, most science ideas that we use in technologies today are likely to be proven wrong.
105. Usually, there is only one correct approach to solving a science problem.
106. Equations do not help my understanding of ideas, they are just for doing calculations.
107. Nearly everyone is capable of understanding science ideas taught in school, if they work at it.
108. The government has to approve new scientific ideas before they can be widely accepted.
109. Sometimes I have to solve a science problem more than one way to understand the idea behind it.
110. It is easier to understand science ideas without mathematics.
111. If I carefully perform the same experiment repeatedly, each time I will get the same numerical result.
112. Scientists build models of natural phenomena without personal bias.
113. Experimentally observed relationships between quantities are summarized by mathematical formulas.

Pilot test 2.

This test was carried out during the fall session, A'07, at Vanier College. The participants were all students in science and mathematics classes. Their instructors allowed us to administer the questionnaire in their classes.

The following questionnaire was tested in the second pilot test:

Survey of Students

It is important to understand that there are no right or wrong answers to the questions below. Your answers should reflect what you actually and honestly think. Try not to get stuck on any particular question. Instead, respond with what comes to mind when you read the question.

Please do not make marks on the questionnaire itself.
Use a dark pencil and mark one answer per item on the NCS Answer sheet.

Thank you in advance for your cooperation.

1. This survey is ANONYMOUS. Do not enter on the NCS answer sheet any information that would identify you personally, such as your name, birth date or correct student identity number.
2. In the area labelled IDENTIFICATION NUMBER, please enter 1111111 (seven 1's), colouring the opscan letters with your pencil.
3. In the area labelled SPECIAL CODES, please use your pencil to enter 0 if you are in the Science Program (or double DEC including Science), or 1 if you are in any other Program.
4. In the area labelled SEX, please use your pencil to enter your gender (**M**ale or **F**emale).
5. Now proceed to the questions below.

A=1=Strongly Agree B=2=Slightly Agree C=3=Slightly Disagree D=4=Strongly Disagree

1. I like music or book shops because they are clearly organized.
2. When I read something, I always notice whether it is grammatically correct.
3. I find it difficult to read and understand maps.
4. I find it difficult to learn how to use all the features of a new cell-phone.
5. If I had a collection (*e.g.*, CDs, coins, stamps), it would be highly organized.
6. I find it difficult to understand instruction manuals for putting things together.
7. I am not interested in understanding how wireless communication works.
8. I enjoy looking through catalogues of products to see the details of each product and how it compares to others.
9. I know, with reasonable accuracy, how much money has come in and gone out of my bank account each month.
10. I find it easy to grasp what chance I have of winning in a lottery.
11. I do not enjoy games that involve a high degree of strategy.
12. I am fascinated by how machines work.
13. I do not tend to watch science documentaries on TV or read articles about science or nature.
14. If someone stops to ask me for directions, I am able to do so for any part of my neighborhood.
15. I rarely read webpages or articles about new technology.
16. If I were buying a computer, I would want to know the exact details of its hard drive capacity and processor speed.
17. In mathematics, I am intrigued by the rules and patterns governing numbers.
18. When I read a newspaper, I am drawn to tables of information, such as hockey scores or stock market indices.
19. When I have a lot of shopping to do, I like to plan which stores I am going to visit and in what order.
20. If I participate in sports I keep track of the score at all times.

A=1=Strongly Agree B=2=Slightly Agree C=3=Slightly Disagree D=4=Strongly Disagree

21. I can easily tell if someone else wants to enter a conversation.
22. I find it hard to know what to do in social situations.
23. People often tell me that I went too far in driving my point home in a discussion.
24. I often find it difficult to judge whether something I did was rude or polite.
25. In a conversation, I tend to focus on my own thoughts rather than on what my listener might be thinking.
26. I can pick up quickly if someone says one thing but means another.
27. It is hard for me to see why some things upset people so much.
28. I find it easy to put myself in somebody else's shoes.
29. I am quick to spot when someone in a group is feeling awkward or uncomfortable.
30. If I say something that someone else is offended by, I think that that it is their problem, not mine.
31. Seeing people cry doesn't really upset me.
32. I do not find social situations confusing.
33. Other people tell me that I am good at understanding how they are feeling and what they are thinking.
34. When I talk to people, I tend to talk about their experiences rather than my own.
35. I can easily tell if someone else is interested or bored with what I am saying.
36. If I see a stranger in a group, I think that it is up to them to make an effort to join in.
37. I can tune into how someone else feels rapidly and intuitively.
38. I can tell if someone is masking their true emotions.
39. I tend to get emotionally involved with friends' problems.
40. I can usually appreciate other people's viewpoints, even if I don't agree with them.

Results of Pilot test 2:

The one factor model did not confirm for systemizing. Classical testing methodology, used on 7 of the systemizing items generated an α-Cronbach of .727. As a result, in the questionnaire used in A'07 we included additional items and will use the data collection from A07 to verify the reliability of this modified version of the scale.

The one factor model did confirm for empathizing. Classical testing methodology, used on 5 of the empathizing items generated an α-Cronbach of .794. As a result, in the questionnaire used in A'07 we included this scale.