RESEARCH ARTICLE

Social Support and Motivation in STEM Degree Students: Gender Differences in Relations with Burnout and Academic Success

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Abstract

Existing research underscores the importance of both social-environmental factors (e.g., social support) and psychological factors (e.g., motivation) as buffers against attrition, low performance, and psychological maladjustment in science, technology, engineering, and math (STEM) degree programs. Female STEM students in particular contend with additional academic challenges that can hamper their motivation and performance. This study investigated the relations between social support (personal vs. academic) and well-being, persistence, and academic outcomes as mediated by self-determined motivation and moderated by gender. Structural equation modelling with 221 STEM undergraduates showed significant indirect paths between personal support and STEM career intentions via autonomous motivation. Multigroup analyses further showed male STEM students to benefit more from both personal and academic supports, as well as from greater autonomous motivation, with the academic risks of controlled motivation observed primarily for female STEM students. Implications for motivationally supportive teaching practices in STEM degree programs are discussed.

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Introduction

Low recruitment and retention in science, technology, engineering, and mathematics (STEM) undergraduate programs has established student persistence as a crucial issue in STEM higher education. In Canada, only about 30% of students entering university declare a STEM major (Statistics Canada, 2020) with an estimated 28% of male and 34% of female STEM students changing to a non-STEM field or dropping out of university (i.e., 2010-2016; Wall, 2019). Substantial time commitments and well-being challenges have been posited as contributors to the low graduation rates in STEM programs, with students facing a taxing combination of labs, tutorials, lectures, and often additional co-op terms leading to increasing levels of anxiety and distress (Cooke *et al.*, 2006; Leahy *et al.*, 2010). Research has further examined the especially problematic underrepresentation and persistence rates among women in STEM programs who regularly encounter additional challenges including exclusion, harassment, and structural barriers to effective participation (Blackburn, 2017; Leaper & Star, 2019; Settles *et al.*, 2016).[1] To address these varied challenges, existing research has examined the importance of motivation and social support in predicting STEM student development.

Social support has been found to correspond with not only greater well-being (e.g., Kim *et al.*, 2018; Maymon *et al.*, 2019) but also higher academic achievement for students in STEM disciplines (Walton *et al.*, 2015), particularly for female students (Cheng *et al.*, 2012; Jackson *et al.*, 2019; Rosenthal *et al.*, 2011). Students' motivational beliefs have also been shown to play a critical role in promoting student well-being and academic success in STEM domains (Robinson *et al.*, 2019; Kassaee & Rowell, 2016; Simon *et al.*, 2015). In particular, research based on Self-Determination Theory shows students' reasons for academic persistence that reflect reflect *autonomous motivation* (e.g., intrinsic passion, personal values) to contribute to adaptive outcomes such as greater happiness (Yu *et al.*, 2018), metacognitive strategy use

(Vansteenkiste *et al.*, 2009), and intentions to pursue a STEM career (Skinner *et al.*, 2017). Findings further suggest that self-determined motivation should serve as a mediator of the effects of social support on student outcomes (DeFreese & Smith, 2013; Koka, 2013) and be moderated by gender, given that female students are expected to benefit more from social support and adaptive motivational beliefs than their male counterparts (Hilts *et al.*, 2018). To explore this hypothesis, the present study investigated if self-determined motivation mediated the relations between social support (academic vs. personal) and well-being, persistence, and academic outcomes for STEM degree students, and further examined the extent to which these mediational paths were moderated by gender.

Social Support and Student Development in Higher Education

Longstanding conceptual models of social support suggest that young adults who receive greater social support are more likely to effectively buffer the negative psychological consequences of specific stressful events (e.g., academic challenges; Cohen & Wills, 1985; Lee & Goldstein, 2016), and experience lower levels of burnout as a result (e.g., emotional exhaustion; Shin, Kim, & Lee, 2012). Similarly, Self-Determination Theory (Ryan & Deci, 2000) proposes that greater social support is linked to both greater psychological need satisfaction (i.e., "relatedness") and motivational benefits in achievement settings. In academic settings, research has consistently shown that social support from friends and family, as well as professors and university support services, can help buffer against academic and personal problems experienced by university students (Alsubaie *et al.*, 2019; Maymon *et al.*, 2019).

Social support is broadly defined as resources received from one's social network that help one thrive or handle challenging circumstances and take many forms including encouragement, information, or financial support (Kim *et al.*, 2018; Malecki & Demaray, 2003). Social support has consistently been associated with better levels of psychological well-being (Maymon *et al.*, 2019), burnout (Kim *et al.*, 2018), academic achievement (Walton *et al.*, 2015), as well as greater STEM career aspirations in post-secondary students (Jackson *et al.*, 2019; Leaper & Starr, 2019). Students also typically seek out support from different sources to maintain their progress and development, such as emotional support from friends or information from faculty (Ramsay *et al.*, 2007). "Personal" social support has been consistently assessed in prior research on science motivation in marginalized students as support received from meaningful others in students' personal lives, such as parents (e.g., Simpkins, Estrella, Gaskin, & Koberdanz, 2018; Simpkins, Price, & Garcia, 2015), siblings (e.g., Puente & Simpkins, 2020), and close friends (e.g., Simpkins, Liu, Hsieh, & Estrella, 2020). In contrast, "academic" social support has been previously explored among at-risk STEM students as support from educational instructors, administrators, or staff (e.g., faculty mentorship programs; Hernandez *et al.*, 2023).

In the context of post-secondary education, in comparison to studies exploring personal support from friends and family, there is more limited research on the academic social support students receive from instructors or university services. Existing research suggests that students perceive very little support from faculty (Maymon *et al.*, 2019; Young *et al.*, 2011) and may be too intimidated to seek it out (Longwell-Grice & Longwell-Grice, 2008). However, findings also suggest that when faculty and institutional support is received it can contribute significantly to greater enjoyment of class materials (Aldridge *et al.*, 2012) as well as better levels of stress, quitting intentions, sense of belonging, and life satisfaction in university students (Maymon *et al.*, 2019). For example, a recent meta-analysis of 19 studies (95,434 total participants) by Kim *et al.* (2018) found that support from instructors or a student's university had the strongest negative associations with burnout as compared to support from family or peers.

Motivation in Higher Education: Self-Determination Theory

Motivation has been shown to play an essential role in post-secondary students' academic adjustment, with constructs such as self-efficacy, autonomy, perceived competence, values, causal attributions, and intrinsic motivation having been investigated in relation to engagement, achievement, well-being, and persistence (Gadbois & Sturgeon, 2011; Linnenbrink-Garcia *et al.*, 2018; Lee & Hall, 2020; Pintrich, 2003). One of the most prominent approaches to understanding motivation in educational settings is Self-Determination Theory which proposes student motivation to be due to either internal reasons (e.g., passion) or external factors (e.g., others' expectations). This perspective addresses not only the extent but the specific qualities of students' academic motivation (Roth, 2019). Specifically, Self-Determination Theory posits that motivation exists on a continuum consisting of five subtypes ranging from adaptive, internalized motivation to maladaptive approaches driven by external factors (Ryan & Deci, 2000).

According to this framework, *intrinsic motivation* is the most autonomous subtype and refers to when an activity is completed due to personal interest or enjoyment. *Integrated motivation* is slightly less internal and refers to when an individual views an activity as related to their values or identity.[2] *Identified motivation* reflects an activity being pursued to gain skills or opportunities, and *introjected motivation* results from internalized rewards or punishments such as feelings of obligation, guilt, or pride. Finally, *external motivation* is the most extrinsic and driven by external rewards, such as salary or prestige, and avoiding punishments, such as low grades or lost wages (Ryan & Deci, 2000). Educational researchers often simplify this continuum by combining the three most internal subtypes (intrinsic, integrated, and identified) as *autonomous motivation* and the more extrinsic subtypes (external and introjected) as *controlled motivation* (Ryan & Deci, 2020). Overall, findings show that autonomous motivation consistently contributes to better academic and well-being outcomes for students (Howard *et al.*, 2021; Jeno *et al.*, 2018; Ryan & Deci, 2020; Vansteenkiste *et al.*, 2009) whereas controlled motivation is typically associated with poorer outcomes (Howard *et al.*, 2021; Pisarik, 2009; Ryan & Deci, 2020).

Autonomous motivation has been found to predict better learning outcomes (e.g., higher effort, lower procrastination; Mouratidis *et al.*, 2018), metacognitive and time-management strategies (Vansteenkiste *et al.*, 2009), and classroom engagement (Froiland *et al.*, 2012). Studies have also shown autonomous motivation to predict greater academic achievement (Jeno *et al.*, 2018; Taylor *et al.*, 2014; Yu *et al.*, 2018), persistence (Black & Deci, 2000; Simon *et al.*, 2015), and emotional well-being in university students (Yu *et al.*, 2018). Findings from a meta-analysis by Howard *et al.* (2021) based on 344 samples (223,209 participants) showed that intrinsic and identified motivation were each positively correlated with student achievement, persistence, and well-being. However, intrinsic motivation was most strongly associated with well-being, whereas identified motivation was more strongly related to student persistence (Howard *et al.*, 2021). Intrinsic motivation has also been found to correspond with lower levels of student burnout (Pisarik, 2009) and test anxiety (Vansteenkiste *et al.*, 2009), as well as lower stress and better overall adjustment to university (Baker, 2004).

In contrast, research consistently shows controlled motivation to be associated with detrimental outcomes for university students. For instance, Vansteenkiste *et al.* (2009) found that controlled motivation was related to higher levels of procrastination, cheating, and test anxiety. Controlled motivation is also associated with higher dropout rates (Jeno *et al.*, 2018) as well as poorer levels of boredom and life satisfaction (Brunet *et al.*, 2015), negative affect (Gillet *et al.*, 2013), psychological adjustment (Miquelon *et al.*, 2005), and burnout in post-secondary students (Pisarik, 2009). Introjected motivation shows the strongest associations with a range of negative outcomes for university students including poor self-esteem (Magnus *et al.*, 2010) and higher levels of test anxiety, negative affect, academic dissatisfaction, and emotional exhaustion (Litalien *et al.*, 2015; Pisarik, 2009).

Self-Determined Motivation and Academic Development in STEM

Findings to date on the relationship between self-determined motivation and achievement in STEM undergraduates are mixed. Whereas some researchers have found autonomous motivation to predict better academic achievement (Hall & Webb, 2014; Jeno *et al.*, 2018), others have found no relationship (Black & Deci, 2000; Sturges *et al.*, 2016). Researchers have also found intrinsic motivation to predict better performance on conceptual exam questions (Matthews *et al.*, 2013) or within a specific STEM discipline (e.g., mathematics; Guay & Bureau, 2018), yet observed no relationship with students' overall GPA (Guay & Bureau, 2018; Matthews *et al.*, 2013; Simon *et al.*, 2015). Findings for external motivation are similarly inconsistent, with studies showing it to predict better achievement (e.g., course grade; Sturges *et al.*, 2016), be unrelated to students' grades (Matthews *et al.*, 2013), as well as negatively predict achievement (Guay & Bureau, 2018). Nevertheless, studies consistently show introjected motivation to predict poorer grades for STEM students (Guay & Bureau, 2018; Matthews *et al.*, 2013; Sturges *et al.*, 2016).

With respect to student persistence in STEM fields, findings show autonomous motivation to correspond with lower attrition (Black & Deci, 2000; Jeno *et al.*, 2018; Simon *et al.*, 2015) and stronger intentions to pursue a science career in STEM undergraduates (Skinner *et al.*, 2017), with controlled motivation instead corresponding to greater attrition (Jeno *et al.*, 2018). Findings with high-school students in STEM courses similarly show autonomous motivation to correspond with stronger intentions to pursue further study in science (Lavigne *et al.*, 2007). Although research examining the effects of self-determined motivation on well-being in STEM undergraduates is limited, longitudinal studies have found autonomous motivation to predict greater interest and enjoyment, a focus on learning over grades, and less anxiety related to STEM subjects (Black & Deci, 2000; Hall & Webb, 2014). Black and Deci (2000) also found autonomous motivation to predict better adjustment to university and greater self-perceived competence in STEM undergraduates, with Skinner *et al.* (2017) showing autonomous motivation to be positively correlated with behavioural and emotional engagement in STEM students. In contrast, controlled motivation has been found to predict more anxiety about studying STEM and a focus on grades rather than learning (Black & Deci, 2000).

Social Support in STEM: A Motivational Perspective

Although social support consistently predicts greater academic success and well-being for students in STEM degree programs (Pugh *et al.*, 2019; Rosenthal *et al.*, 2011; Walton *et al.*, 2015), the mechanism by which this happens is unclear. One proposed mediating variable examined in other disciplines is student motivation, such that receiving social support should increase student motivation and lead to beneficial outcomes. For example, research by Koka (2013) with secondary school students showed support from physical education teachers to predict higher autonomous motivation and lower controlled motivation in students 12 months later, with DeFreese and Smith (2013) similarly finding university student athletes who perceived greater teammate support to report greater autonomous motivation. Young *et al.* (2011) further showed that although social support (i.e., from friends, family, professors) predicted greater intrinsic and extrinsic motivation for African American college students across disciplines, it did not predict either type of motivation for white or Hispanic students.

Although the mediational roles of autonomous vs. controlled motivation in the effects of social support on academic development have not been explicitly examined in previous research,[3] studies do show students' psychological needs to mediate these effects. According to Self-Determination Theory, three psychological needs of autonomy, relatedness, and competence must be met in order for students to experience high levels of self-determined motivation (Ryan & Deci, 2000), thus implying that self-determined motivation subtypes might similarly act as mediators of social support effects on student development. For example, a study by Schenkenfelder *et al.* (2020) with undergraduates across disciplines found that psychological needs mediated the positive relationship between support from faculty and peers, and satisfaction with their major. Similarly, a serial mediation study by George *et al.* (2013) with undergraduates across disciplines found that social support was associated with satisfaction of psychological needs that, in turn, was related to greater autonomous motivation and intentions to exercise.

The Present Research: Gender, Social Support, and Motivation in STEM

In addition to the often highly demanding nature of STEM degree coursework, female students in STEM disciplines must also contend with additional challenges due to underrepresentation, gender stereotypes, and structural challenges. For example, gender stereotypes signaled by the media, parents, or teachers may lead female students to perceive STEM fields as intended primarily for men and to experience incongruence between their identities as women and scientists (Blackburn, 2017; Settles *et al.*, 2016). Gender-based discrimination in the form of derogatory comments, in-class favouritism, and sexual harassment from male peers, teaching assistants, or faculty has additionally been found to alienate female students (Leaper & Star, 2019; Robnett, 2016). Female STEM students also typically report lower levels of confidence in their mathematical abilities and higher personal standards than male students with the same level of abilities (Blackburn, 2017; Cimpian *et al.*, 2020; Ellis *et al.*, 2016). Moreover, key structural elements of STEM programs such as deliberately difficult entry level courses, competitive teaching practices (e.g., grading on a curve), and passive learning practices also tend to disproportionally dissuade promising female students from pursuing a STEM career (Cimpian *et al.*, 2020; Hyde & Gess-Newsome, 2000; Seymour & Hunter, 2019).

Research on post-secondary student development suggests that women are significantly more likely than men to seek out social support as a coping strategy for dealing with stressful situations (e.g., Stoliker & Lafreniere, 2015; Weckwerth & Flynn, 2006), with findings further showing social support to be especially beneficial for female students. For example, Cheng *et al.* (2012) found that although emotional support from families generally predicted better and more stable GPAs over three semesters, family support was notably more important for sustaining optimal performance in female students. Findings from Jackson *et al.* (2019) further showed that encouragement and supportive listening from friends and family specifically benefited female students' career aspirations in STEM, with this association being strongest for women with low or average levels of science identity. Moreover, whereas other research shows services aimed at improving retention of women in STEM degree programs by facilitating support from family and peers, as well as academic sources, to promote persistence and well-being (Hyde & Gess-Newsome, 1999; Rosenthal *et al.*, 2011), female students in STEM degree programs may nevertheless perceive less of a connection with their instructors than male students even when such programs are successful (e.g., geoscience; Pugh *et al.*, 2019).

Research on self-determined motivation in university students has also consistently found gender differences in autonomous and controlled motivation. Female students consistently report greater autonomous motivation than male students (Baker, 2004; Köseoğlu, 2013; Mouratidis *et al.*, 2018; Ratelle *et al.*, 2007) with male students often reporting either higher levels of controlled motivation (particularly external motivation; Orvis *et al.*, 2018; Ratelle *et al.*, 2007) or lower levels across all types of motivation (Köseoğlu, 2013). For example, Köseoğlu found that female first-year students reported higher levels of identified motivation than other motivation subtypes, as well as higher levels of all motivation subtypes than male students, who instead most strongly endorsed external motivation. Orvis *et al.* (2018) similarly found external motivation to be more commonly reported as a primary subtype among male students in an introductory chemistry course (61.5%) as compared to female students (55.9%). However, findings also show female students in STEM to report greater introjected motivation relative to males (Orvis *et al.*, 2018; see also Ratelle *et al.*, 2007); a troubling finding given that introjected motivation is typically associated with detrimental academic outcomes (Litalien *et al.*, 2015; Pisarik, 2009).

Despite the intuitive link between social support and self-determined motivation for women in STEM programs, prior research exploring this potential motivational pathway is lacking. Nevertheless, related research based on Self-Determination Theory by Hilts *et al.* (2018) does suggest that self-determined motivation could serve an important mediational role in translating the potential benefits of social support to performance and persistence for women in STEM. More specifically, these authors found that social support from peers corresponded with significantly higher levels of psychological need satisfaction (i.e., perceptions of relatedness with others) that, in turn, predicted better grades and stronger intentions to stay in the STEM program; albeit only for female students. As such, it is possible that self-determined motivation may act similarly to psychological needs in underlying the benefits of social support for students in STEM degree programs. However, given that the self-determined motivation and psychological needs constructs are indeed conceptually distinct, it is also possible similar mediational relations may not be observed for self-determined motivation variables in STEM degree students.

Therefore, beyond studies showing psychological needs to mediate the benefits of social support for undergraduates more generally (e.g., George *et al.*, 2013; Schenkenfelder *et al.*, 2020), preliminary findings further suggest that social support may also be beneficial for sustaining self-determined motivation and academic outcomes, especially for women in STEM degree programs. To explore this hypothesis, the present study used a moderated mediation model to examine the extent to which autonomous and controlled motivation mediated the relations between personal/academic support and well-being, persistence, as well as academic outcomes for STEM degree students. Additionally, the study investigated whether the mediated relationships between social support and student outcomes were moderated by gender. More specifically, whereas the hypothesized mediational model was evaluated for all STEM students in the present sample, additional multigroup analyses were conducted to test for process-level gender differences in relations between the support, motivation, and outcome variables.

Accordingly, it was expected that personal and academic support would be positively associated with autonomous motivation (Hypothesis 1a) and negatively associated with controlled motivation (Hypothesis 1b). Autonomous motivation was further expected to have positive direct relations with well-being, persistence, and academic outcomes (Hypothesis 2a). Moreover, it was expected that autonomous motivation would mediate the expected benefits of both types of support on well-being and academic success (Hypothesis 2b). In contrast, controlled motivation was expected to be negatively associated with well-being, persistence, and academic outcomes (Hypothesis 3a; Pisarik, 2009; Vansteenkiste *et al.*, 2009) and mediate the expected adaptive relations between personal/academic support and student outcomes (Hypothesis 3b).

Following from findings from multiple prior studies showing process-level differences in mediated relations between social support, self-determined motivation, and academic outcomes by gender (Hilts *et al.*, 2018; Jackson *et al.*, 2019), it was also expected that the hypothesized mediational relationships would be moderated by gender. Specifically, the mediated paths between support and well-being, persistence, and academic outcomes via autonomous motivation should be stronger for women (Hypothesis 4a) and the mediational path through controlled motivation should be more negative for women (Hypothesis 4b). Contrary to prior achievement motivation research with STEM students that has examined relations with other academic variables controlling for mean-level gender differences (e.g., autonomous motivation and procrastination; Mouratidis *et al.*, 2018), the present multigroup analysis used to assess Hypothesis 4 was consistent with studies exploring higher-order, process-level differences in these relations by gender (e.g., math utility value and achievement: Guo, Parker, Marsh, & Morin, 2015; science self-concept and persistence in STEM: Jiang, Simpkins, & Eccles, 2020).

Method

Participants and Procedure

A sample of 221 first-year undergraduates enrolled in the faculties of science and engineering at a research-intensive Canadian university were recruited via an internal email in coordination with the campus student affairs office. Participants were primarily female (60.6%) with a mean age of 18.7 years (*SD* = 1.67) and average high-school GPA of 91.5% (*SD* = 5.18). The sample was predominantly Caucasian (47.1%), followed by East Asian (25.8%), West Asian (5.9%), and South Asian (4.5%). The majority of participants were majoring in engineering (30.8%), biological sciences (21.7%), or computer science (16.3%) with less than 10% majoring in other disciplines (mathematics, pharmacology, neuroscience, biochemistry, physics, chemistry, environment).

The study was approved by the university's Research Ethics Board and conducted in Fall 2020. After reviewing an online consent form, students completed a web-based questionnaire consisting of demographic items and self-report measures of social support, self-determined motivation, well-being, persistence, and academic outcomes. High-school and Fall 2020 university Grade Point Averages (GPAs) were obtained from the university Registrar's Office at the end of the term. Students were entered into a draw for one of five $50 cash prizes as compensation for participation.

Study Measures

Social Support: Social support was measured using four scales developed by Maymon *et al.* (2019) that assessed the frequency and quality of support from four different sources: friends, family, faculty/staff, and university services. Each scale consisted of two items assessing the frequency of received support (e.g., "In the last month, how often did you receive support from your friends?") and quality of support received (e.g., "How would you describe the quality of support received from your friends in the last month?") on a five-point scale (1 = *very poor*, 5 = *very good*). Confirmatory factor analysis (CFA) showed a two-factor model differentiated by overall source of support (personal vs. academic) to demonstrate acceptable fit (CFI = .991, TLI = .943, RMSEA = .075), with each latent variable predicting four manifest parcelled variables summing the frequency and quality items for that source.[4]

Self-Determined Motivation: Self-determined motivation was assessed using an adapted version of the Academic Self-Regulation Questionnaire (SRQ-A, Vansteenkiste *et al.*, 2009;

for original, see Ryan & Connell, 1989) and the Motivation for PhD Studies Questionnaire by Litalien *et al.* (2015; MPhD). Scale preambles asked participants to rate how important each item was to their motivation to do well in their STEM courses (1 = *not important* at all, 5 = *very important*). Three four-item subscales from the SRQ-A measured external motivation (e.g., “Because that’s something others (parents, friends, etc.) pressure me to do”), *introjected motivation* (e.g., “Because I would feel guilty if I didn’t study”), and *intrinsic motivation* (e.g., “Because I am highly interested in doing this”).

As there to date exists no published measure of integrated motivation for use with K-12 or post-secondary students (Deci *et al.*, 2013), a three-item subscale adapted from the MPhD was used to assess *integrated motivation* (e.g., “Because my studies are consistent with my values (e.g., interests, morals, etc.)”). Finally, an additional three-item subscale from the MPhD was employed to measure students’ *identified motivation* (e.g., “Because I can improve my skills in my field of study”), due to this measure more closely reflecting the construct of identified motivation as defined by Ryan and Deci (2000; e.g., MPhD items emphasized skill development and opportunities whereas the SRQ-A did not clearly differentiate between skill development and values).

Existing theory and research on self-determined motivation supports both a five-factor model differentiating between increasingly autonomous forms of motivation (external, introjected, identified, integrated, intrinsic; Howard *et al.*, 2017; Ryan & Deci, 2020) and a two-factor model collapsing subtypes into autonomous motivation (intrinsic, integrated, identified) vs. controlled motivation (external, introjected; Ryan & Deci, 2020; Williams & Deci, 1996). Comparative CFAs showed the five-factor model to have better fit (CFI = .857, TLI = .793, RMSEA = .113) but also high multicollinearity between the autonomous motivation subscales (e.g., standardized latent covariances between intrinsic, integrated, and identified motivation over .70). As such, the two-factor autonomous/controlled model of self-determined motivation in which multicollinearity was not observed was adopted for our main SEM analyses (CFI = .757, TLI = .679, RMSEA = .140).[5]

Burnout – Emotional Exhaustion: The seven-item emotional exhaustion subscale of the Maslach Burnout Inventory (MBI; Maslach, *et al.*, 1996) was used to assess psychological well-being for two reasons. First, prior research has specifically identified reduced emotional exhaustion as a critical outcome of social support for students (e.g., Shin, Kim, & Lee, 2012). Second, international research with undergraduates consistently shows the exhaustion subscale to demonstrate stronger internal reliability as compared to other MBI subscales (e.g., Schaufeli *et al.*, 2002: α = .80 vs. .67 for reduced efficacy; Liu *et al.*, 2023: α = .89 vs. .87 for cynicism, .79 for reduced personal accomplishment). Participants answered items such as “I feel used up at the end of the day” on a seven-point scale (1 = *never*, 7 = *every day*). CFA results indicated acceptable fit (CFI = .946, TLI = .892, RMSEA = .136).

Academic Performance: Academic performance was assessed by obtaining students’ high-school GPAs and Fall 2020 semester GPAs from the university Registrar’s Office. As all participants were majoring in a STEM discipline, nearly all courses included in the GPA calculation were within the STEM domain. The means for both high school and university GPA were notably high with low standard deviations indicating limited variability in these performance measures. Three extreme univariate outliers were removed from the university GPA variable as they were beyond an acceptable range of |3| standard deviations from the mean (Kline, 2015).

Creative Thinking: The 10-item Creative Thinking/Problem Solving subscale of the Self Description Questionnaire III (Marsh & O’Neill, 1984) was used to assess creative thinking as an academic outcome.[6] This measure was selected to complement the preceding measure reflecting a typical academic learning outcome (i.e., grades) by also assessing a critical learning process. More specifically, creative thinking was assessed in recognition of the burgeoning OECD recognition of this construct as an important yet underexamined cognitive skill underpinning effective learning and societal innovation specifically in higher education contexts (e.g., Saroyan, 2022). Scale items focused on aspects of creative thinking such as “I am good at combining ideas in ways that others have not tried” and were assessed on a five-point scale (1 = *strongly disagree*, 5 = *strongly agree*). CFA results indicated adequate fit (CFI = .907, TLI = .845, RMSEA = .086).

STEM Career Intentions: The Science Career Plans subscale of the SPIRES survey (Skinner *et al.*, 2017) was used to assesses students’ intentions to pursue a career in STEM. The three-item subscale asked participants about the important of science to their future career goals (e.g., "I am planning on a job that involves science") on a five-point scale (1 = *not true at all*, 5 = *totally true*). No fit indices were available for the CFA for STEM career intentions as the model was just-identified, however, factor loadings were acceptable (> 0.80).

Results

Preliminary Analyses

Descriptive information (means, standard deviations, observed ranges) and internal reliabilities for the study measures are displayed in Table 1, with correlations outlined in Table 2. Gender-based analyses showed that female students reported experiencing more support from friends ($t(220) = -2.49$, $p = .014$, $d = 0.36$) but also higher levels of controlled motivation ($t(220) = -3.35$, $p = .001$, $d = 0.46$) and emotional exhaustion ($t(220) = -2.83$, $p = .005$, $d = 0.39$) than males. Female students also rated themselves lower in creative thinking than male students ($t(219) = 3.97$, $p < .001$, $d = 0.54$). Concerning analyses of potential covariates (i.e., age, ethnicity, high-school GPA), younger students (aged 17-18) reported receiving more support from friends ($t(208) = 2.06$, $p = .041$, $d = 0.28$) and faculty ($t(201) = 2.10$, $p = .037$, $d = 0.29$) and had higher university GPAs ($t(202) = 2.15$, $p = .033$, $d = 0.30$) than older students (aged 19+).[7] There were no significant differences due to ethnicity, however, high-school GPA did positively correspond with both faculty support ($r = .182$, $p = .008$) and university GPA ($r = .366$, $p < .001$). When age and high-school GPA were individually entered into the main analytic model as potential covariates, the model fit and parameters remained nearly identical and thus the main analyses excluding covariates was retained for the sake of parsimony. In contrast, the magnitude and number of significant gender differences observed provided preliminary support for the analysis of gender as a moderating variable.

Table 1. Descriptive Statistics for Study Measures.

Scale	*n*	*M*	*SD*	Observed range	*α/r*
Support from friends	219	3.87	0.96	1-5	.73
Support from family	220	4.02	0.92	1-5	.60
Support from faculty/staff	218	2.86	0.86	1-5	.64
Support from university programs	213	2.70	0.84	1-4.5	.50
Autonomous motivation	221	3.97	0.69	1.4-5.0	.90
Controlled motivation	221	2.81	0.85	1-5	.84
Emotional exhaustion	221	4.91	1.38	1-7	.92
Creative thinking	220	3.32	0.64	1.33-4.89	.81
STEM intentions	220	4.44	0.82	1-5	.91
University GPA	217	3.88	0.18	0.46-4.00	-

Note. Inter-item *r*s are presented for the two-item support measures.

Mediational SEM Analysis: Total Sample

Structural equation modelling (SEM) was employed to examine the hypothesized relationships between personal and academic social support, motivation (autonomous and controlled), and measures of student well-being, persistence, and academic success. Both direct effects from personal and academic support to the dependent variables, and indirect effects via self-determined motivation, were modelled to ensure a suitably conservative analysis of the study hypotheses. Covariances were modelled between personal and academic support, between the residual errors for autonomous and controlled motivation (mediators), and between the residual errors for the dependent variables consistent with the zero-order correlations (Table 2).

Table 2. Zero-order Correlations among Study Variables.

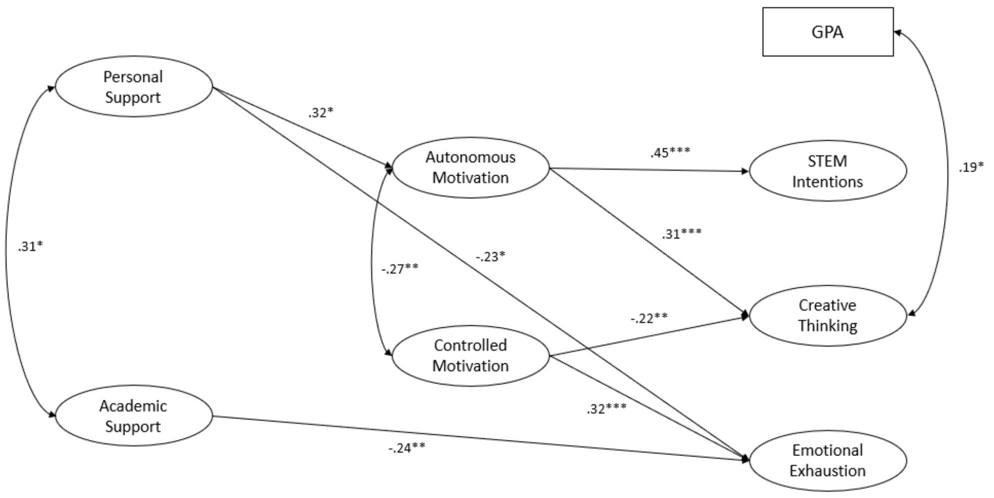
	1	2	3	4	5	6	7
1. Personal support	-						
2. Academic support	.191*	-					
3. Autonomous motivation	.233**	.202*	-				
4. Controlled motivation	.046	-.082	-.147*	-			
5. Emotional exhaustion	-.204*	-.302**	-.214*	.305**	-		
6. University GPA	.094	.162*	.165*	.009	-.097	-	
7. Creative thinking	.051	.131	.310**	-.214*	-.205*	.208**	-
8. STEM intentions	.066	.022	.372**	-.121	-.076	.117	.138*

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

All SEM analyses were completed in AMOS 28.0 using a maximum likelihood estimator with multiple imputation used to estimate the missing values. Model fit was assessed with the chi-squared goodness of fit test, comparative fit index (CFI > .90), Tucker-Lewis index (TLI > .90), and root mean square error of approximation (RMSEA < .07). Whereas the CFI and TLI are comparative indices best suited for exploratory studies where the focus is on identifying to what extent relations between variables exceed those of a null model, RMSEA is instead better suited to confirmatory studies aiming to evaluate if a given hypothesized model "fits well enough to yield interpretable parameters" (p. 378; Rigdon, 1996). Given that the present study tested an a priori moderated-mediation model based on evidence from existing theory and research on social support and achievement motivation, RMSEA fit indices were prioritized when interpreting study findings. Nevertheless, the comparative CFI and TLI indices were reported to provide information on the strength of relations between study variables as compared to a baseline model in which no relations are proposed. Follow-up bootstrapping analyses with 1,000 samples (Preacher & Hayes, 2008) and 95% confidence intervals were conducted to evaluate the significance of indirect effects of personal and academic support on university GPA, STEM career intentions, creative thinking, and emotional exhaustion as mediated by autonomous and controlled motivation.

The main SEM mediational model evaluated with the total study sample demonstrated an acceptable RMSEA fit index (.067) and a significant chi-squared index ($\chi^2(713) = 1415.98$, $p < .001$), but otherwise mediocre levels on the comparative fit indices: CFI = .837, TLI = .813. As outlined in Figure 1, results showed that personal support was positively associated with autonomous motivation ($\beta = .32$, $p = .010$) but had no relationship with controlled motivation. Academic support was not significantly related to either type of motivation. However, both academic support ($\beta = -.24$, $p = .004$) and personal support ($\beta = -.23$, $p = .049$) showed negative direct relationships with emotional exhaustion. Autonomous motivation was positively associated with STEM career intentions ($\beta = .45$, $p < .001$) and creative thinking ($\beta = .31$, $p < .001$). In contrast, controlled motivation was negatively associated with creative thinking ($\beta = -.22$, $p = .010$) and showed a positive relationship with emotional exhaustion ($\beta = .32$, $p = .001$). University GPA was not predicted by any variable in the model. Supplemental bootstrapping analysis showed significant indirect effects for only personal support on STEM intentions via autonomous motivation ($\beta = .14$, $p = .012$, 95% CI = [0.03, 0.29]) and for personal support on creative thinking via autonomous motivation ($\beta = .10$, $p = .018$, 95% CI = [0.01, 0.20]).

Figure 1. Mediational SEM Results for Total Sample.

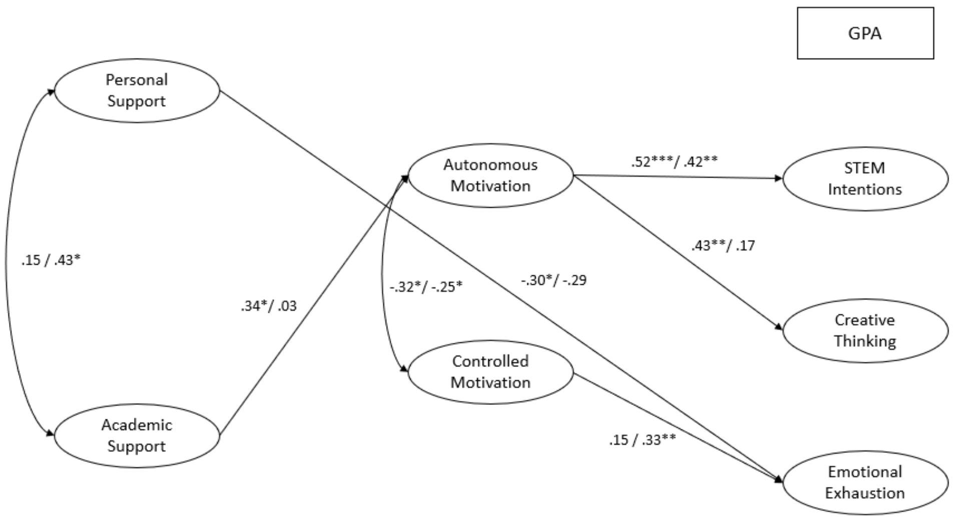


Note. Standardized coefficients for the mediational analysis. Only statistically significant paths are shown. *p < .05. **p < .01. ***p < .001.

Multigroup SEM Analysis by Gender

To examine hypothesized gender differences, the mediational, multigroup SEM was assessed contrasting male and female STEM students at the measurement and structural levels. First, the unconstrained mediational model was examined separately by gender (see Figure 2), with a subsequent multigroup analysis examining the extent of measurement invariance (i.e., constrained measurement weights and intercepts) and structural invariance (i.e., constrained measurement weights and intercepts, structural weights, intercepts, means, and covariances) by gender. Bootstrapping analyses to identify indirect effects by gender were not possible at the latent level due to non-positive estimates of variance and were instead conducted with composite variables using PROCESS 3.5 in SPSS 26.0.

Figure 2. Multigroup SEM by Gender: Unconstrained Model.



Note. Standardized coefficients for male vs. female students are presented before vs. after the slash, respectively. Only statistically significant paths are shown. *p < .05. **p < .01. ***p < .001.

The unconstrained multigroup SEM mediational model differentiating based on gender showed a good RMSEA fit index (.057) and a significant chi-squared index ($\chi^2(1{,}426) = 2{,}424.433$, $p < .001$), but otherwise continued to demonstrate mediocre levels on comparative fit indices: CFI = .777, TLI = .743. In the unconstrained model for male students, academic support was positively associated with autonomous motivation ($\beta = .34$, $p = .014$) that, in turn, was positively associated with creative thinking ($\beta = .43$, $p = .004$) and STEM intentions ($\beta =$

.52, $p < .001$). Personal support was not related to either type of motivation but had a negative direct path to emotional exhaustion ($\beta = -.30$, $p = .026$). For female students, the unconstrained model showed few significant relationships, with neither type of support predicting motivation or any dependent variables. Autonomous motivation was positively related to STEM career intentions for female students ($\beta = .42$, $p = .003$), with controlled motivation having a positive association with emotional exhaustion only for women ($\beta = .33$, $p = .001$).

PROCESS mediation analyses of indirect effects showed multiple small yet significant indirect effects. For female students, autonomous motivation mediated the effects of personal support on both STEM career intentions ($\beta = .037$, $SE = .017$, 95% CI = [.0088, .0761]) and creative thinking ($\beta = .027$, $SE = .015$, 95% CI = [.0049, .0619]). For male students, autonomous motivation mediated the effects of academic support on STEM career intentions ($\beta = .081$, $SE = .041$, 95% CI = [.0142, .1731]), creative thinking ($\beta = .042$, $SE = .022$, 95% CI = [.0071, .0924]), and emotional exhaustion ($\beta = -.059$, $SE = .033$, 95% CI = [-.1307, -.0034]). Controlled motivation was not a significant mediator of relations between social support and the well-being, persistence, and academic outcomes assessed. Finally, multigroup chi-squared difference tests comparing the unconstrained latent model with one including measurement constraints did not reach significance ($\chi^2(76) = 94.89$, $p = .070$), with a follow-up contrast between the constrained measurement and structurally constrained model similarly showing no overall model differences by gender ($\chi^2(19) = 19.65$, $p = .416$).

Discussion

The current study proposed that both personal and academic social support should be positively associated with students' well-being, persistence, and academic achievement in STEM degree programs via a positive relationship with autonomous motivation and lower levels of controlled motivation. Moreover, these relationships were expected to be stronger for female students for whom STEM degree programs pose additional challenges. Study findings provided partial support for the hypothesized relationships as discussed in detail below.

Relations with Social Support

The first hypothesis proposed that personal and academic social support would be positively associated with autonomous motivation (Hypothesis 1a) and negatively associated with controlled motivation (Hypothesis 1b). Hypothesis 1a was partially supported by the zero-order correlations showing that autonomous motivation was positively correlated with personal and academic support. However, the mediational SEM model showed only personal support, and not academic support, to have a significant positive relationship with autonomous motivation. Contrary to expectations and existing research (Koka, 2013), neither type of support was significantly related to controlled motivation levels (Hypothesis 1b). Additionally, both personal and academic support showed negative direct relationships with emotional exhaustion.

It is perhaps not surprising that personal support was associated with greater emotional well-being but not with better academic outcomes. However, it was unexpected to find the same pattern of results for academic support, particularly since the support provided by academic sources are typically specific to academic issues (Hyde & Gess-Newsome, 1999; Ramsay *et al.*, 2007). Whereas receiving academic support may help students feel less overwhelmed, it is commonly assumed that such support should also impact students' academic outcomes including their creative thinking skills (e.g., when receiving assistance with problem solving) and GPA, as well as their intentions to pursue a STEM career.

Mediational Role of Autonomous Motivation

Existing research has consistently shown autonomous motivation to predict beneficial outcomes in post-secondary students such as engagement, well-being, and persistence (Black & Deci, 2000; Jeno *et al.*, 2018; Vansteenkiste *et al.*, 2009). Although our findings are generally consistent with this literature, not all expected relationships were significant (Hypothesis 2a). In the SEM model, autonomous motivation was associated with higher levels of creative thinking and intentions to continue in a STEM career. However, contrary to previous research (e.g., Brunet *et al.*, 2015; Pisarik, 2009) this model did not show an inverse relationship between autonomous motivation and emotional exhaustion. Although university GPA was also not significantly associated with autonomous motivation, this latter finding is consistent with existing literature (Black & Deci, 2000; Simon *et al.*, 2015; Sturges *et al.*, 2016) and may simply reflect a ceiling effect due to the highly competitive admission requirements of the participants' institution (e.g., 49% of study participants achieved a university GPA of 4.0).

Concerning Hypothesis 2b, the mediation analysis showed relations between personal support and STEM career intentions to be fully mediated by autonomous motivation. These results are similar to Hilts *et al.* (2018) who found psychological needs to mediate the relationship between peer support and STEM intentions. However, contrary to Hypothesis 2b, no other statistically significant indirect paths via autonomous motivation were found. Moreover, whereas existing research in non-STEM domains has shown academic support to benefit autonomous motivation and learning (Koka, 2013; Schenkenfelder *et al.* 2020), no mediation of relations between academic support and autonomous motivation was observed in this study. It is possible that the mediocre CFA fit for the self-determined motivation measures, combined with lower frequency/quality of self-rated academic support, could have contributed to this result (for more on low academic help-seeking in competitive environments, see Karabenick, 2004).

Mediational Role of Controlled Motivation

In contrast to autonomous motivation, controlled motivation is typically associated with detrimental academic outcomes in post-secondary contexts (Howard *et al.*, 2021; Vansteenkiste *et al.*, 2009). Consistent with prior research, our findings showed that controlled motivation was related to poorer outcomes for STEM students, including poorer levels of creative thinking and emotional exhaustion (Hypothesis 3a). Interestingly, controlled motivation did not demonstrate a significant relationship with students' intentions to pursue STEM careers. This finding suggests that although STEM students who are motivated by more extrinsic reasons (e.g., to satisfy others' expectations, get a prestigious job, appear intelligent) may experience greater exhaustion, this type of motivation is unlikely to impact their career plans. Lastly, similarly to autonomous motivation, controlled motivation was not related to university GPA, once again likely due to ceiling effects (high GPA levels with low variability).

It was additionally expected that controlled motivation would mediate the effects of personal and academic support on student outcomes (Hypothesis 3b). Specifically, students who reported higher levels of support were expected to experience lower levels of controlled motivation and, in turn, better outcomes (e.g., lower emotional exhaustion, higher STEM intentions). However, our results instead showed controlled motivation to not significantly mediate relations between either personal or academic support and students' well-being, career intentions, or academic outcomes. These findings are consistent with the lack of zero-order correlations between personal or academic support and controlled motivation. Although this result is inconsistent with previous findings (DeFreese & Smith, 2013; Koka, 2013; Schenkenfelder *et al.*, 2020), this lack of mediation may again be due to the poor fit overall for the self-determined motivation measures or the competitive nature of the institution from which students were recruited (see Study Limitations).

Moderation by Gender

Findings from the initial difference tests provided initial support for the gender moderation hypothesis (Hypothesis 4) in showing that although female students reported more support from friends, they also reported higher levels of controlled motivation and poorer levels of emotional exhaustion and creative thinking. These gender differences in self-rated support and exhaustion are consistent with existing literature with post-secondary students (e.g., support: Weckwerth & Flynn, 2006; emotional exhaustion: Pisarik, 2009). Moreover, although female post-secondary students have generally been found to report higher levels of autonomous motivation than their male peers (Baker, 2004; Vansteenkiste *et al.*, 2009), prior studies with STEM students similarly show female students to report higher levels of controlled motivation than male students (Köseoğlu, 2013; Orvis *et al.*, 2018; Ratelle *et al.*, 2007).

When the hypothesized model was assessed separately for male and female students, gender differences were also found in the number of significant direct and indirect relationships observed. In particular, although male students showed expected inverse relationships between personal support and exhaustion, as well as positive relations between academic support and autonomous motivation, neither type of support was directly related to motivation, well-being, career intentions, or academic outcomes for female students. Whereas autonomous motivation was associated with STEM intentions for both male and female STEM students, autonomous motivation was only associated with more creative thinking for male students. For female students, the only other significant direct effect observed was a detrimental relationship between controlled motivation and exhaustion. Additionally, significant indirect effects for male students showed autonomous motivation to mediate the positive relations between academic support and STEM intentions, creative thinking, and the negative relation with exhaustion, with female students instead showing positive relations between personal support and STEM intentions as well as creative thinking to be mediated by greater autonomous motivation.

These gender effects suggest that male STEM students benefited significantly from support provided by their personal relationships and their academic environment, whereas women in STEM programs derived more limited benefits from personal support and negligible benefits from academic supports. Findings further suggested that male students were more likely to benefit from autonomous motivation and not suffer if motivated by more controlled reasons, with the potential risks of controlled motivation instead being observed primarily for female STEM students. Although these results are contrary to Hypothesis 4a and existing findings that suggest female students benefit more from social support (Cheng *et al.*, 2012; Jackson *et al.*, 2019; Kamen *et al.*, 2011), most previous studies have examined only personal support and have not examined gender differences in the benefits of academic support in STEM disciplines. Nevertheless, these results are partially consistent with Hypothesis 4b in that although mediation via controlled motivation was not observed, the maladaptive relationships between this type of motivation and the outcome variables were notably worse for female STEM students.

It is important to note that our multigroup SEM analysis testing for gender invariance in the measurement model and structural model showed no statistically significant differences in the overall hypothesized model for male vs. female STEM students. Thus, although there were gender differences found for specific indirect pathways (e.g., personal support → autonomous motivation → STEM intentions and creative thinking for female students), most parameters in the overall hypothesized model were equivalent for male and female STEM students. This multigroup pattern of results is contrary to the fourth hypothesis that social support should have stronger indirect relations for female as compared to male STEM students via self-determined motivation. Regardless, this finding is consistent with existing research with post-secondary students showing gender-invariance in self-determined motivation (Jeno *et al.*, 2018; Litalien *et al.*, 2019), and expands on previous studies in demonstrating a lack of gender differences in relations between social support, self-determined motivation, and academic outcomes for students in STEM degree programs.

Study Limitations

When considering the replicability and generalizability of the study findings, multiple key limitations should be considered. Firstly, although the sample size of 221 was acceptable for conducting SEM analyses, it did afford limited power when conducting multigroup analyses thus representing a potential explanation for few gender moderation effects. Future research in which the study hypotheses are evaluated with a substantially larger sample size is recommended, with a larger-scale dataset also expected to mitigate the discrepancy between the acceptable RMSEA and poor CFI/TLI fit indices observed in this study (e.g., $n > 1{,}000$; Lai & Green, 2016). Second, because all study variables except for GPA were assessed with self-report measures, it is possible that hindsight bias or social desirability may have influenced responses (Sigmon *et al.*, 2005; Thomas & Diener, 1990). Moreover, given that emotional exhaustion was the only self-report indicator of well-being assessed in the present study, additional positively- and negatively-valenced measures of psychological adjustment such as life satisfaction or depression should be examined in future studies to more comprehensively examine the extent to which social support and motivation impact this critical aspect of STEM student development.

Since study participation was voluntary, it is also possible that selection bias may have impacted our results. For example, successful STEM students or struggling female students may have been particularly motivated to participate in a study providing an opportunity to reflect on their academic and social experiences in STEM degree programs. Relatedly, generalizing study results to students in STEM programs at other universities should be done with caution given that the highly competitive admissions requirements of the present research-intensive institution may not be representative of other institutions (e.g., comprehensive universities, four-year colleges). Moreover, as program demands and gender ratios/inclusiveness can vary widely among STEM disciplines, future research examining similar constructs within individual STEM degree programs (e.g., biology, chemistry, computer science) is encouraged to better assess generalizability of findings across STEM domains.

As with all cross-sectional studies, claims about the causal nature of relationships between the study variables are also not afforded by the present data. Although the study measures and analytical methods were based on existing research, further studies of an experimental or longitudinal nature are warranted to directly examine the directionality of relationships between study variables (e.g., tracking persistence in subsequent years, exploring the efficacy of support interventions vs. a control groups). Lastly, the mediocre fitting CFA for the self-determined motivation measures may have contributed to the mediocre fit of the main analyses and lack of mediation results. Specifically, the inclusion of the typically omitted integrated motivation subscale may have led to the poorer fit due to possible issues with discriminant validity (Deci *et al.*, 2013; see Footnote 5). Alternatively, the lack of mediation results could suggest that self-determined motivation may not be the most effective mediator of relationships between social support and student outcomes in STEM disciplines. Future research is encouraged to examine other potential mediators such as math anxiety or endorsement of gender stereotypes that have consistently been found to correspond with social support and student success in STEM domains (Lavasani & Khandan, 2011; Riegle-Crumb & Morton, 2017).

Implications and Future Directions

Perhaps the most surprising finding from this study was that suggesting that male STEM students appear to benefit substantially more from social support than female students. Given that many programs that help to improve retention of female students in STEM heavily feature academic and peer support (Hyde & Gess-Newsome, 1999; Rosenthal *et al*, 2011), further investigation is needed to examine why personal and academic support may not be as beneficial for female students in this study. It is possible that due to the male-dominated nature of many STEM programs, the supports provided by departments and individual professors are more oriented towards male students' struggles. Alternatively, it is possible that female students may feel less comfortable using support services provided in STEM degree programs (e.g., due to a lack of female faculty who identify with their concerns).

Research by Pugh *et al.* (2019) suggests that even in STEM departments regarded as successful at retaining female students, females regularly report experiencing less of a connection with their instructor than do male students. Leaper and Starr (2019) further observed a majority of female STEM students to report experiencing gender bias and sexual harassment from various individuals in their program including faculty and teaching assistants. These types of findings suggest that female students may indeed benefit less from academic support due to social-environmental factors that could counteract these positive effects. As academic support represents a key contributor to the learning experiences of female STEM students, it is crucial to learn why academic support may not benefit female STEM students and consider how a more gender-inclusive approach could be adopted to better equip all students rather than further contributing to the male-dominated nature of STEM disciplines.

Another notable finding was the relations between different types of academic motivation and the outcome variables for women in STEM programs. Although findings suggested that autonomous motivation did not substantially benefit women participants, female students who were autonomously motivated were more likely to report creative thinking and intentions to pursue a STEM career. Results also showed that women in STEM programs who reported more controlled motivation also reported notably poorer well-being. Relatedly, motivational interventions based on Self-Determination Theory have shown considerable promise in encouraging students to adopt more adaptive motivational beliefs (e.g., programs targeting tutors' mentoring style or presenting information to students using intrinsic priming and choice; McLachlan & Hagger, 2010; Vansteenkiste *et al.*, 2005). However, considering that brief interventions attempting to change students' reasons for studying have also been found to have unintended negative consequences for STEM students (e.g., Hall & Sverdlik, 2016), a more straightforward method for improving motivation in female STEM students may be to simply re-examine teaching practices used by STEM programs.

As outlined in the literature review, STEM degree programs tend to employ controlling teaching styles in introductory courses, such as authoritarian instruction and competitive grading, that have especially negative impacts on female students (e.g., reduced motivation, confidence, grades; Seymour & Hunter, 2019). As such teaching practices may also contribute to the low retention of female students in STEM programs by dampening autonomous motivation and promoting controlled motivation, STEM faculty and administrators might encourage greater representation of women by limiting these practices. Moreover, although such practices may have fewer detrimental effects for male students in STEM, adopting more autonomy supportive teaching should lead to greater learning, persistence, and well-being for male and female students alike (Pugh *et al.*, 2019; Black & Deci, 2000). Additionally, university support programs and STEM departments should consider how existing resources and workshops can be improved to better support autonomous motivation in students (e.g., providing more options, transparent rationales) while also minimizing controlling elements (e.g., one-way vs. interactive messaging, providing directions vs. allowing discussion). Overall, our findings suggest that such modifications to existing programs could lead to greater creativity, well-being, and persistence for students in STEM degree programs, particularly women, by improving their self-determined motivation.

In sum, the present study contributes to existing research by showing self-determined motivation to mediate specific relationships between social support and student outcomes, with different indirect paths being observed for male vs. female students. In particular, our findings suggest that whereas academic support may be beneficial for male students in STEM programs, it was not effective for female STEM students. Moreover, these results suggested that male students in STEM may derive greater benefit from autonomous motivation, with female students instead being more likely to demonstrate the commonly observed detrimental relations with controlled motivation. These findings clearly indicate that course instruction, departmental support programs, and faculty interactions in STEM degree programs have the potential to more meaningfully include female students if modified to promote autonomous motivation and discourage controlled motivational beliefs. Further longitudinal research is thus encouraged to examine the long-term effects of social support and self-determined motivation on academic achievement, persistence, and well-being for post-secondary students in STEM, and the efficacy of institutional efforts to optimize the supports provided to both male and female students in these demanding degree programs.

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Footnotes

[1]It is important to note that the underrepresentation of women in STEM fields is not applicable to health-related domains, such as biology and medicine, in which female graduates are typically overrepresented relative to males (Statistics Canada, 2016).

[2]Integrated motivation has not been assessed in most educational research due to factor analyses being consistently unable to distinguish it from identified motivation, and the theoretical rationale that integrated motivation is not a meaningful psychological construct prior to adulthood (Deci *et al*., 2013).

[3]Although Cassidy and Giles (2009) found that intrinsic motivation mediated the relationship between social support and academic performance and problem-solving efficacy of undergraduates, the measure of intrinsic motivation was problematic due to inclusion of scale items assessing additional constructs including work ethic and competitiveness.

[4]The relative fit of this model was contrasted with two other CFA models, a two-factor model of frequency vs. quality and a four-factor model by source of support (friends, family, faculty, university programs), both of which displayed poorer model fit.

[5]One extrinsic motivation item (e.g., “I'm supposed to do so”) and one integrated motivation item (e.g., “My studies are a fundamental part of who I am and my identity”) were removed due to poor factor loadings in the CFA analysis (e.g., $\beta < .50$). EFA analyses also supported the removal of these two items, and showed the subscales to differentiate as expected except for integrated and identified motivation items that loaded together (.56-.80). Chronbach’s alpha was also lower for the integrated subscale (.64) than the other subscales (.73-.89). Although researchers often exclude the integrated motivation measure from further analysis for these reasons (see Deci *et al*., 2013), this measure was included to maintain the theoretical integrity of the five-factor model proposed for adult samples in Self-Determination Theory (Ryan & Deci,

2020) and based on a restricted, two-factor EFA showing items to clearly load according to the superordinate autonomous motivation (.60-.86) or controlled motivation dimensions (.47-.85).

[6]One item was removed due to its mention of curiosity which is largely considered to represent a separate construct (Schutte & Malouff, 2019).

[7]Age was converted to a dichotomous variable with groups of comparable size (age: 17-18, 19+) due to being highly skewed (skew = 8.67, kurtosis = 103.57).

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