Exploring Student Persistence in STEM Programs: A Motivational Model

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Abstract

To address continually decreasing enrollment and rising attrition in post-secondary STEM degree (science, technology, engineering, and mathematics) programs, particularly for women, the present study examines 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, Hulleman, & Harackiewicz, 2011), structural equation modelling based on data from 1,309 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.

Keywords: academic motivation, persistence, STEM, gender differences

Résumé

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, Hulleman, & Harackiewicz, 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.

Mots-clés : motivation scolaire, persévérance, STEM, différences liées au sexe

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Introduction

Student persistence in STEM (science, technology, engineering, and mathematics) fields deserves close attention given the alarming attrition rates from such programs—particularly for women—in light of the increasingly problematic nature of staffing difficulties and turnover among science educators and practitioners in North America (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011; Ingersoll & May, 2012; Ingersoll & Perda, 2010). Over the past 20 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, as evidenced by substantial declines in the number of earned bachelor's degrees and doctorates in these fields over the past decade (National Science Foundation, 2013; Xie & Achen, 2009). In the province of Quebec, this issue is particularly salient, with provincial universities shown to graduate fewer science graduates than those of other OECD member countries (Baillargeon et al., 2001). Traditionally, research on student persistence has focused on the predictors of dropout, with less attention paid to why students change programs without leaving school. Accordingly, notably few studies have examined students' choices or decisions to change their academic focus or career aspirations away from STEM to other disciplines.

Research has found both classroom factors (e.g., student–teacher interaction, pedagogy, classroom culture; Seymour & Hewitt, 1997; Tinto, 1997), as well as individual differences in students (e.g., self-determined motivation) to significantly predict students' career aspirations and persistence (e.g., Quebec high school students; Vallerand, Fortier, & Guay, 1997). In research on motivation in STEM programs, findings have shown post-secondary students' levels of self-efficacy (e.g., Sawtelle, Brewe, & Kramer, 2012), achievement goals (e.g., Deemer, Smith, Carroll, & Carpenter, 2014), and perceived autonomous support (e.g., Hall & Webb, 2014) to predict attrition, emotional well-being, and achievement. Although studies also show self-determined motivation to predict performance in Quebec junior college (CEGEP) students (e.g., Taylor, Lekes, Gagnon, Kwan, & Koestner, 2012), research on motivation and persistence among CEGEP students in STEM disciplines is lacking. The present study aims to address this research gap by utilizing structural equation modelling to examine the motivational factors that influence CEGEP students' decisions to pursue STEM degrees by examining the effects of self-efficacy, goals, and autonomy support on persistence, emotional well-being, and achievement.

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'études 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% 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 occurring just prior to, or shortly after, enrollment 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 among females (e.g., Riegle-Crumb, Moore, & Ramos-Wada, 2011).

Gender and STEM

When exploring issues of persistence in the sciences, it is essential to examine the role of gender. 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 in physics classes are female, women are significantly under-represented at both the undergraduate and graduate level in post-secondary education (e.g., U.S.: 20.3% of physics BSc degrees, 22.6% of physics MSc degrees, 19.4% of physics PhDs; National Science Foundation, 2013). In Canada, only 22 to 30% of university students in mathematics, computer, and information sciences, architecture, and engineering programs are women (Statistics Canada, 2010), with notably few pursuing doctoral degrees in related disciplines (e.g., 21% engineering, 25% mathematics, computer, and information sciences; AUCC, 2011; Engineers Canada, 2012).

Despite these discouraging trends, educational research suggests that males and females do not differ in their intrinsic aptitude for mathematics and science (e.g., Hyde, Lindberg, Linn, Ellis, & Williams, 2008). Nevertheless, existing reviews of research on gender and science education highlight persistent social-cultural norms and gender stereotypes that undermine females' participation in STEM disciplines (e.g., Brotman & Moore, 2008), with motivation studies consistently showing females' subjective perceptions of self-efficacy and competence to be lower for STEM subjects as compared with males (e.g., Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013). Therefore, although Canadian women have made significant gains in their participation in the field of science over the past few decades, many females continue to avoid occupations in science domains (e.g., 22.3% of STEM professionals; Statistics Canada, 2010; see also Ceci & Williams, 2010; Cheryan, 2012).

Motivation and Emotions in Education

Self-efficacy. 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). As such, self-efficacy represents one's perceived capability and expectations for success based on prior achievement, rather than a measure of personal qualities such as physical or personality characteristics. Efficacy beliefs affect behaviour 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 particularly relevant variable for explaining persistence in science education, especially since science and mathematics self-efficacy beliefs are 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). Among students in STEM programs, self-efficacy beliefs have been found to influence academic performance (e.g., mathematics; Fast et al., 2010) and key indicators of academic motivation, including choice of activities and goals, persistence (e.g., graduation rates), and positive emotions (e.g., Larson et al., 2014; Lent, Lopez, & Bieschke, 1991; 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 has additional positive effects on educational and career decision-making, an assertion supported by research by findings from Lent and Hackett (1987) and Multon, Brown, and Lent (1991) showing self-efficacy to predict both college-major choices and academic performance.

Achievement goals. Achievement goals theory provides a complementary perspective on motivation in educational settings, with academic goals referring to students' motives and values underlying their learning behaviour and academic decision-making (Senko, Hulleman, & Harackiewicz, 2011). These goals are generally categorized into one of two main categories, with mastery goals reflecting the students' desire to develop competence by acquiring new knowledge or skills, and performance goals involving a desire to demonstrate one's competence relative to others. Whereas *mastery* goals involve challenging oneself intellectually and learning as an end in itself, *performance* goals represent a concern with outperforming others and appearing intelligent (Elliot & Dweck, 1988; Midgley et al., 1998).

Although achievement goal research further differentiates between students who strive for mastery or performance by pursuing academic success (approach orientation) or preventing failure experiences (avoidance orientation), studies consistently show approach orientations to be most beneficial for learning and achievement (e.g., Elliot & McGregor, 2001; Elliot & Murayama, 2008). More specifically, mastery-approach goals have been linked to higher intrinsic motivation and enjoyment, positive affect, engagement, deep learning, and persistence (for a review, see Senko et al., 2011), with performance-approach goals showing mixed results in predicting higher grades as well as anxiety (e.g., Harackiewicz, Barron, Pintrich, Elliot, & Thrash, 2002). Research with STEM students further shows mastery-approach goals to predict greater persistence in high-school courses (e.g., Chouinard, Karsenti, & Roy, 2007), and both mastery- and performance-approach goals to buffer the negative effects of gender stereotypes on learning in post-secondary STEM programs, specifically for females (Deemer et al., 2014),

Autonomy support and intrinsic motivation. From an educational perspective, self-determination theory (SDT) focuses on the role of psychological need satisfaction in predicting academic persistence, well-being, and achievement (Deci & Ryan, 2012; Ryan & Deci, 2009). Motivated actions are understood as self-determined when they are engaged in volitionally and driven by personal values, as opposed to being mandated or solicited by the social environment. With respect to student persistence and achievement, two key tenets of SDT have received considerable empirical support, namely the effects of intrinsic motivation and support for autonomy as provided by instructors. *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). SDT proposes that when students feel autonomous (rather than controlled), they are more likely to be *intrinsically motivated* and to adopt intrinsic goals that promote continued interest and persistence.

Research on the effects of autonomy-supportive versus controlling teacher practices show that controlling behaviours, such as strict deadlines, discouraging dissenting opinions, and focusing on directives as opposed to discussion can significantly undermine intrinsic motivation by increasing negative affect and reducing student participation (Assor, Kaplan, Kanat-Maymon, & Roth, 2005; Deci & Ryan, 2012; Reeve, 2009; Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004). In contrast, autonomy-supportive teachers who offer students choices, allow them to work at their own pace, and build on prior knowledge tend to enhance students' intrinsic motivation and active engagement in the learning process (e.g., Reeve, Jang, Carrell, Barch, & Jeon, 2004). Research with STEM students similarly shows perceived autonomy support from the instructor to predict higher levels of intrinsic motivation, emotional well-being, and academic performance (e.g., Black & Deci, 2000; Hall & Webb, 2014).

Academic emotions. Research has long suggested that the major causes of attrition in first-year college students are emotional rather than academic (e.g., Szulecka, Springett, & de Pauw, 1987). However, studies examining the effects of students' emotions on their success and decision-making are under-represented relative to work exploring structural or motivational predictors (cf. Pekrun, Elliot, & Maier, 2006). This lack of research is surprising given that emotions are often cited in theories of motivation (e.g., arousal in social learning theory; Bandura, 1986), with students' motivational beliefs typically hypothesized to influence positive and negative emotions in the classroom (e.g., self-efficacy; Bandura, 1997; Lent, Brown, & Hackett, 1994). Reviews of scattered empirical findings indeed show students' emotions to predict learning and achievement in secondary education (e.g., Hall & Goetz, 2013) as well as post-secondary education (e.g., Pekrun, Hall, Perry, & Goetz, 2014; Pekrun & Stephens, 2010). Recent motivation studies further show mastery-approach goals to predict positive emotions, and performance-approach goals to predict negative emotions in university students (e.g., Daniels et al., 2009; Pekrun, Elliot, & Maier, 2009), with higher self-efficacy and perceived autonomy support shown to predict positive emotions specifically in STEM students (e.g., Black & Deci, 2000; Hall & Webb, 2014; Larson et al., 2014; Lent et al., 2011).

The Present Study

To address the under-representation 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-efficacy, achievement goals, and self-determined motivation. Based on the extant research literature, a number of direct relationships were predicted and evaluated using structural equation modelling. Concerning self-relevant motivational variables, self-efficacy was expected to positively predict intrinsic motivation (1a) and positive affect (1b), negatively predict negative affect (1c), and positively predict achievement (1d). Mastery-approach goals were expected to positively predict intrinsic motivation (2a) and positive affect (2b) whereas performance-approach goals were expected to predict higher negative affect (2c) and achievement (2d). As an indicator of students' perceptions of the motivating nature of their instructional context, autonomy support was expected to positively predict intrinsic motivation (3a) and positive affect (3b) but negatively predict negative affect (3c). 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) recruited from 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 enrolled 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 from published research or minimally adapted for CEGEP students, with institutional data obtained from participating CEGEPs following the study. 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.

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-approach orientation α = .70; e.g., "An important reason why I do my schoolwork is because I like to learn new things"; performance-approach orientation α = .74; e.g., "Doing better than other students in school is important to me").

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").

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).

Positive and negative 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.

Table 1: Variable Means and Standard Deviations by Gender

	Females		Males		
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-approach	3.74	0.48	3.69*	0.55	(.10)
7. Performance-approach	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*.
*$p < .05$; **$p < .001$.

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 math and physical science, and Grade 11 math, physics, and chemistry (Quebec high schools do not include Grade 12). Persistence in STEM education was operationalized dichotomously as students' enrollment 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 modelling (SEM) was used to examine the extent to which our proposed model could reliably predict CEGEP students' decisions to enroll in STEM programs. More specifically, our analytical model was based directly on the study hypotheses outlined above (see "The Present Study" section), with each path corresponding to a specific study hypothesis. Additionally, the analytical model was tested for not only the entire sample of CEGEP students, but also for male and female students separately given prior research suggesting gender differences in both attrition (Larose et al., 2006; Mau, 2003) and motivation (Brotman & Moore, 2008; Goetz et al., 2013) in STEM disciplines. First, the model evaluated the effects of the motivational variables (autonomy support, self-efficacy, mastery goals, performance goals) on the emotion-related variables (positive and negative affect, intrinsic motivation) and achievement. Second, the model evaluated the effects of the motivational, emotion, and achievement variables on persistence, allowing us to examine to what extent the effects of motivational variables on persistence were due to earlier effects on students' emotions and achievement (indirect effects).[1]

Results

Full Sample

The hypothesized model fit the data well[2] with the results presented in Figure 1. As anticipated, students with higher self-efficacy reported higher levels of intrinsic motivation as well as positive affect and achievement. Students with higher self-efficacy also reported lower negative affect. Students endorsing mastery-approach goals also report higher levels of intrinsic motivation and, to a lesser extent, positive affect. Conversely, students with higher levels of performance-approach goals reported greater negative affect despite higher achievement levels. Contrary to expectations, students' perceptions of autonomy support were not found to significantly predict intrinsic motivation. However, higher levels of perceived autonomy support did predict greater emotional well-being in terms of both greater positive affect and lower negative affect. With respect to persistence, students with higher levels of positive affect were more likely to persist in STEM programs. However, students' negative affect and intrinsic motivation did not significantly predict persistence. Finally, students with higher levels of academic achievement were found to be more likely to persist in STEM programs.

1 EQS software was utilized for the SEM analysis and the robust maximum likelihood (RML) method of estimation employed for missing data (Byrne, 2001). Directional paths between latent variables were modelled as per the study hypotheses based on existing motivation research. Non-significant paths, as identified by Wald tests, were retained due to evaluations of models with these paths removed showing no improvement in model fit, thereby providing a more conservative analysis of the analytical models.

2 Model fit indices for the entire sample: χ^2 (101) = 467.52, p < .001, χ^2/df = 4.63, CFI = .940, NNFI = .918, RMSEA = .053.

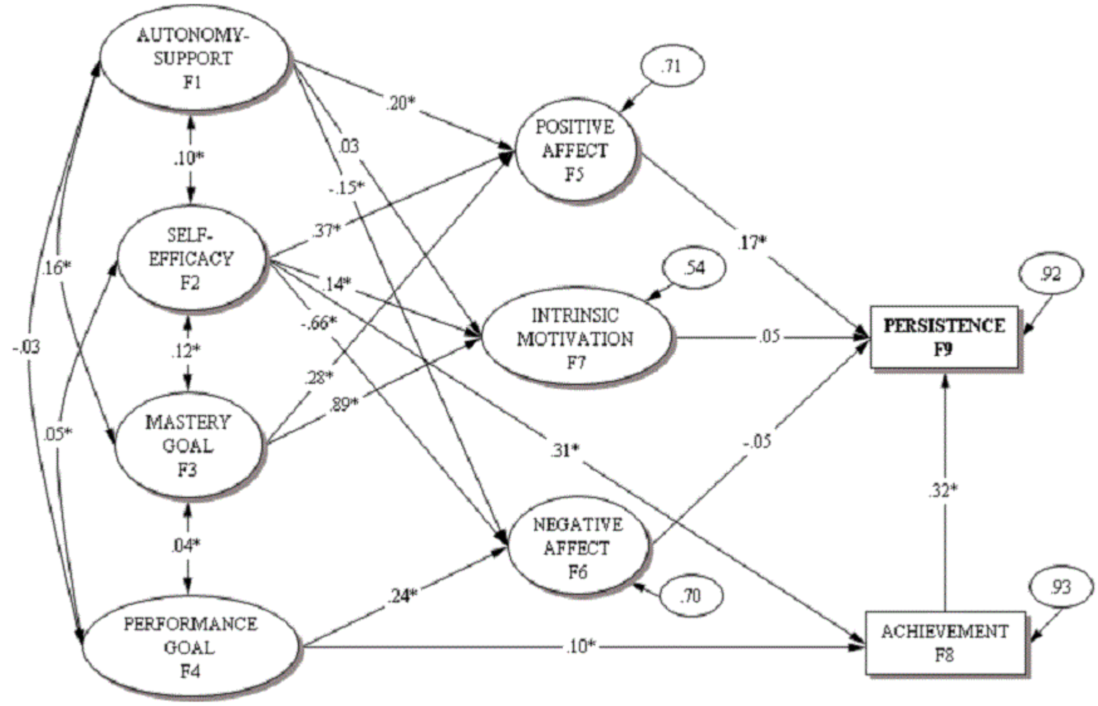

Figure 1: Structural Equation Model: Total Sample.

Females vs. Males

To evaluate if the results for the hypothesized model were moderated by gender, we evaluated the model separately for female and male students. For both female and male students, the model fit the data well[3] with the results for females presented in Figure 2 and for males depicted in Figure 3. Concerning the gender differences observed, whereas higher levels of performance-approach goals corresponded to higher achievement levels for female students, this relationship was not significant for male students. Conversely, although higher levels of perceived autonomy support were unrelated to emotional well-being for female students, male students who felt supported by their instructors did report both more positive affect and lower negative affect. However, post-hoc comparisons of specific path values found only one path to significantly differ based on gender,

3 Model fit indices for female students: χ^2 (104) = 347.20, $p < .001$, χ^2/df = 3.34, CFI = .930, NNFI = .907, RMSEA = .058. Model fit for male students: χ^2 (104) = 256.43, $p < .001$, χ^2/df = 2.47, CFI = .942, NNFI = .923, RMSEA = .049.

namely the path from self-efficacy to negative affect.[4] This finding indicated that although higher levels of self-efficacy did indeed predict lower negative affect for male students, this emotional benefit was substantially stronger for female students who reported even lower negative affect if they perceived themselves as competent in STEM disciplines.

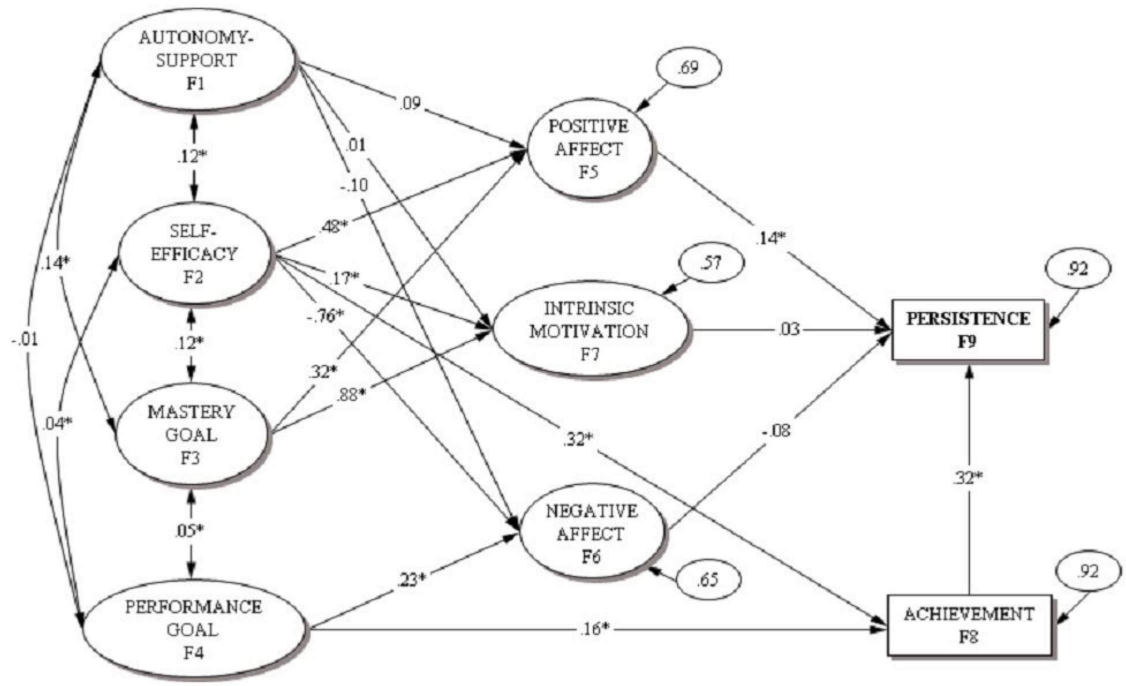

Figure 2: Structural Equation Model: Females.

4 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, χ^2 (219) = 588.09, $p < .0001$, and χ^2/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).

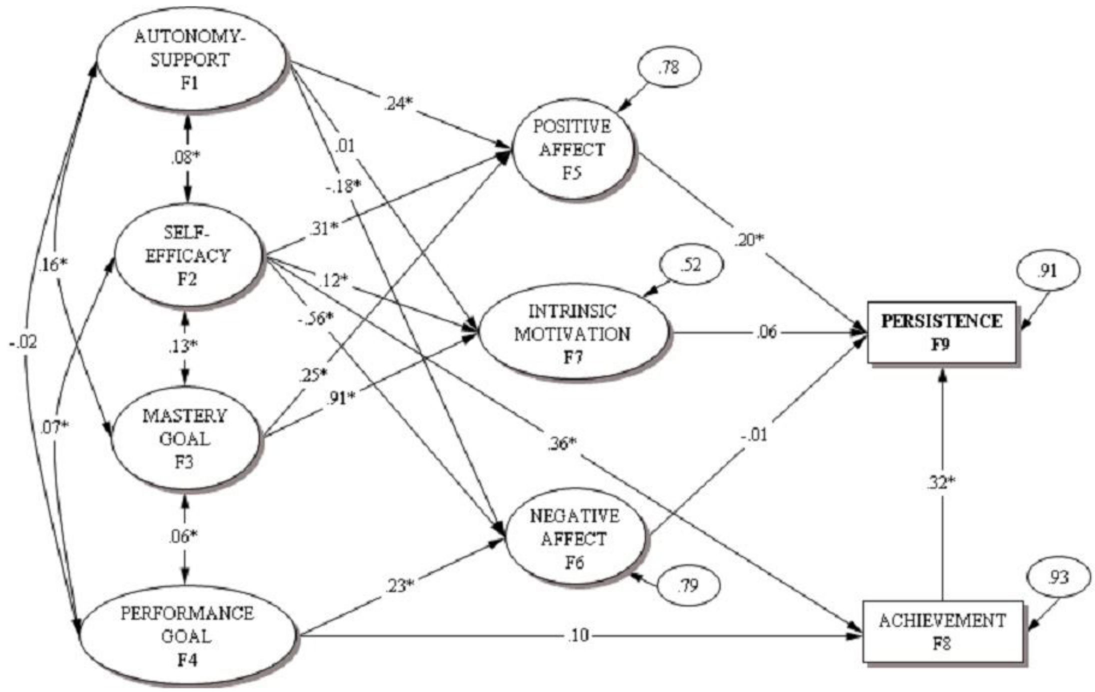

Figure 3: Structural Equation Model: Males.

Discussion

The current study examined the extent to which 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) and *self-determination theory* (Deci & Ryan, 2012), with CEGEP students reporting higher self-efficacy and autonomy support experiencing more positive affect (1b, 3b) and less negative affect (1c, 3c), and students with higher self-efficacy also receiving higher grades (1d). Higher levels of positive affect and achievement, in turn, contributed to greater persistence (4a, 5), with students who felt more efficacious also tending to be intrinsically motivated (1a). 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-approach 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-approach orientation was beneficial for intrinsic motivation (2a) and positive affect (2b), whereas a performance-approach orientation led to greater negative affect (2c) despite higher achievement (2d). 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 group discussions 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-approach 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 et al., 2014). Finally, self-efficacy more strongly predicted lower levels of negative affect in females than in 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).

Limitations

Past research has demonstrated ethnic and cultural differences in science achievement (National Center for Education Statistics, 2000); however, students' demographic characteristics such as ethnic background, socio-economic status, or first language were not explored in the present study. Understanding if and how these characteristics impact students' success and persistence in science is recommended in future research on STEM persistence in CEGEP students, particularly with respect to replicating the present findings with francophone students. Second, although this study used structural equation analyses to test the proposed model, our self-report data was cross-sectional in nature, warranting future research utilizing experimental or longitudinal methods allowing for more substantive evidence in support of our hypothesized causal relations. Finally, this study focused on a limited set of dispositional, motivational variables in line with research on self-efficacy, achievement goals, and self-determined motivation. Further research exploring the effects of social variables on CEGEP student persistence in STEM programs is therefore encouraged, for example, to further examine the effects of parental support and involvement (e.g., Niemiec et al., 2006; Ratelle, Larose, Guay, & Sénécal, 2005) as well as integration in the school milieu (e.g., Grayson, 1994) on academic success and persistence in this population.

Conclusion

The present findings suggest that by supporting students' autonomy in science classrooms (e.g., providing greater choice, encouraging active involvement), instructors in STEM programs may see positive changes in student development—particularly among male students. For female students, however, perceptions of self-efficacy and achievement goals were found to be more important determinants of emotional well-being, persistence, and performance, suggesting that motivational programs aimed at increasing females' sense of competence may contribute to greater engagement in STEM disciplines (e.g., control-enhancing programs, see Hall et al., 2007). More generally, the effects of students' affective experiences on persistence further suggest that instructional efforts to make science activities enjoyable and relevant, and create an emotionally adaptive classroom environment, could also help to promote persistence and achievement in STEM students (cf. emotionally adaptive instruction, see Hall & Goetz, 2013). 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., self-efficacy, mastery, autonomy) 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.

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

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*. Quebec City, QC: 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, NY: Freeman.

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

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

Brophy, J. (2005). Goal theorists should move on from performance goals. *Educational Psychologist*, *40*, 167–176.

Brotman, J. S., & Moore, F. M. (2008). Girls and science: A review of four themes in the science education literature. *Journal of Research in Science Teaching*, *45*, 971–1002.

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.

Chouinard, R., Karsenti, T., & Roy, N. (2007). Relations among competence beliefs, utility value, achievement goals, and effort in mathematics. *British Journal of Educational Psychology*, *77*, 501–517.

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.

Daniels, L. M., Stupnisky, R. H., Pekrun, R., Haynes, T. L., Perry, R. P., & Newall, N. E. (2009). A longitudinal analysis of achievement goals: From affective antecedents to emotional effects and achievement outcomes. *Journal of Educational Psychology*, *101*, 948–963.

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.

Deemer, E. D., Smith, J. L., Carroll, A. N., & Carpenter, J. P. (2014) Academic procrastination in STEM: Interactive effects of stereotype threat and achievement goals. *The Career Development Quarterly*, *62*, 143–155.

Elliot, E. S., & Dweck, C. S. (1988). Goals: An approach to motivation and achievement. *Journal of Personality and Social Psychology*, *54*, 5–12.

Elliot, A. J., & Murayama, K. (2008). On the measurement of achievement goals: Critique, illustration, and application. *Journal of Educational Psychology*, *100*, 613–628.

Elliot, A. J., & McGregor, H. A. (2001). A 2 X 2 achievement goal framework. *Journal of Personality and Social Psychology*, *80*, 501–519.

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

Fast, L. A., Lewis, J. L., Bryant, M. J., Bocian, K. A., Cardullo, R. A., Rettig, M., & Hammond, K. A. (2010). Does math self-efficacy mediate the effect of the perceived classroom environment on standardized math test performance? *Journal of Educational Psychology*, *102*, 729–740.

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.

Goetz, T., Bieg, M., Lüdtke, O., Pekrun, R., & Hall, N.C. (2013). Do girls really experience more anxiety in mathematics? *Psychological Science*, *24*, 2079–2087.

Grayson, J. P. (1994). *Who leaves science? The first year experience at York University*. Toronto, ON: Institute for Social Research, York University.

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., & Goetz, T. (Eds.). (2013). *Emotion, motivation, and self-regulation: A handbook for teachers*. Bingley, UK: Emerald.

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.

Hall, N., & Webb, D. (2014). Instructors' support of student autonomy in an introductory physics course. *Physical Review Special Topics–Physics Education Research*, *10*, 1–22.

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 beliefs during the college transition and academic and vocational adjustment in science and technology programs. *Educational Research and Evaluation*, *12*(4), 373–393.

Larson, L. M., Pesch, K. M., Surapaneni, S., Bonitz, V. S., Wu, T. -S., & Werbel, J. D. (2014). Predicting graduation: The role of mathematics/science self-efficacy. *Journal of Career Assessment*, 1–11.

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 Center for Education Statistics. (2000). *Entry and persistence of women and minorities in college science and engineering education* (NCES 2000-601), by Gary Huang, Nebiyu Taddese, and Elizabeth Walter. Project Officer, Samuel S. Peng. Washington, DC: U.S. Department of Education.

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

Niemiec, C. P., Lynch, M. F., Vansteenkiste, M., Bernstein, J., Deci, E. L., & Ryan, R. M. (2006). The antecedents and consequences of autonomous self-regulation for college: A self-determination theory perspective on socialization. *Journal of Adolescence*, *29*, 761–775.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research*, *66*, 543–578.

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.

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., Elliot, A. J., & Maier, M. A. (2009). Achievement goals and achievement emotions: Testing a model of their joint relations with academic performance. *Journal of Educational Psychology*, *101*, 115–135.

Pekrun, R., & Stephens, S. J. (2010). Achievement emotions in higher education. In J. C. Smart (Ed.), *Higher education: Handbook of theory and research* (vol. 25, pp. 257–306). New York, NY: Springer.

Pekrun, R. H., Hall, N. C., Perry, R. P., & Goetz, T. (2014). Boredom and academic achievement: Testing a model of reciprocal causation. *Journal of Educational Psychology*, *106*, 696–710.

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.

Ratelle, C. F., Larose, S., Guay, F., & Sénécal, C. (2005). Perceptions of parental involvement and support as predictors of college students' persistence in a science curriculum. *Journal of Family Psychology*, *19*, 286–293.

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.

Sawtelle, V., Brewe, E., & Kramer, L. H. (2012). Exploring the relationship between self-efficacy and retention in introductory physics. *Journal of Research in Science Teaching*, *49*, 1096–1121.

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: 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, ON: 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.

Taylor, G., Lekes, N., Gagnon, H. Kwan, L., & Koestner, R. (2012). Need satisfaction, work–school interference and school dropout: An application of self-determination theory. *British Journal of Educational Psychology*, *82*, 622–646.

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.

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.