### **Abstract**

To address continually decreasing enrolment and rising attrition in post-secondary STEM degree programs, particularly for women, the present study examined the utility of motivation and emotion variables to account for persistence and achievement in science in male and female students transitioning from high school to junior college. Consistent with self-determination theory (Deci & Ryan, 2012) and achievement-goal theory (Senko et al., 2011), structural equation modeling based on data from 1309 students from four English-language CEGEPs showed students’ achievement goals, self-efficacy, and perceived autonomy support to impact intrinsic motivation, emotions, and achievement that, in turn, predicted persistence in the science domain.

**Précis**

Afin d'adresser la baisse continue d'inscription et la hausse des taux d'attrition dans le cadre des programmes d'études en sciences, technologie, ingénerie et mathématiques au niveau post-secondaire, en particulier chez les femmes, la présente étude a examiné l'utilité des variables motivationelles et émotionelles quant à la prediction de la persistance et de la réussite en sciences chez les élèves de sexe masculin et féminin transitionant de l'école secondaire au premier cycle universitaire. Conformément à la théorie de l’autodétermination (Deci & Ryan, 2012) et de la théorie de la réalisation des buts (Senko et al., 2011), la modélisation par équation structurelle basée sur les données de 1309 élèves issues de quatre cégeps anglophones démontre que les objectifs de rendement des élèves, l'auto-efficacité, et le soutien perçu de l'autonomie, ont un impact envers la motivation intrinsèque, les émotions, et la réussite, ce qui prédit à son tour la persistance dans le domaine des sciences.

### **Exploring Student Persistence in STEM Programs: A Motivational Model**

Student persistence in STEM (Science, Technology, Engineering, and Mathematics) fields deserves close attention given the alarming attrition rates from such programs–especially for women–as well as current issues regarding the staffing and turnover of science teachers in various regions of North America (Ingersoll & May, 2012; Ingersoll & Perda, 2010). Over the past twenty years the number of college-bound students interested in STEM majors has dropped by 50% and approximately half of the students who do enter STEM programs transfer out before completing their degree (Chen, 2013; Daempfle, 2003). The physical sciences and engineering are at particular risk, with declines in the number of earned bachelor’s degrees and doctorates in these fields in the past decade (National Science Foundation, 2013; Xie & Achen, 2009). Research has found a significant influence of classroom factors (e.g., student-teacher interaction, pedagogy, classroom culture; Seymour & Hewitt, 1997; Tinto, 1997) as well as individual psychosocial factors within the student (e.g., motivation, achievement goals, self-efficacy) in determining whether students pursue their career aspirations (e.g., Vallerand, Fortier, & Guay, 1997). The present study aims at understanding the factors that influence students’ decisions to pursue their interests in the sciences beyond high school to CEGEP (i.e., junior college, see “Quebec’s CEGEP System”) by examining the role of a unique subset of variables (i.e., perceptions of the learning environment, self-efficacy, achievement goals, affect, motivation, and achievement) using structural equation modeling.

Traditionally, research about student persistence has focused on the causes of school dropout. However, many students change programs without actually leaving school. Much less research has examined student choices or decisions to change their academic or career aspirations. The area of science is particularly interesting since student attrition rates remain high from science and engineering programs despite the fact that the demand for qualified scientists and engineers outweighs the number of available individuals (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011). Furthermore, examining student persistence during the transition from high school to CEGEP is especially important given the fact that it is during this period that many capable students decide to abandon their plans to pursue their studies in the sciences. Finally, examining the situation in Quebec is particularly relevant given that Quebec universities graduate fewer science graduates than universities in member countries of the Organization for Economic Cooperation and Development (Baillargeon et al., 2001).

**Quebec’s CEGEP System**

The term CEGEP is an acronym for *collège d’enseignement général et professionnel* (College of General and Professional Education). A *Diplôme d'etudes collégiales* (DEC; Diploma of College Studies) is a requirement for all Quebec students who wish to pursue subsequent studies in Quebec universities. Students are admitted to the science programs at CEGEP on the basis of their performance in high school mathematics, chemistry, and physics courses. Typically, they must have an average of at least 70 to 80 percent in their high school science courses in order to be accepted into the CEGEP science program. Because of this stringent requirement, CEGEP science students are often the highest performing students from Quebec high schools. Examining newly admitted CEGEP students is particularly relevant given that it is during the transition from high school to university that approximately half of science-bound students decide to leave the sciences and switch to non-science majors, with the greatest loss of potential science students occurs just prior to, or shortly after, enrolment in college (Daempfle, 2003; Rosenfield et al., 2005). This finding is consistent with research showing that at every stage in the educational system, student interest in science and mathematics declines, especially amongst females (e.g., Riegle-Crumb, Moore, & Ramos-Wada, 2011).

**Gender and Persistence in STEM Disciplines**

When exploring issues of persistence in the sciences, it is essential to examine the role of gender. Males and females do not differ in their intrinsic aptitude for mathematics and science (e.g., Hyde, Lindberg, Linn, Ellis, & Williams, 2008), however, female’s subjective perceptions of efficacy and competence are lower for these subjects compared with males (e.g., Goetz, Bieg, [Lüdtke](http://pss.sagepub.com/search?author1=Oliver+L%C3%BCdtke&sortspec=date&submit=Submit), Pekrun, & Hall, 2013). At every level of education, science is the only academic domain in which more females tend to leave than males (Larose, Ratelle, Guay, Senecal, & Harvey, 2006; Mau, 2003). In Canada, recent reports reveal that only 17.7% of undergraduate students in engineering (Engineers Canada, 2012) and 26% of undergraduate students in mathematics, computer, and information sciences are female (AUCC, 2011).

Although 42% of high school students taking physics are women, this percentage drops significantly at the university level where women are underrepresented at both the undergraduate and graduate level. In 2010 in the U.S., just 20.3% of physics bachelor’s degrees, 22.6% of physics master’s degrees, and 19.4% of physics PhDs were awarded to women (National Science Foundation, 2013). In mathematics, computer and information sciences, architecture, and engineering and related services, women only represent between 22-30% of university graduates in Canada (Statistics Canada, 2010). By the time they reach graduate school, only 21% of doctoral students in engineering and 25% of doctoral students in mathematics, computer, and information sciences are women (AUCC, 2011; Engineers Canada, 2012). Therefore, although women have made significant gains in their participation in the field of science over the past few decades in Canada, these gains have not been manifested beyond education as many women continue to avoid considering the viability of a career in the sciences (e.g., 22.3% of STEM professionals, Statistics Canada, 2010; see also Ceci & Williams, 2010; Cheryan, 2012), and in the U.S., women represent approximately 26.8% of the science and engineering workforce (National Science Foundation, 2013).

**Motivation in Education**

 **Self-determination.** From an educational perspective, self-determination theory (SDT) focuses on the content of the goals that individuals have for learning and the learning context within which these goals are pursued (Deci & Ryan, 2012; Ryan & Deci, 2009). Motivated actions are perceived of as being self-determined when they are engaged in truly volitionally and when the perceived locus of control is internal to the self. With respect to student persistence, three basic psychological needs must be met in order to promote students’ continued interest and enjoyment of learning experiences: autonomy, competence, and relatedness. *Autonomy* refers to the students’ perceptions that the learning environment is interactive rather than controlled. Students need to feel that they have some control over what is being taught and that their thoughts and feelings about the material are being acknowledged and integrated (Filak & Sheldon, 2003). *Competence* (cf. academic self-efficacy, e.g., Fortier, Vallerand, & Guay, 1995) refers to students’ perceptions that they are effective in their learning, and that they have opportunities to exercise and express their capabilities. *Relatedness* refers to the need to interact with others in order to promote the enjoyment of a task or lesson. SDT proposes that when students feel autonomous (rather than controlled), competent (or self-efficacious), and related, they are more likely to be *intrinsically motivated* and to adopt intrinsic goals that promote continued interest and persistence in a given subject area. Examining persistence in science using an SDT framework may therefore shed some light on how science educators can implement certain practices in the classroom to ensure that the conditions necessary for self-determined motivation are present.

Researchers have examined the influence of autonomy-supportive versus controlling teacher practices on students’ classroom performance and persistence (e.g., Reeve, 2009; Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004). Researchers demonstrated that controlling behaviors such as imposing strict deadlines, not allowing students to voice opinions different from those expressed by the teacher, and continually giving directives to students undermine intrinsic motivation by increasing negative feelings and reducing students’ active engagement in their learning (Assor, Kaplan, Kanat-Maymon, & Roth, 2005; Deci & Ryan, 2012). Contrarily, autonomy-supportive teachers who offer choices to students, allow students to work at their preferred pace, and who build on students’ prior knowledge, promote students’ active engagement in their learning, thereby increasing their intrinsic motivation to learn (e.g., Reeve, Jang, Carrell, Barch, & Jeon, 2004). When students feel engaged and involved in their learning and interested in class material, they tend to adopt mastery goals, which in turn predicted intrinsic motivation and performance (e.g., Church, Elliot, & Gable, 2001). Students who perceive the teacher as controlling and solely concerned with student performance as opposed to student learning tend to adopt performance goals, which in turn predict their performance but not their intrinsic motivation.

**Self-efficacy.** From an SDT perspective, perceptions of self-efficacy in students can be understood as evidence of having supported students’ need for competence, with domain-specific, self-report measures of self-efficacy (e.g., in science) often serving as proxies for need for competence (e.g., Van den Broeck, Vansteenkiste, De Witte, Soenens, & Lens, 2010). More specifically, self-efficacy is a performance-based measure of perceived capability rather than a measure of personal qualities such as one’s physical or psychological characteristics. As the central construct in social cognitive theory (Bandura, 1986), self-efficacy is defined as “the belief in one’s capability to organize and execute the courses of action required to produce given attainments” (Bandura, 1997, p. 2). Efficacy beliefs affect behavior by influencing the choices people make, the courses of action they pursue, the amount of effort they will expend, and their persistence in the face of difficulty or failure (Bandura, 1997). Pajares (1996) argues that the higher the sense of self-efficacy, the greater the effort, persistence, and resilience. Hence, self-efficacy is a very relevant variable to account for in attempting to explain persistence in science from high school to college, especially since research has shown that science and mathematics self-efficacy beliefs are increasingly likely to decline during school transitions (e.g., Watt, 2004).

Self-efficacy has been identified as a major influence on student performance and persistence (e.g., Schunk & Pajares, 2005). STEM self-efficacy beliefs have been shown to influence such key indices of academic motivation as choice of activities and goals, persistence, and emotional reactions (e.g., Lent, Lopez, Sheu, & Lopez, 2011). Self-efficacious students participate more readily, work harder, persist longer, and have fewer negative reactions when encountering difficulty than students who doubt their capabilities (Zimmerman, 2000). Hackett and Betz (1981) further proposed that self-efficacy also influences educational and career decision-making, an assertion supported by subsequent research by Lent and Hackett (1987) and meta-analytic findings by Multon, Brown, and Lent (1991) showing self-efficacy to predict both college-major choices and academic performance.

**Achievement goals.** In the context of achievement goal theory, academic goals refer to motives that students use for guiding their classroom behavior and decisions (Senko, Hulleman, & Harackiewicz, 2011). These goals are generally categorized into one of two main categories: (1) Mastery goals (also referred to as learning or task goals) reflect the students’ desire to develop competence or ability by acquiring new knowledge or skills. Mastery goals represent a concern with mastering course content, improving one’s knowledge and skills, seeking new challenges, and learning as an end in itself. (2) Performance goals (also referred to as performance-approach or ability-approach goals) reflect the students’ desire to demonstrate competence or ability relative to others. Performance goals represent a concern with social comparisons, outperforming others, and looking smart (Midgley et al., 1998; Elliot & Dweck, 1988). Mastery goals, that focus on increasing competence over time, have been linked to intrinsic motivation and enjoyment, positive affect, task engagement, deep learning, and persistence (for a review see Senko et al., 2011). In contrast, research on performance goals has elicited more controversy with some researchers having characterized them as detrimental to interest and performance, while others have emphasized positive outcomes (e.g., Harackiewicz, Barron, Pintrich, Elliot, & Thrash, 2002).

### **Affect, Persistence, and Achievement** **in STEM Education**

**Academic emotions.** Szulecka, Springett, and de Pauw (1987) suggested that the major causes of attrition in first-year college students are emotional rather than academic. However, very few studies to date have focused on the emotional experiences of students and how these experiences relate to student success and pursuit of future careers (cf. Pekrun, Elliot, & Maier, 2006). This lack of research interest is surprising given that emotions are often cited as a key element in theories of self-efficacy and motivation. According to social cognitive theory (Bandura, 1986), beliefs about one’s abilities are derived from four informational sources, one of which is emotional arousal. If an individual feels anxious, depressed, or ineffectual while performing an academic task, he or she is likely to infer that they are not competent at that task. Conversely, feelings of happiness, joy, or excitement may enhance perceived self-efficacy (Lent, Brown, & Hackett, 1994). Students’ beliefs about their ability to manage academic task demands may also influence positive and negative emotions in the classroom (Bandura, 1997). Therefore, not only does affect inform self-efficacy beliefs, but these beliefs, in turn, influence one’s affect.

With respect to the science domain, students with high science self-efficacy should be less likely to become anxious or depressed while performing a science-related task because they are more likely to expect success and experience positive affect while performing the task. Similarly, students with low self-efficacy are more likely to perceive the same task as more difficult, to expect poorer performance, and therefore be more likely to feel depressed or anxious while performing the task. In one of the few studies that focus on affect as a predictor of student success, Pritchard and Wilson (2003) found undergraduate students’ emotional health to predict performance and persistence over and above the effects of more traditional demographic and academic indicators. With respect to the effects of classroom practices and teaching behaviors on students’ affect, several studies show a positive relationship between teachers’ support for student autonomy and positive emotions in students (Assor et al., 2005). As such, students in autonomous learning environments tend to feel more engaged in their studies, and therefore are more likely to invest effort in learning, be intrinsically motivated, and show high levels of attention and persistence while studying (Assor et al., 2005).

Students’ achievement goals and perceptions of competence are also assumed to influence students’ emotions (Pekrun et al., 2006), such that students who adopt mastery goals (learning for its own sake) and feel competent in their ability to succeed in science (e.g., self-efficacy) should be more likely to experience positive affect in science classes. Therefore, these goals and competence beliefs are expected to positively predict enjoyment of learning more generally, as well as the experience of positive emotions during science-related activities. In contrast, students who are performance-oriented, and thus more focused on outperforming others than accomplishing learning goals, are more likely to experience negative affect due to the unlikely nature of consistently outperforming others in a demanding science classroom.

**Achievement and persistence.** Bandura (1986) suggests that among a variety of sources of one’s self-efficacy beliefs, past performance constitutes the most influential source of efficacy information. This hypothesis was supported in research by Lent, Lopez, and Bieschke (1991) showing prior achievement to predict self-efficacy better than other sources of competence-related information (e.g., verbal persuasion) and demographic variables (e.g., sex), and self-efficacy to mediate the effect of prior performance on interest and persistence. Past performance is hypothesized to impact one’s self-efficacy beliefs, with those beliefs, in turn, assumed to predict persistence. However, prior performance also has a direct impact on future performance that, in turn, impacts one’s intention to persist. Prior performance has consistently been shown to be the strongest predictor of future performance (e.g., Grandy, 1998), with this effect likely due to students who experience academic success in mathematics and science courses being more likely to infer that they have the capability to continue to succeed in this domain. Whereas research based on the well-known 25-year Study of Mathematically Precocious Youth (SMPY; Benbow & Stanley, 1982; 5,000 students) showed no overall sex differences in courses taken or course grades in the sciences, sex differences favoring males on science achievement tests (i.e., mathematics portion of the Scholastic Aptitude Test) suggest that exploring sex differences in how persistence is affected by achievement may be warranted.

# The Present Study

To address the underrepresentation of females in STEM disciplines, and specifically gender differences in performance and persistence among Quebec’s CEGEP students in science programs, the present study evaluated the effects of student motivation and affect on achievement and attrition as informed by research on self-determination, self-efficacy, and achievement goals. Based on the extant research literature, a number of direct relationships were predicted and evaluated using structural equation modeling. As an indicator of students’ perceptions of the motivating nature of their instructional context, autonomy support was expected to positively predict intrinsic motivation (1a) and positive affect (1b) but negatively predict negative affect (1c). Concerning self-relevant motivational variables, self-efficacy was expected to positively predict intrinsic motivation (2a) and positive affect (2b), negatively predict negative affect (2c), and positively predict achievement (2d). Mastery goals were expected to positively predict intrinsic motivation (3a) and positive affect (3b) whereas performance goals were expected to positively predict negative affect (3c) and achievement (3d). Consistent with present research showing emotions to mediate the effects of motivational variables on achievement (e.g., Villavicencio, 2011), persistence was expected to be positively predicted by positive affect (4a) and intrinsic motivation (4b), and negatively predicted by negative affect (4c). Finally, achievement was expected to positively predict academic persistence (5), with the final analytical model evaluated for the total sample, as well as for males and females separately, to determine the extent to which hypothesized relations were moderated by gender differences.

##### **Method**

##### **Participants and Procedure**

The sample for this study included 1,309 first-year junior college students (46% male) enroled at one of the four public, English-language CEGEPs in the greater Montreal area. The mean age of the participants was 17.33 years (range 15 to 19) with 74.7% of students enroled in a science program as per an intensive recruitment focus on science majors. All study participants had nonetheless completed optional, advanced science courses in grades 10 and 11 and obtained a high school average of 70% or above in their mathematics and science classes, and therefore had the potential for admission into a science program. All participants completed a questionnaire during the first two weeks of CEGEP that included various demographic, social, motivational, and affective self-report measures concerning their high-school experiences. All self-report measures were obtained directly from published research or minimally adapted for CEGEP students, with institutional data obtained from participating CEGEPs following study completion. Participants were compensated through random prize draws totaling $600 per institution.

**Study Measures**

All questionnaire items were rated on a 5-point Likert scale (1 = *strongly disagree/very rarely or not at all*; 5 = *strongly agree/very often*). See Table 1 for variable means and standard deviations by gender.

**Autonomy support.** Student perceptions concerning the extent to which the learning environment in mathematics and science classes during high school facilitated perceptions of autonomy were measured using four items from the Perceptions of Science Classes Survey (PSCS; Kardash & Wallace, 2001; α = .67; e.g., “Teachers encouraged me to think for myself”).

**Self-efficacy.**Self-efficacy was measured using items adapted from the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1991; e.g., “I can succeed in math or science classes”). The six MSLQ items were selected and adapted based on feedback received from members of an item-review team (e.g., CEGEP and university science and mathematics professors) to best reflect the experiences of CEGEP science students (α = .77).

**Achievement goal orientation.** Students’ achievement goal orientation was measured using 12 items from the Patterns of Adaptive Learning Survey (PALS; Midgley et al., 1997). For the present study, two four-item scales measuring the two goal orientation types of interest were administered (mastery orientation α = .70; e.g., “An important reason why I do my schoolwork is because I like to learn new things”; performance orientation α = .74; e.g., “Doing better than other students in school is important to me”).

Table 1

*Variable Means and Standard Deviations as a Function of Gender*

 Females Males

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Measures *M SD M SD*

1. Autonomy support 3.51 0.66 3.49 0.67
2. Self-efficacy 3.32 0.55 3.63\*\*\* 0.57 (.55)
3. Intrinsic motivation 3.83 0.60 3.75\* 0.60 (.13)
4. Positive affect 3.14 0.77 3.18 0.76
5. Negative affect 2.47 0.77 2.24\*\*\* 0.68 (.32)
6. Mastery goal 3.74 0.48 3.69\* 0.55 (.10)
7. Performance goal 3.30 0.62 3.34 0.62
8. Achievement 81.50 7.08 81.39 7.07

*Note.* Effect sizes are noted in parentheses and calculated using Cohen’s *d.*

\**p* < .05. \*\**p* < .01. \*\*\**p* < .001.

**Intrinsic motivation.** Intrinsic motivation was measured using two items from the Academic Motivation Scale (AMS; Vallerand et al., 1992; α = .75; e.g., “I am going to CEGEP because I experience pleasure and satisfaction while learning new things”), an English version of the *Echelle de Motivation en Education* (EME; Vallerand, Blais, Brière, & Pelletier, 1989).

**Affect.** Affect was measured using two four-item scales evaluating how often participants experienced positive emotions (joyful, happy, pleased, enjoyment; α = .86) and negative emotions (frustrated, worried/anxious, depressed, unhappy; α = .77; see Emmons, 1992) in high school math and/or science classes.

**Achievement and persistence.** Grades for all students’ high school science courses were obtained from government records (*Ministère de l’Éducation, du Loisir et du Sport*). A total science achievement score for high school was computed by taking the mean of students’ grade 10 and 11 science grades from the following courses: grade 10 mathematics and physical science, and grade 11 mathematics, physics, and chemistry (Quebec high schools do not include grade 12). Persistence in STEM education was operationalized dichotomously as students’ enrolment in a science program (*N* = 978) vs. non-science program (*N* = 331) in one of the four participating CEGEP institutions.

**Rationale for Analysis**

Structural equation modeling (SEM) was conducted using EQS software to examine the extent to which the proposed model accounted for male and female students’ decisions to enrol in science in CEGEP (see preceding hypotheses in “The Present Research”). The model was first evaluated for the total sample and then assessed separately for males and females students to examine structural differences due to gender. The robust maximum likelihood (RML) method of estimation was used for missing data (Byrne, 2001). Directional paths between latent variables were modeled as per the study hypotheses based on existing motivation research, with non-significant paths retained to provide a more conservative analysis of the analytical model.

**Results**

**Full Sample**

The overall fit of this model was satisfactory: χ2 (101) = 467.52, *p* < .001, χ2/df = 4.63, CFI = .940, NNFI = .918, RMSEA = .053. Results of the Wald test showed three parameters to be non-significant (F7,F1, F9,F7, and F9,F6). Re-running the model without the three non-significant paths yielded the following results: χ2 (104) = 469.86, *p* < .001, χ2/df = 4.52, CFI = .940, NNFI = .920, RMSEA = .052 (see Figure 1). Contrary to expectations, autonomy support was not found to significantly predict intrinsic motivation (β = .03, *p* > .05), but did significantly predict positive affect (β = .20, *p* < .05) and negative affect (β = -.15, *p* < .05) in the expected directions. Self-efficacy was, however, found to positively predict intrinsic motivation (β = .14, *p* < .05) as well as positive affect (β = .37, *p* < .05) and achievement (β = .31, *p* < .05), and negatively predict negative affect (β = -.66, *p* < .05). Mastery goals also positively predicted intrinsic motivation (β = .89, *p* < .05) and, to a lesser extent, positive affect (β = .28, *p* < .05), with performance goals positively predicting negative affect (β = .24, *p* < .05) and achievement (β = .10, *p* < .05). Concerning the hypothesized effects on persistence, whereas positive affect positively predicted persistence (β = .17, *p* < .05) the effects of negative affect (β = -.05, *p* > .05) and intrinsic motivation (β = .05, *p* > .05) were not significant. Finally, the effect of achievement on persistence was positive and significant (β = .32, *p* < .05).



*Figure 1*. Structural equation model: Total sample.

**Females vs. Males**

To evaluate the extent to which the results above were moderated by gender, the analytical model was also evaluated separately for female and male participants. For *females*, the model fit was satisfactory (Figure 2): χ2 (104) = 347.20, *p* < .001, χ2/df = 3.34, CFI = .930, NNFI = .907, RMSEA = .058. The Wald test indicated that three parameters were not significant (F4,F3, F5,F1, and F6,F1), with a reanalysis of the model without these paths yielding the following results: χ2 (107) = 354.16, *p* < .0001, χ2/df = 3.31, CFI = .929, NNFI = .908, RMSEA = .057. For *males*, model fit was satisfactory (Figure 3): χ2 (104) = 256.43, *p* < .001, χ2/df = 2.47, CFI = .942, NNFI = .923, RMSEA = .049. As the Wald test showed one parameter to not be significant (F8,F4), the model was reassessed without it yielding the following results: χ2 (105) = 256.62, *p* < .001, χ2/df = 2.44, CFI = .942, NNFI = .924, RMSEA = .049.

Concerning the differences between the best-fitting models for female vs. male students, perceptions of autonomy support were unrelated to affect for females (β = .09 for positive affect and β = -.10 for negative affect, *p* > .05), but for males were found to predict more positive affect (β = .24, *p* < .05) and lower negative affect (β = -.18, *p* < .05). For females, performance goals positively predicted achievement (β = .16, *p* < .05) whereas for males, this path was not significant (β = .10, *p* > .05). However, a test for invariance (Byrne, 2001) involving a series of equality constraints to evaluate equivalent strengths of the structural relationships for males vs. females showed only the effect of self-efficacy on negative affect to be significantly moderated by gender. As indicated by a CFI of .934, NNFI of .917, χ2 (219) = 588.09, *p* < .0001, and χ2/df = 2.68, and a significant constraint between self-efficacy and negative affect (F6,F2), this path was found to be significantly stronger for females (β = -.76) than for males (β = -.56).



*Figure 2*. Structural equation model: Females.

*Figure 3*. Structural equation model: Males.

## Discussion

The current study examined whether students’ perceptions of autonomy support, self-efficacy, and achievement goals predicted their intrinsic motivation to attend CEGEP and their affect in mathematics and science classes, and whether their motivation and affect predicted their achievement and persistence in science. Concerning the overall structural model, our hypotheses were generally supported and consistent with *social learning theory* (Bandura, 1986) with CEGEP students who felt autonomous or competent having more positive affect (1b, 2b) and less negative affect (1c, 2c), and students who felt more competent also receiving higher grades (2d). Consistent with *self-determination theory*, positive affect and achievement, in turn, contributed to greater persistence (4a, 5), with students who felt competent also tending to be intrinsically motivated (2a). However, our results differed from previous research in that perceptions of autonomy support were unrelated to intrinsic motivation (1a), likely due to the notably strong effects of an overlapping construct, mastery orientation (*r* = .37, *p* < .01), on intrinsic motivation in the overall SEM analysis. Additionally, students’ intrinsic motivation was not significantly related to persistence (4b), perhaps resulting from the self-report motivation items not being specific to science topics (cf., domain-specific measures in Goetz et al., 2013; Pajares & Miller, 1995).

 With regard to observed relations consistent with *achievement* *goal theory*, all hypotheses were confirmed. A mastery orientation was beneficial for intrinsic motivation (3a) and positive affect (3b), whereas a performance orientation led to poorer negative affect (3c) despite higher achievement (3d). As such, mastery-oriented students reported feeling more positive in the science classroom and were more motivated by the opportunity to continue learning at the CEGEP level than performance-oriented students who received higher grades but experienced more negative emotions in the classroom. Finally, our results underscored the mediating role of students’ emotions with positive affect predicting greater persistence (4a). Although negative affect was not found to significantly predict persistence (4c), our findings showed CEGEP students to not only experience more positive than negative emotions in the classroom, but also how students’ motivation impacts their emotions that, in turn, predict persistence in STEM disciplines.

With respect to *gender differences*, students’ perceptions of autonomy as afforded by their science and math instructors were linked to better emotional outcomes for males but not for females. Given our findings showing females to have lower self-efficacy regarding science than males (Cohen’s *d* = .55), they may not have felt adequately prepared to assume more responsibility in STEM courses and instead preferred a more structured or controlling learning environment (Jones & Wheatley, 1990). Female students may also have been less receptive to efforts to increase communication and participation in the science classroom, where males tend to dominate groups discussion and create a climate of competition (Beaman, Wheldall, & Kemp, 2006) and females tend to be more compliant during class (Assor et al., 2005). Further, whereas performance goals predicted better grades only for females, this effect was notably weak (cf., Brophy, 2005; Harackiewicz et al., 2002; Kaplan & Maehr, 1999; Roeser, Midgley, & Urdan, 1996), likely due to participants having obtained relatively high grades (i.e., above 70) thereby contributing to lower variability in achievement as compared to recent studies (e.g., Pekrun, Hall, Perry, & Goetz, in press). Finally, self-efficacy more strongly predicted lower levels of negative affect in females than for males, highlighting the need for future intervention research addressing maladaptive, and often unfounded, perceptions of competence concerning STEM disciplines in female students (see Goetz et al., 2013).

The present study reiterates the need to encourage and support students’ autonomy in science classrooms by offering greater choice and encouraging students’ active involvement in both the content and enactment of the curriculum. Indeed, the learning environment needs to be a central focus for promoting persistence in STEM programs because the classroom is the primary arena within which teachers can influence their students (Pintrich, 2003; Tinto, 1997). For males, their emotions mediated the relationship between perceived autonomy and persistence, suggesting that efforts to promote autonomy in science classrooms may be particularly beneficial for males with respect to their emotional experiences and, in turn, persistence. The emotional experiences of female students, on the other hand, seemed to derive more from internal characteristics such as their sense of competence and personal achievement goals. As such, these findings underscore the need for greater efforts to increase females’ sense of competence with respect to mathematics and science, particularly given that their resulting emotional well-being should have a direct impact on observed persistence in STEM disciplines (e.g., through control-enhancing programs such as Attributional Retraining; see Hall et al., 2007). More generally, the positive relationship between affective experiences and persistence for both males and females reiterates the importance of students’ emotional adjustment in STEM education in that by providing positive feedback to students, and making science activities enjoyable and relevant, positive changes in persistence and achievement should result. In sum, these findings provide empirical support for the importance of psychosocial variables in the science classroom, highlighting the need for instructional methods and interventions that promote critical aspects of student motivation (i.e., mastery, autonomy, competence) and in turn, emotional adjustment, achievement, as well as persistence for students in STEM disciplines.

**References**

Assor, A., Kaplan, H., Kanat-Maymon, Y., & Roth, G. (2005). Directly controlling

teacher behaviors as predictors of poor motivation and engagement in girls and boys: The role of anger and anxiety. *Learning and Instruction, 15*, 397–413.

AUCC (The Association of Universities and Colleges of Canada). (2011). *Trends in higher education: Volume 1 – Enrolment.* Ottawa, Canada: Author.

Baillargeon, G., M., Demers, P., Ducharme, D., Foucault, J., Lavigne, A., Lespérance, S., . . . A. Vigneault (2001). *Education Indicators, 2001 Edition*. Québec City, Canada: Ministère de l’Éducation, Gouvernement du Québec.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*.

Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: Freeman.

Beaman, R., Wheldall, K., & Kemp, C. (2006). Differential teacher attention to boys and girls in the classroom. *Educational Review, 58,* 339–366.

Benbow, C. P., & Stanley, J. C. (1982). Consequences in high school and college of sex

differences in mathematical reasoning ability: A longitudinal perspective. *American Educational Research Journal, 19,* 598–622.

Brophy, J. (2005). Goal theorists should move on from performance goals. *Educational*

*Psychologist, 40*, 167–176.

Byrne, B. M. (2001). Structural equation modeling with EQS and EQS/Windows: Basic

concepts, application and programming. Mahwah, NJ: Erlbaum.

Ceci, S. J., & Williams, W. M. (2010). Sex differences in math-intensive fields. *Current Directions in Psychological Science, 19*, 275–279.

Chen, X. (2013). STEM attrition: College students' paths into and out of STEM fields. *National Center for Education Statistics, Institute of Education Sciences (NCES 2014-001).* Washington, DC: U.S. Department of Education.

Cheryan, S. (2012). Understanding the paradox in math-related fields: Why do some gender gaps remain while others do not? *Sex Roles, 66*, 184–190.

Church, M. A., Elliot, A. J., & Gable, S. L. (2001). Perceptions of classroom

environment, achievement goals, and achievement outcomes. *Journal of Educational Psychology*, *93*, 43–54.

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*, 37–52.

Deci, E. L., & Ryan, R. M. (2012). Self-determination theory. In P. A. M. Van Lange, A. W. Kruglanski, & E. T. Higgins (Eds.), *Handbook of theories of social psychology: Vol. 1* (pp. 416–437). Thousand Oaks, CA: Sage.

Elliot, E. S., & Dweck, C. S. (1988). Goals: An approach to motivation and achievement.

*Journal of Personality and Social Psychology, 54*, 5–12.

Engineers Canada. (2012). *Canadian engineers for tomorrow: Trends in engineering enrolment and degrees awarded 2007-2011*. Ottawa, Canada: Author.

Emmons, R. A. (1992). Abstract versus concrete goals: Personal striving level, physical

illness, and psychological well-being. *Journal of Personality and Social Psychology, 62*, 292–300.

Filak, V. F., & Sheldon, K. M. (2003). Student psychological need satisfaction and

college teacher-course evaluations. Educational Psychology: An International Journal of Experimental Educational Psychology, 23, 235–247.

Fortier, M. S., Vallerand, R. J., & Guay, F. (1995). Academic motivation and school

performance: Toward a structural model. *Contemporary Educational Psychology*, *20*, 257–274.

[Goetz, T.](http://www.scopus.com/search/submit/author.url?author=Goetz+T.&origin=resultslist&authorId=7006674828), [Bieg, M.](http://www.scopus.com/search/submit/author.url?author=Bieg+M.&origin=resultslist&authorId=55878385300" \o "Search for all articles by this author), [Ludtke, O.](http://www.scopus.com/search/submit/author.url?author=Ludtke+O.&origin=resultslist&authorId=6603505385), [Pekrun, R.](http://www.scopus.com/search/submit/author.url?author=Pekrun+R.&origin=resultslist&authorId=6602769314" \o "Search for all articles by this author), & [Hall, N.C.](http://www.scopus.com/search/submit/author.url?author=Hall+N.C.&origin=resultslist&authorId=35320079000) (2013). [Do girls really experience more anxiety in mathematics?](http://www.scopus.com/record/display.url?eid=2-s2.0-84885356380&origin=resultslist&sort=plf-f&cite=2-s2.0-84885356380&src=s&imp=t&sid=240399CFB09EE86C77B6A5F063B3616C.FZg2ODcJC9ArCe8WOZPvA%3a20&sot=cite&sdt=a&sl=0) *Psychological Science, 24*, 2079–2087.

Grandy, J. (1998). Persistence in science of high-ability minority students. *The Journal*

*of Higher Education*, *69*, 589–620.

Hackett, G., & Betz, N. E. (1981). A self-efficacy approach to the career development of

women. *Journal of Vocational Behavior, 18*, 326–336.

Hall, C., Dickerson, J., Batts, D., Kauffmann, P., & Bosse, M. (2011). Are we missing opportunities to encourage interest in STEM fields? *Journal of Technology Education, 23*, 32–46.

Hall, N. C., Perry, R. P., Goetz, T., Ruthig, J. C., Stupnisky, R. H., & Newall, N. E. (2007). Attributional retraining and elaborative learning: Improving academic development through writing-based interventions. *Learning and Individual Differences, 17*, 280-290*.*

Harackiewicz, J. M., Barron, K. E., Pintrich, P. R., Elliot, A. J., & Thrash, T. M. (2002).

Revision of achievement goal theory: Necessary and illuminating. *Journal of Educational Psychology*, *94*, 638–645.

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A., & Williams, C. (2008). Gender similarities characterize math performance. *Science, 321*, 494–495.

Ingersoll, R., & May, H. (2012). The magnitude, destinations and determinants of mathematics and science teacher turnover. *Educational Evaluation and Policy Analysis, 34*, 435–464.

Ingersoll, R., & Perda, D. (2010). Is the supply of mathematics and science teachers sufficient? *American Educational Research Journal, 47*, 563–594.

Jones, M. G., & Wheatley, J. (1990). Gender differences in teacher-student interactions in

science classrooms. *Journal of Research in Science Teaching, 27*, 861–874.

Kaplan, A., & Maehr, M. L. (1999). Achievement goals and student well-being.

*Contemporary Educational Psychology*, *24*, 330–358.

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*, 199–210.

Larose, S., Ratelle, C. F., Guay, F., Senecal, C., & Harvey, M. (2006). Trajectories of science self-efficacy and academic and vocational adjustment in science and technology programs. *Educational Research and Evaluation, 12*, 373–393.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive

theory of career and academic interest, choice, and performance. *Journal of*

*Vocational Behavior, 45*, 79–122.

Lent, R. W., & Hackett, G. (1987). Career self-efficacy: Empirical status and future

directions. *Journal of Vocational Behavior, 30*, 347–382.

Lent, R. W., Lopez, F. G., & Bieschke, K. J. (1991). Mathematics self-efficacy: Sources

and relation to science-based career choice. *Journal of Counseling Psychology*, *38*, 424–430.

Lent, R. W., Lopez, F. G., Sheu, H., & Lopez, A. M. (2011). Social cognitive predictors of the interests and choices of computing majors: Applicability to underrepresented students. *Journal of Vocational Behavior, 78*, 184–192.

Mau, W. C. (2003). Factors that influence persistence in science and engineering career

aspirations. *The Career Development Quarterly*, *51*, 234–243.

Midgley, C., Kaplan, A., Middleton, M., Maehr, M. L., Urdan, T., Anderman, E. M., . . . Roeser, R. (1998). The development and validation of scales assessing students’ achievement goal orientations. *Contemporary Educational Psychology, 23,* 113–131.

Midgley, C., Maehr, M. L., Hicks, L., Roeser, R., Urdan, T., & Anderman, E. M. (1997).

*Patterns of Adaptive Learning Survey (PALS).* Ann Arbor, MI: University of Michigan.

Multon, K. D., Brown, S. D., & Lent, R. W. (1991). Relation of self-efficacy beliefs to

academic outcomes: A meta-analytic investigation. *Journal of Counseling Psychology, 38*, 30–38.

National Science Foundation. (2013). *Women, minorities, and persons with disabilities in science and engineering: 2013 (NSF 13-304).* Arlington, VA: Author.

Pajares, F., & Miller, D. M. (1995). Mathematics self-efficacy and mathematics performances: The need for specificity of assessment. *Journal of Counseling Psychology, 42*, 190–198.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational*

*Research*, 66, 543–578.

Pekrun, R., Elliot, A. J., & Maier, M. A. (2006). Achievement goals and discrete

achievement emotions: A theoretical model and prospective test. *Journal of*

*Educational Psychology, 98*, 583–597.

Pekrun, R. H., Hall, N. C., Perry, R. P., & Goetz, T. (in press). Boredom and academic achievement: Testing a model of reciprocal causation. *Journal of Educational Psychology*.

Pintrich, P. R. (2003). A Motivational science perspective on the role of student

motivation in learning and teaching contexts. *Journal of Educational Psychology*, *95*, 667–686.

Pintrich P. R., Smith D., Garcia T., & McKeachie, W. (1991). *A manual for the use of the*

*motivated strategies for learning questionnaire*. Technical report 91-B-004. Ann Arbor, MI: The Regents of the University of Michigan.

Pritchard, M. E., & Wilson, G. S. (2003). Using emotional and social factors to predict

student success. *Journal of College Student Development, 44*, 18–28.

Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educational Psychologist, 44*, 159–175.

Reeve, J., Jang, H., Carrell, D., Barch, J., & Jeon, S. (2004). Enhancing high school students’ engagement by increasing their teachers’ autonomy support. *Motivation and Emotion, 28*, 147–169.

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math? Exploring adolescents’ future aspirations by gender and race/ethnicity. *Science Education, 95*, 458–476.

Roeser, R. W., Midgley, C., & Urdan, T. C. (1996). Perceptions of the school psychological environment and early adolescents’ psychological and behavioral functioning in school: The mediating role of goals and belonging. *Journal of Educational Psychology*, *88*, 408–422.

Rosenfield, S., Dedic, H., Dickie, L., Rosenfield, E., Aulls, M. W., Koestner, R., . . . Abrami, P. (2005). A study of the factors influencing the success and retention of students in CEGEP science programs. Report submitted to FQRSC, ISBN 2-921024-69-1.

Ryan, R. M., & Deci, E. L. (2009). Promoting self‐determined school engagement: Motivation, learning, and well‐being. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of motivation at school* (pp. 171–196). New York, NY: Routledge.

Schunk, D. H., & Pajares, F. (2005). Competence perceptions and academic functioning. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 85–104). New York, NY: The Guilford Press.

Senko, C., Hulleman, C. S., & Harackiewicz, J. M. (2011). Achievement goal theory at the crossroads: Old controversies, current challenges, and new directions. *Educational Psychologist, 46*, 26–47.

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave*

*the sciences.* Boulder, CO: Westview Press.

Statistics Canada. (2010). *Women in Canada: A gender-based statistical report.* (Catalogue no. 89-503-X). Ottawa, Canada: Minister of Industry.

Szulecka, T. K., Springett, N. R., & de Pauw, K. W. (1987). General health, psychiatric

vulnerability and withdrawal from university in first-year undergraduates. *British Journal of Guidance & Counseling Special Issue: Counseling and health, 15*, 82–91.

Tinto, V. (1997). Classrooms as communities: Exploring the educational character of

student persistence. *Journal of Higher Education*, *68*, 599–623.

Vallerand, R. J., Blais, M. R., Brière, N. M., & Pelletier, L.G. (1989). Construction and

validation of the Echelle de Motivation en Education (EME). *Canadian Journal of Behavioral Sciences, 21*, 323–349.

Vallerand, R. J., Fortier, M. S., & Guay, F. (1997). Self-determination and persistence in a real-life setting: Toward a motivational model of high school dropout. *Journal of Personality and Social Psychology, 72*, 1161–1176.

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Brière, N. M., Senécal, C., & Vallières, E.

F. (1992). The academic motivation scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and Psychological Measurement*, *52*, 1003–1017.

Van den Broeck, A., Vansteenkiste, M., De Witte, H., Soenens, B., & Lens, W. (2010). Capturing autonomy, competence, and relatedness at work: Construction and initial validation of the Work-related Basic Need Satisfaction scale. *Journal of Occupational and Organizational Psychology, 83*, 981–1002.

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*, 246–260.

Villavicencio, F. T. (2011). Critical thinking, negative academic emotions, and achievement: A mediational analysis. *The Asia-Paciﬁc Education Researcher*, *20*, 118–126.

Watt, H. (2004). Development of adolescents’ self-perceptions, values, and task perceptions according to gender and domain in 7th- through 11th-grade Australian students. *Child Development, 75,* 1556–1574.

Xie, Y., & Achen, A. (2009). *Science on the decline? Educational outcomes of three cohorts of young Americans. Population Studies Center Research Report 09-684.* Ann Arbor, MI: University of Michigan, Institute for Social Research.

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary*

*Educational Psychology*, *25*, 82–91.