Exploring the Impacts of Social Support and Motivation on STEM Students' Well-Being and Academic Success

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Table of Contents

Abstract

Students in science, technology, engineering, and math (STEM) programs face high attrition rates, substantial time commitments, and well-being challenges. Female STEM students must additionally contend with lower self-efficacy, gender stereotypes, and exclusionary academic environments. Existing research underscores the importance of both social-environmental factors (e.g., social support) and internal psychological factors (e.g., motivation) as potential buffers against attrition, low performance, and psychological maladjustment in STEM disciplines. The present study thus investigated the relationship 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 findings with 221 undergraduate STEM students showed a significant indirect effect of personal support on future STEM intentions via autonomous motivation. Multigroup analyses further showed both types of support and autonomous motivation to have stronger benefits for men, with controlled motivation predicting higher burnout only for women. Implications for gender-specific social and motivational supports for STEM students are discussed.

Abrégé

Les étudiants des programmes de sciences, de technologie, d'ingénierie et de mathématiques (STEM) sont confrontés à des taux d'attrition élevés, à des engagements de temps substantiels et à des défis de bien-être. Les étudiantes en STEM doivent en outre faire face à une moindre efficacité personnelle, des stéréotypes de genre et des environnements académiques d'exclusion. Les recherches existantes soulignent l'importance des facteurs socio-environnementaux (par exemple, le soutien social) et des facteurs psychologiques internes (par exemple, la motivation) en tant que tampons potentiels contre l'attrition, les faibles performances et l'inadaptation psychologique dans les disciplines STEM. La présente étude a donc examiné la relation entre le soutien social (personnel vs académique) et le bien-être, la persévérance et les résultats scolaires tels que médiés par la motivation autodéterminée et modérés par le sexe. Les résultats de la modélisation des équations structurelles avec 221 étudiants de premier cycle en STEM ont montré un effet indirect significatif du soutien personnel sur les intentions futures des STEM via une motivation autonome. Des analyses multigroupes ont en outre montré que les deux types de soutien et de motivation autonome présentaient des avantages plus importants pour les hommes, une motivation contrôlée prédisant un épuisement plus élevé uniquement pour les femmes. Les implications pour les soutiens sociaux et motivationnels spécifiques au genre pour les étudiants en STIM sont discutées.

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List of Tables

List of Figures

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. Substantial program time commitments and well-being challenges have been posited as contributors to the low graduation rates, with students in STEM degree programs 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). Female students in particular often contend with underrepresentation, gender stereotypes, and lack of support in STEM disciplines that can lead to feeling isolated and unwelcome in STEM environments (Blackburn, 2017) and negatively impact their confidence and motivation (Hyde & Gess-Newsome, 2000; Seymour & Hunter, 2019).

To address these issues, existing research has examined the importance of social support and motivation as potential buffers of detrimental outcomes in STEM students. Social support has consistently been associated with better levels of life satisfaction (Maymon et al., 2019), burnout (Kim et al., 2018), academic achievement (Walton et al., 2015), and STEM career aspirations in post-secondary students (Jackson et al., 2019; Leaper & Starr, 2019). Furthermore, students typically seek out support from different sources to maintain their progress and development, such as emotional support from friends or informational support from faculty (Ramsey et al., 2007). Existing research also shows that social support may be especially beneficial for female STEM students (Cheng et al., 2012; Jackson et al., 2019), with services aimed at improving retention of women in STEM degree programs showing support from family and peers, as well as academic sources, to play a crucial role in promoting persistence and well-being (Hyde & Gess-Newsome, 1999; 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. In particular, research based on self-determination theory shows students' reasons for academic persistence that reflect *autonomous motivation* (e.g., intrinsic passion, personal values) to contribute to adaptive outcomes such as greater happiness (Yu et al., 2018), use of metacognitive strategies (Vansteenkiste et al., 2009), and intentions to pursue a STEM career (Skinner et al., 2017). In contrast, motivational beliefs focused on more *controlled motivation* (e.g., extrinsic rewards, guilt) have been found to correspond with negative student outcomes such as test anxiety (Black & Deci, 2000), lower life satisfaction (Brunet et al., 2015), procrastination (Vansteenkiste et al., 2009), and attrition from STEM degree programs (Jeno et al., 2018).

Findings further suggest that self-determined motivation should serve as a mediator of the effects of social support on student outcomes. In other words, receiving social support should increase students' adaptive motivational beliefs (e.g., greater autonomous, less controlled motivation) and, in turn, lead to beneficial well-being and academic outcomes. This mediational hypothesis is consistent with findings showing support from teachers and peers to predict higher autonomous motivation and lower controlled motivation (DeFreese and Smith, 2013; Koka, 2013), however no research to date has fully explored this proposed mediational pathway. Furthermore, research by Hilts et al. (2018) suggests that this proposed mediational pathway may be moderated by gender with female students benefiting more from social support and adaptive motivational beliefs than their male counterparts. To explore this hypothesis, the present study investigated the extent to which self-determined motivation mediated the effects of social support (academic vs. personal) on STEM students' well-being, persistence, and achievement and the extent to which these mediated relationships were moderated by gender.

Literature Review

Well-being and Persistence in STEM Degree Programs

Over the past few decades, countries around the world have devoted extensive research, policymaking, and funds to address the problem of low recruitment and retention in STEM fields. In Canada, only about 30% of students entering university declare a STEM major (Statistics Canada, 2020). Despite the continuing recruitment efforts, this number has increased by less than 4% from 2010 to 2016 (Statistics Canada, 2020). During this six-year period, 28% of male and 34% of female STEM students changed to a non-STEM field or dropped out of university all together (Wall, 2019). Moreover, from 2010-2016, only 29% of students in Canadian STEM programs had graduated within 4 years compared to 51% of non-STEM students (Statistics Canada, 2020).

One potential reason for these disappointing graduate rates is that STEM programs may require a larger time-commitment and greater persistence compared with many non-STEM programs. For example, one study found that students in engineering and science spent 15-24 hours in courses, tutorials, and labs every week, as compared to liberal arts students who spent 10-14 hours per week in the classroom (Larcombe et al., 2016). In addition, approximately 30-35% of math, computer science, and engineering students take part in a co-op program that can add an additional year before graduation (Wyonch, 2020). Moreover, many engineering programs require students to take six courses rather than the typical five in order to graduate within four years (McGill University, 2020; Memorial University, 2021; University of British Columbia, 2021; Western University, 2021). Faced with these demands, STEM students may choose to reduce their semester course load even though it means extending the length of their program or withdraw from their STEM program completely. Not surprisingly, such program demands have been found to negatively impact STEM students' motivation and further increase their likelihood of dropping out (Robinson et al., 2018).

These programmatic challenges faced by STEM students can also have a negative effect on their well-being. Mental health problems such as anxiety and depression have become a widespread concern for university students (Hussain et al., 2013; Larcombe et al., 2016) and research suggests that they are becoming more prevalent (Brailovskaia & Margraf, 2020). A study by Leahy et al. (2010) found that 48% of undergraduates reported being distressed; a rate 4.4 times higher than peers not attending university. In a 2019 Canadian survey of issues experienced by students, multiple types of psychological distress were commonly reported to affect students' academic performance including stress (41.9%), anxiety (34.6%), sleep difficulties (29.0%), and depression (24.2%; as compared to cold or flu: 19.6%; work: 17.5%; American College Health Association, 2019). For STEM students, these psychological health problems are compounded by the challenging requirements of their STEM programs.

In research by Leahy et al. (2010) on student distress, upper-year engineering and law students reported higher levels of distress compared to upper-year students studying psychology or medicine. Furthermore, longitudinal research by Cooke et al. (2006) found that psychological well-being in STEM students showed a significant drop during their first semester of university whereas well-being among arts students remained consistent. Further research is needed to understand the nuances in psychological well-being between STEM and non-STEM students, however, it is clear that STEM students are experiencing distress at concerning levels and that action is needed to improve their well-being. Accordingly, the present study aimed to examine the contributors to well-being in STEM students, with a specific focus on the roles of gender differences in how social support and motivation predict performance and mental health outcomes.

Women in STEM: Persistence and Challenges

STEM retention initiatives have also focused on increasing representation of female students in STEM disciplines. The last several decades have shown a dramatic increase of women studying in STEM fields (Hill et al., 2010). In 1993, women comprised only 15% of first-year STEM students, with this number increasing to approximately 44% in Canada by 2010 (Hyde & Gess-Newsome, 1999; Wall, 2019). However, this proportion is not found in all STEM fields, with remarkable differences in female representation found between subdisciplines (Cheryan et al., 2017; Hill et al., 2010). For example, although enrollment of female students is approximately 40% in chemistry and mathematics, and as high as 59% in biological sciences, enrollment of women in physics, engineering, and computer science is approximately 20% (Cheryan et al., 2017; Wall, 2019). Even more worryingly, some research shows that the percentage of female students has plateaued or even decreased in some STEM fields, such as mathematics (45% to 42% degree completion) and computer science (28% to <20% degree completion) since the early 2000s (Cheryan et al., 2017; Hill et al., 2010).

The primary reasons for why some STEM fields have fewer female students have been categorized by researchers in two ways: (1) female students' perceptions about themselves and their place in the discipline and (2) an unwelcoming or "chilly" climate (Blackburn, 2017; Shapiro & Sax, 2011). Guided by the media and parents' or teachers' perceptions, female students may develop perceptions that STEM fields are intended primarily for men. If women believe that they do not belong in a particular discipline, they may feel uncomfortable choosing to study that subject or not consider it an option. This is especially true when strong gender stereotypes lead them to feel an incongruency between their identities as a women and as a scientist (Settles et al., 2016). Even women who do not view STEM fields as male-dominated may still feel that they do not belong because of the perceptions they hold about their abilities. Research has consistently shown that female students have lower levels of confidence in their mathematical abilities than male students with the same level of abilities (Ellis et al., 2016).

Women who go into STEM fields have also been found to report holding themselves to high standards and expecting exceptional performance from themselves rather than just "getting by" (Blackburn, 2017; Hill et al., 2010). In fact, a study of 5,960 US students in physics, engineering, and computer science found that the ratio of male to female students among high-achieving students (2:1) is much closer than among low-achieving students (10:1; Cimpian et al., 2020). They also found that among high school students, male students with grades in the first percentile were just as likely to intend to major in physics, engineering, or computer science as female students in the 80th percentile (Cimpian et al., 2020). These findings are consistent with gender differences in STEM attrition, with women who drop out of STEM programs being more likely to transition to a non-STEM major (23%) than to drop out completely (11%), and male students who withdraw being more likely to quit university entirely (transition: 12%, drop out: 16%; Wall, 2019). These patterns support the idea that women feel that they must be exceptional to succeed or be taken seriously in male-dominated STEM fields and that this belief may dissuade many female students from pursuing a STEM major (Corbett & Hill, 2015; Robnett, 2016).

The other main category of reasons that fewer women persist in some STEM fields is commonly referred as to as a "chilly climate." This term refers to an environment in which female and male students receive differential treatment leading to women feeling unwelcome

(Blackburn, 2017; Morris & Daniel, 2008). The actions of faculty and peers can have a significant impact on how comfortable female students feel and their persistence in STEM fields. For instance, Leaper and Starr (2019) found that of 685 female life science majors surveyed, 61% had experienced gender bias (social exclusion, negative comments about women's abilities, gender-based favoritism, patronizing comments) and 78% had experienced some type of sexual harassment (unwanted comments, jokes, gestures, contact) in the past year from faculty, teaching assistants, classmates, or peers. Likewise, Robnett (2016) found that 70% of female participants in math intensive programs had experienced gender bias, such as derogatory comments about women's abilities by male peers, with 50% of female participants in life sciences reporting similar experiences. Leaper and Starr (2019) further found that both bias and harassment negatively predicted female students' motivation to continue in their STEM program and higher education more generally, with harassment from peers also associated with lower competence beliefs in female STEM students. Accordingly, female students can feel alienated and lacking support in STEM programs, leading them to feel isolated and unwelcome in their chosen discipline (Herrmann et al., 2016).

The underlying structure of STEM programs can also contribute the chilly climate towards female students. Research has shown that the deliberately difficult entry level courses meant to "weed out" less competent students may instead select out capable but less confident female students who have high expectations for themselves (Cimpian et al., 2020; Seymour & Hunter, 2019). Research also suggests that female students tend to dislike competitive environments (e.g., grading on a curve) and are more demotivated by theoretical curriculum and passive learning more than their male counterparts; both of which are common features of traditional STEM programs (Hyde & Gess-Newsome, 2000; Seymour & Hunter, 2019). In summary, although female post-secondary students across disciplines consistently report poorer levels of stress (Welle & Graf, 2011), emotional exhaustion (Pisarik, 2009), and mental health (Alsubaie et al., 2019) relative to their male counterparts, these gender differences in well-being are likely exacerbated in STEM degree programs due to additional psychological, interpersonal, and structural challenges faced by female STEM students (Seymour & Hunter, 2019).

Social Support and Student Development in Higher Education

Research has shown that social support from friends and family, as well as professors and university support services, can serve as a protective factor against many 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 (Kim et al., 2018; Malecki & Demaray, 2003). These supports can take many forms, such as an empathetic listener, help with assignments, a list of resources, advice, or a companion for non-academic activities (Kim et al., 2018; Ramsay et al., 2007). These social resources have been linked to various personal and academic benefits in post-secondary students, including better physical and emotional health (Friedlander et al., 2007; Hartung et al., 2015), lower burnout (Kim et al., 2018), as well as greater academic achievement and persistence (Chang et al., 2014; Walton et al., 2015).

Social support is most commonly categorized by researchers as emotional, informational, or instrumental in nature (Burke & Greenglass, 1996; Hombrados-Mendieta et al., 2012; Östberg & Lennartsson, 2007). Emotional support involves listening, affection, encouragement, or communicating to someone that they are valued (Malecki & Demaray, 2003; Pines et al., 2002; Ramsay et al., 2007). Instrumental or "practical" support instead consists of providing needed materials, money, or other tangible assistance such as helping someone accomplish a task

(Cohen & Wills, 1985; Malecki & Demaray, 2003). Finally, informational support consists of providing information or advice, such as guidance on course selection, informational handouts, or first-year information sessions (Malecki & Demaray, 2003; Ramsay et al., 2007). Additional types of support are also studied by researchers, such as "appraisal" or "approval" support that includes positive feedback and building esteem (Himle et al., 1991; Malecki & Demaray, 2003; e.g., classified by Cohen & Wills, 1985 as a subset of emotional support). "Social companionship" has also been proposed to reflect the close physical proximity aspect of social support, such as participating in leisure activities together (Östberg & Lennartsson, 2007; Ramsay et al., 2007), that can mitigate detrimental effects of social isolation (Cacioppo & Cacioppo, 2014; Turagabeci et al., 2007).

Sources of Social Support

Social support can also have varying results depending on who provides the support. Important sources of support for university students include family, peers, instructors, and institutional support services (Alsubaie et al., 2019; Maymon et al., 2019; Roberts & Styron, 2010). Many studies on social support also include romantic partners as a source of support, however, research has shown that significant others play a less important role in first-year students' support than for upper-level students (Ramsay et al., 2007). Typically, students will seek different types and amounts of support from different sources, such as informational support from professors, emotional support from parents, and social companionship support from friends (Belanger & Patrick, 2018; Ramsay et al., 2007).

A study by Ramsay et al. (2007) with first-year students showed friends to be the most frequently reported source of emotional, practical, and social companionship support as compared to family, significant others, and university professionals, with the second most common source being university professionals providing informational support. Jacobs and Dodd (2003) similarly found support from friends, family, and significant others to be negatively correlated with burnout in undergraduates, with only support from friends significantly predicting lower burnout after controlling for other variables. Other research shows support from friends to predict lower levels of loneliness (Maymon et al., 2019), greater social and personal-emotional adjustment to university (Friedlander et al., 2007), as well as lower depression and greater quality of life among undergraduates (Alsubaie et al., 2019).

With respect to family as social support for undergraduates, Ramsay et al. (2007) found family to be the second most frequent source of practical support after friends and the least frequent source of informational support and social companionship. Among traditional first-year students (entering after high school), parents were additionally reported to be the second most utilized source of emotional support (Ramsay et al., 2007). Support from family has been shown to predict greater life satisfaction (Maymon et al., 2019) and GPA in post-secondary students (Cheng et al., 2012), as well as better levels of life satisfaction and depression (Alsubaie et al., 2019). In contrast, Friedlander et al.’s (2007) study with first-year students did not find parental support to significantly predict psychological adjustment. However, this result may have been due to 81% of participants living in residence contributing to a relatively greater social influence of friends and peers. The importance of physical proximity to the source of support was demonstrated in a cross-cultural study by Khallad and Jabr (2016) who found that support from friends predicted lower depression in Turkish students, most of whom were attending university away from home. In contrast, Jordanian students—the majority of whom lived at home—showed support from family but not friends to predict lower stress and depression.

Existing research on the social support students receive from professors and departmental staff is limited but 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). In a study by Ramsey et al. (2007), students reported university professionals (such as faculty and staff) to be their most common source of informational support but their least likely source for any other type of support. In contrast, 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. Faculty support has also been shown to predict greater enjoyment of class material (Aldridge et al., 2012) as well as better levels of stress, quitting intentions, sense of belonging, and life satisfaction (Maymon et al., 2019). Considering that students' perceptions as to the approachability of faculty can have a positive impact on student persistence (Roberts & Styron, 2010), these findings suggest that faculty support can have a significant impact on student development and well-being.

Most research on the impact of institutional support for undergraduates has looked at the effectiveness of specific student services or interventions to enhance belonging rather than institutional services more broadly. Student affairs and wellness programs have become a common type of institutional support for students with programing aimed at improving first-year adjustment by promoting study skills and mental health strategies (Ciobanu, 2013). Conley et al. (2012) examined the effectiveness of one such wellness seminar for first-year students that encouraged adaptive stress management, problem-solving, cognitive restructuring, mindfulness, and social communication techniques, with results showing the program to lead to better psychosocial adjustment to university. Institutional support programs that involve a combination of peer groups, informational resources, and faculty mentors have been found to improve students' sense of belonging and persistence, particularly those aimed at female STEM students (Hyde & Gess-Newsome, 1999; Rosenthal et al., 2011). For example, the WISE (Women in Science and Engineering) program at one Northeastern U.S. university supports 35-50 first-year female STEM students each year through regular meetings, study groups, social and academic events, WISE-specific courses (e.g., introductory subjects, research course), financial support, and mentorship from faculty, staff, and upper-year female STEM students. With respect to the effects of perceived institutional support more broadly on well-being in post-secondary students, Maymon et al. (2019) found greater perceived intuitional support to significantly predict both lower burnout and quitting intentions among first-year students.

Social Support and Gender in STEM

Research suggests that women are more likely than men to seek out social support as a coping strategy for dealing with stressful situations (Stoliker & Lafreniere, 2015; Weckwerth & Flynn, 2006) and may also receive more benefits from social support (Cheng et al., 2012; Kamen et al., 2011). For instance, in a 23-year study following adult participants with depression, greater family support was associated with quicker recovery from depression, especially for women (Kamen et al., 2011). In an academic context, Cheng and colleagues (2012) found that emotional support from families generally predicted better and more stable GPAs over three semesters, with family support being more important for performance in female students than male students.

Existing research also shows that social support may be especially beneficial to counter the challenges female STEM students face. Qualitative research with female STEM students completing an eight-week summer program before their freshman year found both social support (i.e., support from peers, faculty, and staff) and financial support to be key predictors of persistence (e.g., lower attrition) over time (Hyde & Gess-Newsome, 1999). Friendships made during the program gave students emotional and practical support throughout their time in university, particularly during their first year. Support from university support staff and professors was additionally found to give the students knowledge of where to turn when they needed help and the confidence to ask for help. Students also reported receiving emotional, informational, and practical support from their professors, some of whom later became their research supervisors or mentors.

In a more recent study of a persistence-enhancing program for female first-year students completing STEM degrees, Rosenthal et al. (2011) found that support from family and friends, as well as support from program advisors, upper-level students, and faculty role models increased undergraduates' sense of belonging in their STEM major. In another study, Jackson et al. (2019) found that encouragement and supportive listening from friends and family positively impacted female students' career aspirations in STEM. This association was strongest for women with low or average levels of science identity and was not found for male students (Jackson et al., 2019). Similarly, Leaper and Starr (2019) found that encouragement from friends and family was positively related to motivation and STEM career aspirations in first-year students. Additionally, research by Pugh et al. (2019) found geoscience departments with greater success attracting and retaining female students were perceived by male and female students as having higher levels of institutional support and instructor connections than departments with low or average rates of female student retention. Unfortunately, even in the most successful departments, female students perceived less of a connection with their instructors than did male students (Pugh et al., 2019).

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 perceived competence, values, causal attributions, and self-determined motivation being investigated in relation to a range of critical outcomes including engagement, achievement, well-being, and persistence (Pintrich, 2003). Self-efficacy refers to one's perceived ability to complete a given task (e.g., multiplication, computer skills; Bartimote-Aufflick et al., 2016) and has been associated with greater critical thinking (Vogt et al., 2007), self-regulation, and exam performance (Gadbois and Sturgeon, 2011). Expectancy-value theory views motivation as based on expectations for success (competence) and task value (e.g., intrinsic, attainment, or utility value; Wigfield & Cambria, 2010), with these variables predicting interest, grades, and persistence in STEM students (Battle & Wigfield, 2003; Hullemen et al., 2008; Linnenbrink-Garcia et al., 2018). In contrast, Attribution Theory suggests that students' reactions to poor grades is determined mainly by the personal controllability of the perceived cause of their performance (Weiner, 1986), with interventions promoting controllable attributions leading to improved emotional well-being, attrition, and grades in STEM students (Lee, 2020; Ruthig et al., 2004). However, arguably the most prominent approach to understanding motivation in educational settings is Self-Determination Theory that proposes student motivation to be due to either internal reasons (e.g., passion) or external factors (e.g., others' expectations), with this perspective thus addressing not only the extent but the specific qualities underlying 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 motivational approaches driven by external factors (Ryan & Deci, 2000). First, *intrinsic motivation* is the most autonomous 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 part of their identity.[1] *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* represents the most extrinsic type of motivation and is driven by external rewards, such as a salary increase or prestige, and avoiding punishments, such as a bad grade or lost wages (Ryan & Deci, 2000). Educational researchers often simplify this continuum by grouping together the three most internal motivations (intrinsic, integrated, and identified) as *autonomous motivation* and the more externally driven motivations (extrinsic and introjected) as *controlled motivation* (Ryan & Deci, 2020).

With respect to findings for specific motivation subscales in post-secondary students, a meta-analysis by Howard et al. (2021) based on 344 samples (223,209 participants) found that both intrinsic and identified motivation were positively related to student achievement, persistence, and well-being. Whereas intrinsic motivation was most strongly associated with well-being outcomes, identified motivation was more strongly related to student persistence. On the other hand, controlled motivation types tended to show detrimental outcomes in that, although introjected motivation predicted greater persistence, it also predicted stronger

[1] While theoretically important, integrated motivation has not been assessed in most educational research due to a difficulty in distinguishing it from identified motivation in self-report measures and the belief that it cannot be meaningfully measured until adulthood (Deci et al., 2013).

performance goals (i.e., competitiveness) and poorer well-being outcomes. External motivation was not related to persistence or achievement, but was negatively related to student well-being (Howard et al., 2021). Overall, autonomous motivations consistently contributed 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 motivations are typically associated with poorer results (Howard et al., 2021; Pisarik, 2009; Ryan & Deci, 2020).

In terms of specific study findings, autonomous motivations have been found to predict beneficial learning outcomes such as higher effort, less procrastination (Mouratidis et al., 2018; Vansteenkiste et al., 2009), greater use of metacognitive strategies, more effective use of time and resources (Vansteenkiste et al., 2009), and greater classroom engagement (Froiland et al., 2012). Various studies have also shown autonomous motivation to predict higher levels of academic achievement (Jeno et al., 2018; Taylor et al., 2014; Yu et al., 2018) and persistence (Black & Deci, 2000; Jeno et al., 2018; Simon et al., 2015). Specific types of autonomous motivation, particularly intrinsic motivation, have also been shown to be associated with better levels of burnout (Pisarik, 2009) and test anxiety (Vansteenkiste et al., 2009), as well as lower stress and better overall adjustment to university (Baker, 2004). Yu and colleagues found autonomous motivation to also predict vitality and happiness in both American and Chinese university students (Yu et al., 2018).

On the other hand, controlled motivations are usually associated with various detrimental outcomes. For instance, Vansteenkiste et al. (2009) found that controlled motivation was related to higher levels of procrastination, cheating, and test anxiety. Controlled motivation has also been found to be 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 (Pisarik, 2009). Introjected motivation in particular has been found to have the strongest associations with a range of negative outcomes including poor self-esteem (Magnus et al., 2010), test anxiety, negative affect, academic dissatisfaction (Litalien et al., 2015), and emotional exhaustion (Pisarik, 2009).

Self-determined motivation subtypes have also been found to interact with other personal characteristics to influence academic outcomes. For example, Nguyen and Deci (2016) found that setting high standards for oneself could have positive or negative outcomes for students depending on their level of controlled motivation. Students with low levels of controlled motivation experienced less difficulty learning and did not show significant relationships between high standards and studying anxiety. However, when students with high levels of controlled motivation set high standards for themselves, they reported higher levels of anxiety and greater difficulty learning the class material (Nguyen & Deci, 2016).

Finally, research on how autonomous and controlled motivational profiles interact to predict student outcomes further supports the hypothesis that autonomous motivation typically leads to beneficial outcomes while controlled motivation is more detrimental. Studies with high school and university-aged participants have found motivational profiles with high *quality* motivation (high in autonomous and low in controlled motivation) to have better outcomes (e.g., lower test anxiety, procrastination, cheating, greater achievement) than high *quantity* motivation profiles (high in both autonomous and controlled motivation; Vansteenkiste et al., 2009). Ratelle et al. (2007) also found that although the high quality and high quantity motivation groups had similar levels of academic achievement, the high quality motivation group was more likely to persist in their degree program. Vansteenkiste et al. (2009) further demonstrated that of the four combinations of autonomous and controlled motivation, the poorest outcomes were found for the low autonomous-high controlled motivation group (i.e., greater test anxiety, procrastination, lower effort regulation, perceived teacher involvement and autonomy support), suggesting that maladaptive motivation may be worse for students than an overall lack of motivation.

Self-Determined Motivation and Gender in STEM

Research on self-determined motivation in university students has commonly found gender differences in autonomous and controlled motivation. Female students typically report higher levels of 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, research by Köseoğlu (2013) found that female first-year students were most motivated by identified motivation but scored higher than men on all motivation types, with male students most strongly preferring external motivation. Orvis et al. also found external motivation to be most common among male students in an introductory chemistry course (61.5% reported it as their primary motivator vs. 55.9% of female students). However, findings also show female students to report greater introjected motivation relative to their male counterparts (Orvis et al., 2018; Ratelle et al., 2007). Since introjected motivation is typically associated with the most detrimental outcomes (Litalien et al., 2015; Pisarik, 2009), it is concerning that multiple studies show relatively high numbers of female students who are motivated in part for introjected reasons.

Concerning the relationship between self-determined motivation and achievement in STEM undergraduates, findings to date are mixed and content specific. 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). Matthews et al. (2013) found that intrinsic motivation predicted better performance on conceptual exam questions but not the overall exam score, with findings by Simon et al. (2015) similarly showing intrinsic motivation to be unrelated to students' overall GPA. Guay and Bureau (2018) further observed that although intrinsic and identified motivation in a specific discipline were positively associated with achievement that discipline (e.g., mathematics), they did not predict students' grades in other disciplines (e.g., English). Findings for external motivation are similarly inconsistent, with some studies showing it to predict better achievement (e.g., course grade; Sturges et al., 2016) and others finding it to be unrelated to students' grades (Matthews et al., 2013) or negatively related to achievement (Guay & Bureau, 2018). However, research on introjected motivation consistently shows this subtype 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, research with undergraduates has shown that autonomous motivations are typically associated with lower attrition from STEM programs (Black & Deci, 2000; Jeno et al., 2018; Simon et al., 2015) and stronger intentions to pursue a science career (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 higher levels of autonomous motivation to correspond with a stronger intent to pursue future science education (Lavigne et al., 2007). Concerning the limited existing research examining the effects of self-determined motivation on well-being in STEM undergraduates, 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 findings from Skinner et al. (2017) showing autonomous motivation to be positively correlated with both 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, Self-Determined Motivation, and Gender in STEM

Although social support has consistently been identified by researchers as a predictor of academic success and well-being in post-secondary students (Maymon et al., 2019; Rosenthal et al., 2011; Walton et al., 2015), the mechanism by which this happens is unclear. One proposed mediator of this effect is student motivation such that receiving social support should increase student motivation and thus lead to beneficial outcomes. This mediational assumption is consistent with findings from Koka (2013) showing support from physical education teachers to predict higher autonomous motivation and lower controlled motivation in students 12 months later, and research by DeFreese and Smith (2013) with university student athletes showing perceived teammate support to be associated with greater autonomous motivation. Preliminary findings from Young et al. (2011) further suggest that although social support (i.e., from friends, family, professors) predicted both intrinsic and extrinsic motivation for African American college students, it did not predict either type of motivation for white or Hispanic students.

Although the role of autonomous vs. controlled motivation as mediators of social support effects have not yet been examined in educational research,[2] related studies have explored how the three psychological needs that are additionally proposed in Self-Determination Theory might

[2] 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 items measuring distinct constructs of work ethic and competitiveness.

serve this mediational role. According to Self-Determination Theory, three psychological needs must be met for individuals to experience high levels of autonomous motivation (Ryan & Deci, 2000), thus suggesting that if psychological need satisfaction acts as a mediator, autonomous motivational beliefs should act similarly. For example, a study by Schenkenfelder et al. (2020) with undergraduates found that psychological needs mediated the relationship between support from faculty and peers and satisfaction with their major. A longitudinal study of STEM undergraduates by Hilts et al. (2018) likewise found that social support from peers predicted psychological need satisfaction that, in turn, predicted better grades and stronger intentions to stay in the STEM program; albeit only for female students. Lastly, a serial mediation study by George et al. (2013) with undergraduate students similarly found that social support was associated with satisfaction of psychological needs that, in turn, was related to higher levels of autonomous motivation that was in turn, predicted greater intentions to exercise. Overall, despite findings suggesting that self-determined motivation may underlie the benefits of social support in educational settings, this mediational assumption has yet to be examined in a STEM context.

The Present Study

Although there is limited existing research on the relationships between social support, self-determined motivation, and student outcomes such as persistence and well-being in STEM students, the findings outlined above support the hypothesis that self-determined motivation may mediate the relationship between social support and student outcomes. Moreover, existing research suggests that this mediational pathway may differ by gender (Hilts et al., 2018), with these relations expected to be particularly relevant for female STEM students who are likely to benefit more greatly from social support and adaptive motivational beliefs than their male counterparts. To explore this hypothesis, the present study used a moderated mediation model to examine the extent to which autonomous and controlled motivation mediate the effects of personal and academic support on STEM students' well-being, persistence, and achievement (see Figure 1 for proposed model). Additionally, the study investigated whether the mediated relationships between social support and student outcomes were moderated by gender. Following from the existing literature, four hypotheses were assessed in this study.

Hypothesis 1: Social Support and Self-Determined Motivation

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). This hypothesis was derived from existing findings with high school and university students showing support from important others (e.g., teachers, varsity teammates) to predict greater autonomous motivation and lower controlled motivation (DeFreese & Smith, 2013; Koka, 2013).

Hypothesis 2: Autonomous Motivation and Student Outcomes

Consistent with previous findings showing autonomous motivation in students to lead to beneficial academic outcomes (e.g., Howard et al., 2021; Jeno et al., 2018), autonomous motivation was expected to have positive direct effects on the well-being and academic outcomes (Hypothesis 2a). Moreover, it was further expected that autonomous motivation would mediate the relationship between both types of support and the well-being and academic success outcomes, such that higher levels of support would predict greater autonomous motivation that, in turn, would lead to more beneficial outcomes (Hypothesis 2b).

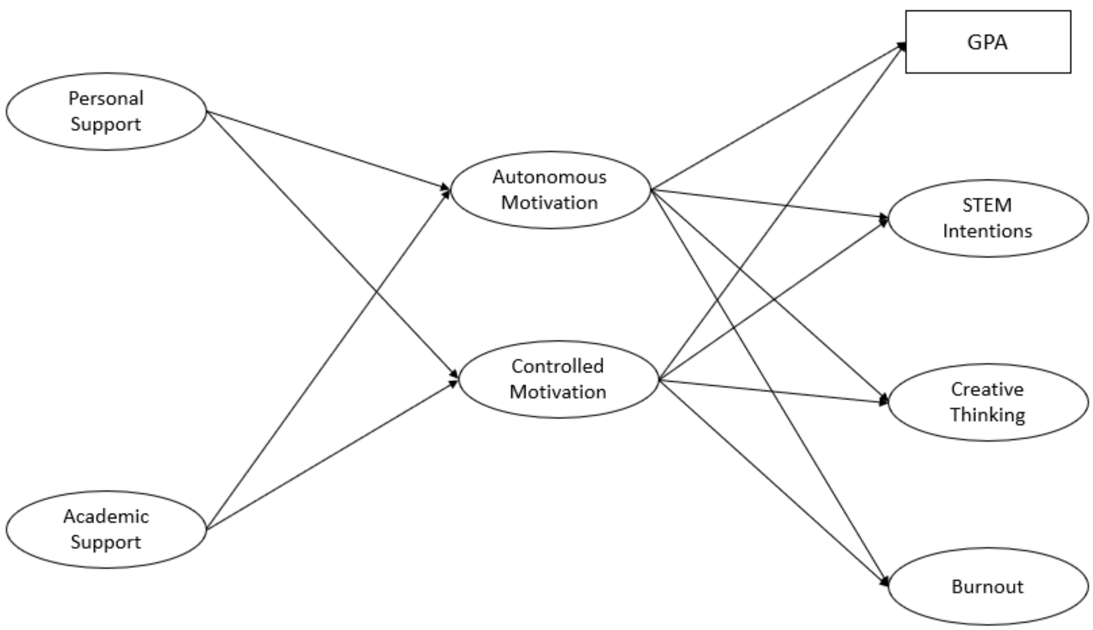
Hypothesis 3: Controlled Motivation and Student Outcomes

In line with previous research, controlled motivation was expected to be negatively associated with the well-being and academic outcomes (Hypothesis 3a; Pisarik, 2009;

Vansteenkiste et al., 2009) and mediate the effects of personal and academic support on the student outcomes (Hypothesis 3b). In other words, lower levels of support should predict higher levels of controlled motivation that, in turn, should lead to more detrimental outcomes.

Figure 1

Hypothesized Mediational Model



Hypothesis 4: Moderation by Gender

Following from previous findings showing differential effects of social support and self-determined motivation on academic outcomes according to gender (Hilts et al., 2018; Jackson et al., 2019; Mouratidis et al., 2018), it was expected that the preceding hypothesized mediational relationships would be moderated by gender. Specifically, the mediational effects of support on the well-being 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).

Method

Participants

The sample consisted of 221 first-year undergraduates enrolled in the Faculties of Science and Engineering at McGill University. Participants were primarily female students (60.6%; male students 39.4%) with a mean age of 18.7 years (*SD* = 1.67). The sample was predominantly Caucasian (47.1%), followed by East Asian (25.8%), West Asian (5.9%), and South Asian (4.5%). Approximately half of the study sample graduated from Quebec CEGEP (junior college) programs (47.5%) and 19.9% were international students. 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 the following disciplines: mathematics, pharmacology, neuroscience, biochemistry, physics, chemistry, and environment. The average high school GPA of participants was 91.5% (*SD* = 5.18) and 95.8% of participants were registered as full-time students (minimum of 12 credits) with an average course load of 14.4 credits (*SD* = 1.78).

Procedure

In October 2020, participants were recruited by email via the McGill Campus Life and Engagement Office (see Appendix C) to complete a one-time survey on their academic experiences. Students first reviewed an online consent form (Appendix B) outlining the study aims, confidentiality of responses, and informing them that they could withdraw from the study at any time. The consent form additionally stipulated that study participation was contingent on participants pursuing a STEM major and agreeing to release their fall semester GPAs from the Registrar's Office. Students were thus required to indicate their major prior to completing the survey with all non-STEM majors[3] redirected to a disqualification page. The survey required approximately 15 minutes to complete and consisted of demographic items (e.g., gender, age, major) and the self-report study measures (e.g., social support, self-determined motivation, well-being, and academic outcomes; see Appendix D). Participants were compensated by being entered into a draw for five $50 cash prizes following study completion. After the end of the term, participants' sessional GPAs for the Fall 2020 semester were obtained from the Registrar's Office. Ethics approval for study protocols was provided by the McGill Research Ethics Board prior to data collection (see Appendix A).

Measures

The independent variable of social support was measured as a multidimensional construct consisting of support from four sources (friends, family, faculty, and university programs). The mediational self-determined motivation variables were assessed as two key dimensions, autonomous and controlled motivation. The dependent variables included critical student outcomes reflecting psychological well-being (emotional exhaustion) and academic indicators (future STEM intentions, creative thinking, semester GPA). The preamble for all measures asked participants to reflect on experiences specific to their STEM courses when responding to the questions. Descriptive statistics and scale reliabilities are displayed in Table 1.

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 programs. Each scale consisted of two items assessing both the

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[3] Statistics Canada's classification of STEM and BHASE (i.e., non-STEM) groupings (Statistics Canada, 2018) were used as criteria to differentiate STEM and Non-STEM majors.

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 analyses (CFA) contrasted the relative fit of a two-factor model of frequency vs. quality, a four-factor model by source of support (friends, family, faculty, university programs), and a two-factor model of personal support (friends, family) vs. academic support (faculty, university programs). The two-factor model differentiating by overall source of support (personal vs. academic) demonstrated the best model 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. Finally, participants completed four additional items asking what types of support they would like to receive more of from each source (friends, family, faculty, university programs) from a checklist including emotional, practical, informational, and social companionship support or none ("I am content with the support I receive"; multiple selections per source were permitted).

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 how important each item was to their motivation to do well in their STEM courses and all items were assessed on a five-point scale (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"). Two three-item subscales adapted from the MPhD assessed *integrated motivation* (e.g., "Because my studies are consistent with my values (e.g., interests, morals, etc.)") and *identified motivation* (e.g., "Because I can improve my skills in my field of study"). The MPhD subscales were selected as no published measures of self-determined motivation previously used with K-12 or postsecondary students have to date included a subscale for integrated motivation (Deci et al., 2013), with the MPhD subscale accurately 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 composite autonomous motivation (intrinsic, integrated, identified) and controlled motivation variables (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, despite the two-factor autonomous/controlled model demonstrating poorer fit (CFI = .757, TLI = .679, RMSEA = .140), it did not show multicollinearity and thus represented a theoretically defensible and parsimonious alternate model of self-determined motivation for our main SEM analyses.[4]

[4] 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 (e.g., $\beta < .50$).

Table 1

Descriptive Statistics for Study Measures

Scale	*n*	*M*	*SD*	Observed range	α/*r*
Support from friends	219	7.73	1.92	2-10	.73
Support from family	220	8.04	1.83	2-10	.60
Support from faculty/staff	218	5.72	1.72	2-10	.64
Support from university programs	213	5.40	1.67	2-9	.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
GPA	217	3.88	0.181	0.46-4.00	-

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

Burnout – Emotional Exhaustion

The seven-item emotional exhaustion subscale of the Maslach Burnout Inventory (MBI; Maslach, et al., 1996) was used as a measure of psychological well-being. Participants answered items such as "I feel used up at the end of the day" on a seven-point scale (0 = *never*, 6 = *everyday*). CFA analysis indicated acceptable fit for emotional exhaustion (CFI = .946, TLI = .892, RMSEA = .136).

Creative Thinking

The 10-item Creative Thinking/Problem Solving subscale of the Self Description Questionnaire III (Marsh & O'Neill, 1984) was used to assess the learning-related outcome creative thinking.[5] 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 analysis indicated adequate fit for the creative thinking scale (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 assess participants' intentions to pursue a career in a STEM field. 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 analysis for STEM career intentions as the model was just-identified, however, the factor loadings were acceptable (> 0.80).

Results

Preliminary Analyses

Statistical Assumptions and Missing Data

Prior to the main analysis, the data was evaluated for outliers, normality, homogeneity, and missing data. Univariate outliers were examined using a boxplot that showed that family support, STEM intentions, and GPA each displayed between three and four outliers beyond the acceptable range of |3| standard deviations. Since the outliers for family support and STEM intentions were measured using bounded Likert scales, these values were meaningful, had minimal impact on the analysis, and were thus retained.[6] However, as the GPA outliers were particularly extreme (GPA = 0.46, 2.45, 2.75) and the GPA measure significantly violated the

[5] One item was removed due to its mention of curiosity which was considered a separate construct (Schutte & Malouff, 2019).
[6] The SEM model showed minimal differences in fit indices and path coefficients when conducted with the outliers removed $\chi^2(713) = 1417.447$, $p < .001$, CFI = .836, TLI = .812, RMSEA = .067).

assumption of normality (skewness = -6.58, kurtosis = 61.90), the three outliers were removed. Multivariate outliers were also examined using a Mahalanobis distance test that found six values to exceed the critical value of the chi-squared test (α = .01). These outliers were not removed as they were a very small proportion of the data (2.7%) and the values were not extreme (Cohen, et al., 2003).

Univariate normality was assessed using scores of skewness and kurtosis with cut-off criteria of ± 3 and ± 10 respectively (Kline, 2015). All study variables satisfied the assumption of normality, including the GPA measure with outliers removed (skewness = -2.22, kurtosis = 5.88). The assumption of homoscedasticity was tested using a scatterplot of the regression standardized predicted values by the regression standardized residuals for each outcome. Values were distributed randomly around zero indicating that residual variances were constant, and that heteroscedasticity was not observed. Lastly, missing data was found to be minimal, with 5.6% of values missing for university support, 1.4% missing for support from faculty, and all other variables missing less than 1% of values. Little's MCAR test for patterns in missing data found the values to be missing completely at random; $\chi^2(57) = 60.166$, $p = 362$.

Initial Difference Tests and Correlations

Independent samples *t*-tests were conducted on all study variables to explore potential mean differences and identify potential covariates based on key background variables including gender, age, international status, ethnicity, and high school average. 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 their male counterparts. Female students also rated themselves lower in creative thinking than did male students ($t(219) = 3.97$, $p < .001$, $d = 0.54$). 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 semester GPA ($t(202) = 2.15$, $p = .033$, $d = 0.30$) than older students. International students reported receiving more support from faculty and staff ($t(219) = 3.33$, $p = .001$, $d = 0.56$) as well as from university programs ($t(219) = 2.90$, $p = .004$, $d = 0.46$) compared to domestic students. There were no significant differences due to ethnicity, however, high school average grades were significantly related to faculty support ($r = .182$, $p = .008$) and semester GPA ($r = .366$, $p < .001$). When age, international status, and high school average were individually entered into the main analytic model as respective covariates, the model fit and parameters remained nearly identical and thus the main analyses excluded 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 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. 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*

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

Zero-order correlations between the study variables are displayed in Table 2. Personal and academic support were positively interrelated and were moderately correlated in the expected directions with autonomous motivation and emotional exhaustion, with academic support also correlating with GPA. Autonomous and controlled motivation were negatively intercorrelated and corresponded with exhaustion and STEM intentions in the expected directions. Autonomous motivation additionally showed positive correlations with GPA and creative thinking.

Mediational SEM Analysis: Total Sample

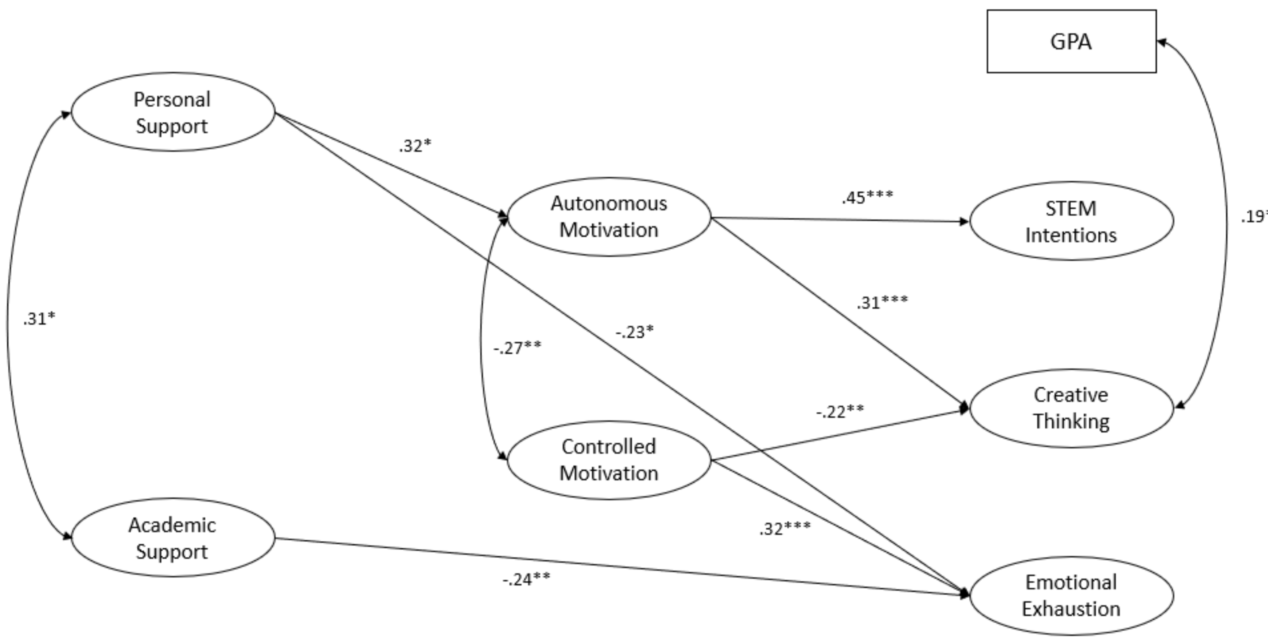
Structural equation modelling (SEM) was employed to examine the hypothesized relationships between personal and academic social support, motivation (autonomous and controlled), and measures of student well-being and academic success. Both direct effects from personal and academic support to the dependent 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 (see Table 2).

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). 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 GPA, STEM 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 poor fit: $\chi^2(713) = 1415.98$, $p < .001$, CFI = .837, TLI = .813, RMSEA = .067. As outlined in Figure 2, 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

Figure 2

Mediational SEM Results for Total Sample



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

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 (*β* = .32, *p* = .001). Semester 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 (*β* = .14, *p* = .012, 95% CI = [0.03, 0.29]) and personal support on creative thinking via autonomous motivation (*β* = .10, *p* = .018, 95% CI = [0.01, 0.20].

Multigroup SEM Analysis by Gender

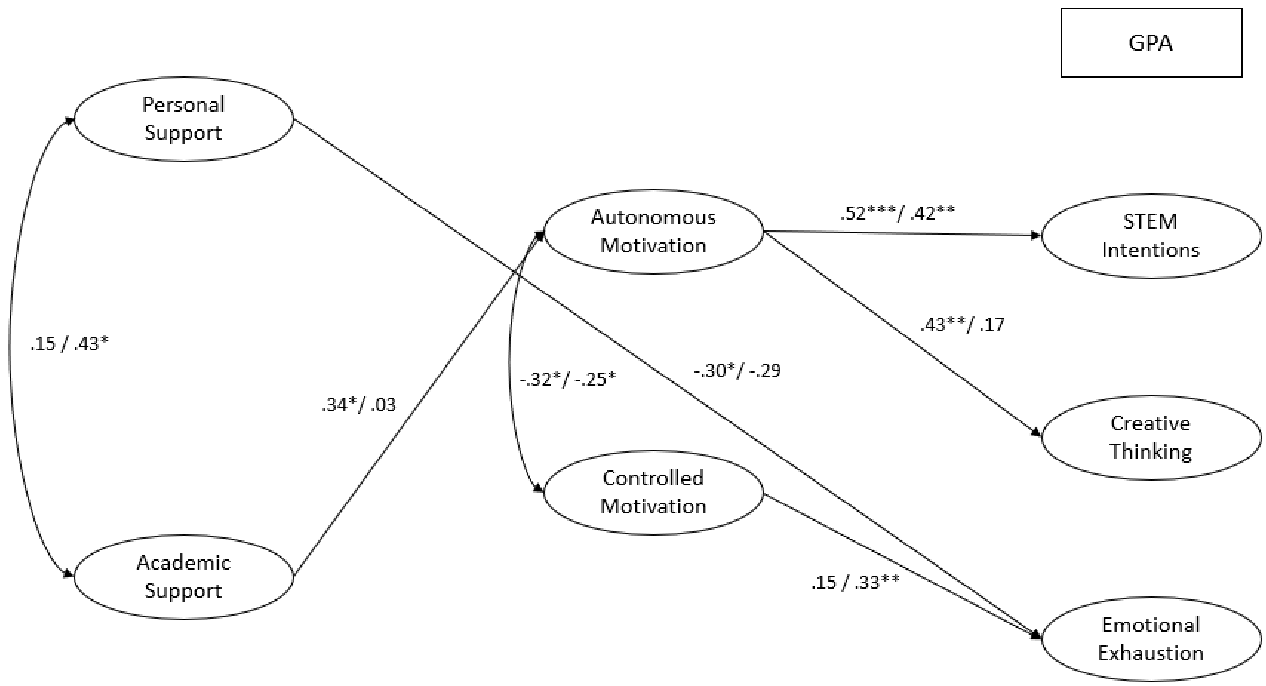
To examine hypothesized gender differences, SEM analyses were first conducted separately for male and female STEM students followed by multigroup SEM analyses conducted at the measurement and structural level. First, the unconstrained mediational model was examined separately by gender (see Figure 3), with the multigroup model subsequently conducted to examine 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 was not possible at the latent level due to non-positive estimates of variance and were instead conducted with summed variables using PROCESS 3.5 in SPSS 26.0.

In the unconstrained model for *male students*, academic support was positively associated with autonomous motivation (*β* = .34, *p* = .014) that, in turn, was positively associated with creative thinking (*β* = .43, *p* = .004) and STEM intentions (*β* = .52, *p* < .001). Personal support was not related to either type of motivation but displayed a negative direct effect on emotional exhaustion (*β* = -.30, *p* = .026). For *female students*, the unconstrained model showed few significant relationships, with neither type of support predicting motivation or any outcome variables. Autonomous motivation was positively related to STEM intentions for female students (*β* = .42, *p* = .003), while controlled motivation showed a positive association with emotional exhaustion only for women (*β* = .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

Figure 3

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.

support on both STEM career intentions (β = .037, *SE* = .017, 95% CI = [.0088, .0761]) and creative thinking (β = .027, *SE* = .015, 95% CI = [.0049, .0619]). For *male students*, autonomous motivation mediated the effects of academic support on STEM career intentions (β = .081, *SE* =

.041, 95% CI = [.0142, .1731]), creative thinking (β = .042, *SE* = .022, 95% CI = [.0071, .0924]), and emotional exhaustion (β = -.059, *SE* = .033, 95% CI = [-.1307, -.0034]). Controlled motivation was not a significant mediator of social support effects on the well-being 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 ($\chi^2(19) = 19.65$, $p = .416$).

Supplemental Analyses: Desired Social Support

Participant responses to the questions asking, "What types of support would you like to receive more of?" were summed and percentages for the total sample are displayed in Table 3.

Table 3

Types of Desired Support for the Total Sample

Source of support	Emotional support	Practical support	Informational support	Social companionship	None
Friends	37.6%	29.9%	20.4%	57.0%	27.6%
Family	40.7%	10.0%	14.0%	11.8%	47.1%
Faculty and staff	19.9%	67.9%	58.8%	18.1%	14.9%
University programs	19.9%	53.4%	62.9%	27.1%	14.9%

Note. As participants were permitted to select more than one option each row/column may sum to more than 100%.

With respect to personal sources of support, participants primarily reported wanting more social companionship from friends and that they were either content with the support they received from family or wanted more emotional support from family. In terms of academic support, most participants wanted more practical and informational support from both faculty/staff and university programs with notably few participants reporting that were content with the support they were currently receiving from these academic sources. When broken down by gender (see Table 4), female students consistently reported wanting to receive more support compared to their male counterparts, particularly with respect to more emotional support from friends and family and social companionship support from faculty and university programs.

Table 4

Types of Desired Support for Male/Female Students

Source of support	Emotional support	Practical support	Informational support	Social companionship	None
Friends	28.7/43.3%*	26.4 /32.1%	24.1/17.9%	52.9/59.7%	34.5/23.1%
Family	26.4/50.0%*	11.5/9.0%	17.2/11.9%	11.5/11.9%	54.0/42.5%
Faculty and staff	14.9/23.1%	59.8/73.1%*	50.6/64.2%*	21.8/15.7%	17.2/13.4%
University programs	16.1/22.4%	43.7/59.7% *	57.5/66.4%	27.6/26.9%	19.5/11.9%

Note. **p* < .05. Cells contain values for male/female students. As participants were permitted to select more than one option each row/column may sum to more than 100%.

Discussion

The challenging demands of STEM programs can lead to poor student well-being and attrition (Hunter, 2019; Perez et al., 2014). This is particularly true for female STEM students who face additional challenges in male-dominated STEM disciplines such as gender stereotypes, low self-efficacy, and unwelcoming environments (Blackburn, 2017). Researchers have identified social support as a protective factor for female STEM students (Hilts et al., 2018;

Jackson et al., 2019), however, the mechanisms by which social support promotes well-being and success are unclear. Whereas some research has shown a relationship between social support and self-determined motivation (DeFreese & Smith, 2013; Koka, 2013), studies have to date not examined how these constructs collectively contribute to student development in STEM domains. To address this research gap, the current study proposed that both personal and academic social support should benefit students' well-being, persistence, and academic achievement in STEM degree programs by promoting autonomous motivation and reducing controlled motivation, with these relationships expected to be stronger for female STEM students. Study findings provided partial support for the hypothesized relationships and are discussed in detail below.

Hypothesis 1: Social Support and Self-Determined Motivation

The first hypothesis proposed that personal and academic social support would be positively associated with autonomous motivation and negatively associated with controlled motivation. The first part of this hypothesis was partially supported by the zero-order correlations showing that although autonomous motivation was positively correlated with personal and academic support, controlled motivation showed no significant correlations. Additionally, the mediational SEM model showed personal support but not academic support to have a significant positive relationship with autonomous motivation. Contrary to expectations and existing research (Koka, 2013), neither type of support had an effect on controlled motivation. In other words, although students with stronger support from friends and family were more likely to also feel autonomously motivated in their STEM program (e.g., because they enjoyed it or saw personal value in it), feeling supported by professors or university programs (e.g., tutoring, writing groups, information sessions, etc.) was substantially less beneficial, with no source of support corresponding with lower controlled motivation (e.g., extrinsic reasons).

In addition to the relationships with motivation, both personal and academic support showed negative direct effects on 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 is less expected that academic support would show the same pattern of results, particularly since the types of support received from academic sources are most often informational or practical in nature (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), GPA, and intentions to continue in STEM.

Hypothesis 2: Autonomous Motivation and Student Outcomes

Existing research has consistently shown autonomous motivation to predict beneficial outcomes such as engagement, well-being, and persistence (Howard et al., 2021; Vansteenkiste et al., 2009). These findings are generally consistent with those of the present study, although not all expected relationships were significant. In the SEM model, autonomous motivation was associated with higher levels of creative thinking and intentions to continue in a STEM career. Based on previous research, it was expected that students who reported greater autonomous motivation would also experience lower emotional exhaustion (Brunet et al., 2015; Pisarik, 2009), however, the model showed no relationship between the two variables. Although semester GPA was also not significantly associated with autonomous motivation, this result is consistent with existing literature showing no relationship between autonomous motivation and achievement (Black & Deci, 2000; Simon et al., 2015; Sturges et al., 2016). However, it is possible that this result may reflect a ceiling effect due to the present sample having been recruited from an institution with highly competitive admission requirements resulting in notably low variability in student GPAs (e.g., 49% of students achieved a semester GPA of 4.0).

Concerning our mediational hypothesis for autonomous motivation, the mediation analysis showed the effects of personal support on STEM career intentions to be fully mediated by autonomous motivation. In other words, students who felt supported by family and friends also reported high levels of autonomous motivation and, in turn, greater intentions to continue in a STEM-related career. These results are similar to findings by Hilts et al. (2018) who found psychological needs to mediate the relationship between support from peers and STEM intentions.

Contrary to this hypothesis, no other indirect effects via autonomous motivation were found. Although personal support was related to autonomous motivation, and autonomous motivation was associated with creative thinking, this indirect relationship was not statistically significant. Moreover, whereas existing research in other subject areas has shown academic support to benefit autonomous motivation and learning outcomes (Koka, 2013; Schenkenfelder et al. 2020), no mediation of academic support effects via autonomous motivation was observed. As it is unclear whether this lack of association is an artifact of the present sample (e.g., poor CFA fit for self-determined motivation scale, lower frequency/quality of academic supports vs. personal supports, low academic help-seeking in competitive environments; Karabenick, 2004), further research is needed to ascertain the generalizability of the findings to other sample or if other mediating variables are more pertinent.

Hypothesis 3: Controlled Motivation and Student Outcomes

In contrast to autonomous motivation, controlled motivation is typically associated with detrimental academic outcomes such as negative learning-related emotions, maladaptive self-regulation, and greater attrition (Howard et al., 2021; Vansteenkiste et al., 2009). Consistent with prior research, controlled motivation was related to poorer outcomes for STEM students including lower levels of creative thinking and higher levels of emotional exhaustion. Interestingly, controlled motivation did not show a significant relationship with students' intentions to continue on in STEM careers, suggesting that although students who are motivated by more extrinsic reasons (e.g., to satisfy others' expectations, to get a prestigious job, to appear smart) 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 semester GPA 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. Specifically, students who reported higher levels of support were expected to experience lower levels of controlled motivation and, in turn, more beneficial outcomes (e.g., lower emotional exhaustion, higher STEM intentions). However, the model instead showed that controlled motivation was not a significant mediator for the effects of either personal or academic support on well-being or academic outcomes. Given that the zero-order correlations showed no significant relationship between personal or academic support and controlled motivation, it is not surprising that this meditational hypothesis was not supported in the SEM analysis. 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 limitations of the present data with respect to poor fit of the CFA for the self-determined motivation measures or the competitive nature of the institution from which students were recruited (see Study Limitations).

Hypothesis 4: Moderation by Gender

Findings from the initial difference tests provided initial support for the gender moderation hypothesis in showing that although female students reported more support from friends, they also reported higher levels of controlled motivation and poorer levels of both emotional exhaustion and creative thinking. These gender differences in support and emotional exhaustion levels are consistent with existing literature (e.g., support: Weckwerth & Flynn; 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 specifically 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 effects observed. In particular, whereas male students received direct benefits from both personal and academic support (lower emotional exhaustion and more autonomous motivation, respectively), neither type of support was directly related to female students' motivation, well-being, or academic outcomes. For both genders, autonomous motivation was associated with STEM intentions, however, autonomous motivation was only associated with more creative thinking for male students. For female students, the only other significant direct effect was a detrimental relationship between controlled motivation and emotional exhaustion. Additionally, indirect effect analyses for male students showed autonomous motivation to mediate the benefits of academic support on STEM intentions, creative thinking, and emotional exhaustion, with female students instead showing mediated effects of personal support on STEM intentions and creative thinking via 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 their academic environment. Findings further showed male students to benefit from autonomous/intrinsic motivation and not suffer if motivated by more controlled/extrinsic reasons, with the risks of controlled motivation instead being observed primarily for female STEM students. Although this pattern of results is 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 relative 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 negative consequences of this type of motivation were notably worse for female STEM students.

However, our multigroup SEM analysis testing for gender invariance in the measurement model (i.e., measurement weights and intercepts) and structural model (i.e., measurement weights and intercepts, structural weights, intercepts, means, and covariances) 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 thus contrary to the fourth study hypothesis that social support would generally have stronger indirect effects for female STEM students as compared to male STEM students via self-determined motivation. Regardless, this finding is consistent with existing research showing gender-invariance in self-determined motivation in post-secondary students (Jeno et al., 2018; Litalien et al., 2019), and expands on previous studies by further demonstrating an overall lack of gender differences in relations between social support, self-determined motivation, and student outcomes in a STEM context.

Implications and Future Directions

Perhaps the most surprising finding from this study was that male STEM students benefitted substantially more from social support than female students. Given that many of the programs that are effective at improving retention of female students in STEM disciplines 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 was not 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 or perhaps that female students feel less comfortable using such support services (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, female students experience less of a connection to their instructor than the 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 aspect of the experiences of female STEM students that universities and individual faculty have the ability to affect, it is crucial to learn why academic support may not benefit female STEM students and implement changes to better equip all students rather than further contributing to the male-dominated nature of STEM disciplines.

Moreover, it should be noted that the mean levels of academic support reported by both male and female students were mediocre (at the scale midpoint) and that only 15% reported feeling content with the types of support they were currently receiving from faculty and university support programs. Supplemental study findings further showed that students primarily reported wanting more practical support from academic sources, such as more educational resources or assistance with assignments, as well as greater informational support, such as advice or information sessions. Smaller proportions of the sample also desired more emotional support and opportunities for social connections from faculty and university programs. Future studies are encouraged to further explore both students' academic and psychological needs in STEM degree programs to determine how to best satisfy these needs while not exacerbating emotional exhaustion for already overextended professors and university staff.

Another notable finding from this study was the impact of different types of academic motivation for women in STEM programs. Although autonomous motivation did not show many beneficial effects for women, female students who were autonomously motivated were more likely to report creative thinking and to intend to pursue a STEM career. Results also showed it to be especially detrimental for the well-being of women in STEM programs if their reasons for persisting were controlled by others or otherwise extrinsic in nature (e.g., to avoid disappointing others). In order to encourage students to adopt more adaptive motivational beliefs, motivational interventions based on self-determination have shown promising results (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 been found to have unintended negative consequences for STEM students (e.g., Hall & Sverdlik, 2016), arguably the most straightforward method for improving motivation in female STEM students may be to re-examine the teaching practices used by STEM programs.

As outlined in the present literature review, many STEM programs employ controlling teaching styles in introductory courses, such as authoritarian instruction and competitive grading, that are known to negatively impact female students (e.g., reduced motivation, confidence, and 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 or replacing these practices. Moreover, although such practices may have fewer detrimental effects for male students, 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 are encouraged to 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). Following from the present findings, it is expected that such modifications to existing programs should be associated with greater creativity, well-being, and persistence in STEM programs, particularly for female students, by improving autonomous motivating and reducing controlled motivational beliefs.

Study Limitations

When considering the replicability and generalizability of the study findings, multiple key limitations should be considered including sample size, self-report measures, sample representation, the cross-sectional design, and hypothesized model. Firstly, although the sample size of 221 was acceptable for conducting SEM analyses, it did afford more limited power when conducting multigroup analyses thus representing one potential explanation for few significant gender differences (e.g., indirect effects by gender, multigroup results). Second, because all study variables except for GPA were assessed with self-report measures, there is the possibility that hindsight bias or social desirability may have influenced responses. For example, students may have felt uncomfortable reporting actual levels of support, reasons for their academic persistence, or emotional exhaustion levels and responded in an idealized or stereotyped manner. Such response patterns are often found for men on measures of well-being (e.g., depression; Sigmon et al., 2005). Moreover, students' memories may be inaccurate when asked to retrospectively recall their emotional experiences over an extended period of time as was the case in this study (i.e., social support over the last month; Thomas & Diener, 1990).

Concerning limitations involving the study sample, since study participation was voluntary it is possible that selection bias may have impacted the study results. For example, successful STEM students may have been more likely to respond to a survey concerning their academic experiences than students who were feeling overwhelmed. Alternatively, female students who were struggling may have been more motivated to voice their experiences in the hopes of feeling heard or having their challenges addressed, perhaps contributing to the overrepresentation of women in the present sample. Relatedly, generalizing the study results to students in STEM degree programs other universities must be done with caution given that the highly competitive admissions requirements of the present research-intensive institution, and corresponding student experiences, may not be representative of students at other post-secondary 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) are encouraged to better assess generalizability of study findings.

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. Whereas the study measures and analytical methods were based on existing research supporting the directional relationships assessed, further studies of an experimental or longitudinal nature are warranted to more 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). For example, some studies suggest that social support could instead moderate the relationships between motivation and academic outcomes (Bowman, 2007; Kuo et al., 2017), thus further research is necessary to explore alternate associations and directional causality.

Lastly, the poorly fitting CFA for the self-determined motivation measure 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 noted issues with discriminant validity (Deci et al., 2013). Alternatively, the lack of mediation results could suggest that self-determined motivation may not be the most effective mediator of the effects of social support on student outcomes in STEM. Thus, future research is encouraged to examine other potential mediators such as math anxiety or stereotype endorsement that have consistently been found to correspond with social support and student success in STEM domains (Lavasani & Khandan, 2011; Riegle-Crumb & Morton, 2017).

Conclusion

The main purpose of this study was to examine the ways in which social support affects well-being and academic outcomes in STEM students as moderated by gender. Support from friends and family, or from one's university and professors, can promote beneficial outcomes in students' personal and academic lives (Alsubaie et al., 2019; Maymon et al., 2019), however, the psychological mechanisms underlying these benefits for STEM students are not clear. The present study contributed to existing research by showing self-determined motivation to mediate specific relationships between social support and student outcomes, with different indirect effects being observed for male vs. female students. In particular, academic support was beneficial for male but not female STEM students, with male students also deriving greater benefit from autonomous motivation while only female students suffered detrimental effects of controlled motivation. These findings suggest that course instruction, departmental support programs, and faculty interactions in STEM degree programs should be re-examined to promote autonomous motivation, reduce controlled motivation, and better include female students. It is also expected that STEM students in general could benefit from greater practical and informational support from faculty and university services, with further longitudinal research required to examine the long-term effects of social support and self-determined motivation on academic achievement, persistence and well-being for students in STEM programs.

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Appendix A

Ethics Approval Certificate

McGill

Research Ethics Board Office
James Administration Bldg.
845 Sherbrooke Street West. Rm 325
Montreal, QC H3A 0G4

Tel: (514) 398-6831

Website: www.mcgill.ca/research/research/compliance/human/

Research Ethics Board 2
Certificate of Ethical Acceptability of Research Involving Humans

REB File #: 20-07-025

Project Title: Exploring the Impacts of Motivation and Social Support on STEM Students' Well-Being and Academic Success.

Principal Investigator: Phoenix Horrocks

Department: Educational and Counselling Psychology

Status: Master's Student

Supervisor: Professor Nathan C. Hall

Funding: SSHRC

Approval Period: **<u>September 30. 20202 – September 29. 2021</u>**

The REB 2 reviewed and approved this project by delegated review in accordance with the requirements of the McGill University Policy on the Ethical Conduct of Research Involving Human Participants and the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Georgia Kalavritinos
Ethics Review Administrator

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* Approval is granted only for the research and purposes described.
* Modifications to the approved research must be reviewed and approved by the REB before they can be implemented.
* A Request for Renewal form must be submitted before the above expiry date. Research cannot be conducted without a current ethics approval. Submit 2-3 weeks ahead of the expiry date.
* When a project has been completed or terminated, a Study Closure form must be submitted.
* Unanticipated issues that may increase the risk level to participants or that may have other ethical implications must be promptly reported to the REB. Serious adverse events experienced by a participant in conjunction with the research must be reported to the REB without delay.
* The REB must be promptly notified of any new information that may affect the welfare or consent of participants.
* The REB must be notified of any suspension or cancellation imposed by a funding agency or regulatory body that is related to this study.
* The REB must be notified of any findings that may have ethical implications or may affect the decision of the REB.

Appendix B

Online Consent Form

CONSENT TO ACT AS A HUMAN RESEARCH SUBJECT

You are being invited to participate in a research study. Participation is completely voluntary. Please read the information below and ask questions about anything that you do not understand before deciding if you want to participate. Either researcher listed below will be happy to answer your questions.

TITLE OF THE STUDY

Exploring the Impacts of Motivation and Social Support on STEM Students' Well-Being and Academic Success

RESEARCH TEAM

Phoenix Horrocks, MA student
Educational and Counselling Psychology, McGill University
phoenix.horrocks@mail.mcgill.ca

Dr. Nathan C. Hall, Faculty Supervisor
Educational and Counselling Psychology, McGill University
nathan.c.hall@mail.mcgill.ca

FUNDING SOURCE

Social Sciences and Humanities Research Council Insight Grant (SSHRC 435-2020-0954)

PURPOSE OF THE STUDY

The main purpose of the study is to learn about the roles that social support, motivation, and curiosity play in undergraduate STEM students' academic success and well-being.

ELIGIBLE SUBJECTS

Undergraduate students enrolled in the Faculty of Science or Faculty of Engineering at McGill University (18 years of age or older, fluent in English) are eligible to participate in this study. Due to the achievement-oriented nature of this study, only students who consent to release their grades/program information to the researchers from the Registrar's Office are eligible to participate. Participants' information to be provided by the Registrar's Office will include semester GPA, credit hours completed, CEGEP or high school GPA and program of study for the Fall 2020 term. Consent to participate is provided by clicking the button below.

PROCEDURES

This study is completed entirely over the Internet (www.qualtrics.com) and consists of a one-time questionnaire regarding your experiences with social support, motivation, and well-being during the Fall 2020 semester. The questionnaire should take approximately 25-30 minutes to complete and must be completed in one sitting. At the end of each page of the survey, you will need to click "next" to save your responses and move on to the next page. Once you have clicked "next" on the last page, all responses will be submitted.

COMPENSATION, COSTS AND REIMBURSEMENT

Students participating in the study have the choice to be entered into a draw for one of five $50 cash prizes. The anticipated odds of winning are 1 in 100. Under federal law, it is necessary that all participants answer a skill-testing question correctly to be eligible to be included in the prize draw. **If you wish to be considered for one of the cash prizes, then please answer the skill-testing question at the bottom of the consent form**. Winners will be contacted by email and if a winner is contacted but does not come forward within 2-4 weeks, another name will be drawn. All participant emails will be deleted as soon as the prize distribution is complete.

CONFIDENTIALITY

Subject Identifiable Data:

Information will be collected through the survey program Qualtrics and initially stored on their secure, encrypted servers. To view Qualtrics privacy policy, please refer to the link (https://www.qualtrics.com/privacy-statement). Once the survey data collection is complete, the data will be transferred to the researchers' secure, password-protected McGill cloud storage (estimated: October 2020). At this time, all data will be deleted from the Qualtrics servers. All identifiable information that will be collected about you (name, email, student ID) will be removed at the end of the data collection (estimated: January 2021). After this point, data becomes anonymized, we will no longer be able to know what data belongs to who since all identifiers have been stripped from all participant datasets. Identifying information will only be used to link your study responses with the data from the Registrar's Office and will be omitted immediately afterward receiving this data to ensure participant anonymity. No identifiable information about participants will be included in the study report or shared with any other parties including McGill financial services.

When answering any open-ended response questions in the survey, we request that you do not share any identifying information about yourself or others to respect individuals' privacy. Any identifying information that is shared will be removed or replaced with pseudonyms to preserve confidentiality.

Data Storage:

All research data will be stored electronically in secure, password-protected cloud storage on McGill servers.

Data Access:

Only the research team (Phoenix Horrocks, Dr. Nathan C. Hall) will have access to your study records. Any information derived from this research that could be personally identifying will not be disclosed by the research team.

Data retention:

The researchers intend to keep the research data in an electronic format on the hard drive of a secure computer in the McGill Education building with password protection for 7 years after publication of the study results.

Dissemination of results:

The results of this study will be presented as part of a master's thesis, at international conferences, and in open access journal publications in 2021. All results will be presented at the group level with identifying information removed prior to the analysis so your identity will remain confidential.

RISKS AND DISCOMFORTS

There are risks involved in all research studies. This study is expected to include only minimal risks, with no known harms or discomforts associated with this study beyond those encountered in everyday life. A possible risk of participation in this study is mild frustration or loneliness that might be associated with reflecting on academic experiences of social support, motivation, well-being, and persistence.

POTENTIAL BENEFITS

There are no expected direct benefits to you from participating in this study, but it is hoped that the opportunity to reflect on your motivation, social experiences, and well-being may be a useful experience. It is anticipated that study findings may inform STEM instructors and university support services such as first-year orientation programs, peer mentorship, and motivational interventions about STEM students' social and motivational needs.

VOLUNTARY PARTICIPATION STATEMENT

Your participation in this study is voluntary. You may choose to refuse to answer any question or may withdraw from the survey at any time. You may also withdraw your data from the study at any time up until the end of data collection (estimated: January 2021). Once de-identified, data can no longer be withdrawn from the study. Your decision will not affect your future relationships with McGill University.

IF YOU HAVE QUESTIONS

If you have any questions or concerns regarding the conduct of this research, please contact the researchers listed above via email. If you have any ethical questions or concerns about your rights or welfare as a participant in this research study, please contact the McGill Ethics Associate Director at 514-398-6831 or lynda.mcneil@mcgill.ca.

PARTICIPANT CONSENT

Please fill in the following information and click **"next"** if you have read the above information and consent to participate in this study. Agreeing to participate in this study does not waive any of your rights or release the researchers from their responsibilities.

Institutional Email Address: __________________
First Name: _____________ Last name: ____________________
McGill Student ID #: _____________

Please answer the following skill-testing problem if you would like to be considered for the prize draws. If you do not want to be entered in the prize draws, do not provide an answer.

(4 x 5) + (2 x 3) + 11 =

Please feel free to copy/print/download the consent information above for your records.

Appendix C

Recruitment Email sent by McGill Campus Life & Learning Office

Sent on behalf of Phoenix Horrocks, Principal Investigator, and Dr. Nathan C. Hall, Department of Educational and Counselling Psychology

Dear ,

This email is to inform you of an opportunity to participate in an online study on students' experiences of social support, motivation, and well-being in science, mathematics, and engineering (STEM) programs at McGill University. **Students who participate will be entered into a draw for 5 cash prizes of $50**. The anticipated odds of winning are 1 in 100.

The study consists of a one-time online questionnaire concerning your academic experiences during the Fall 2020 semester that will require about 15-20 minutes of your time. If you are interested in participating, please click the link below to access the study website **prior to November 9, 2020**:

Click to Begin Survey

If you have any questions about the study, please feel free to contact the Principal Investigator, Phoenix Horrocks, at **phoenix.horrocks@mail.mcgill.ca** or the Faculty Supervisor, Nathan Hall, at **nathan.c.hall@mcgill.ca**.

Thank you for your time!

Sincerely,

Phoenix Horrocks, Principal Investigator
Achievement Motivation and Emotion Research Group
Department of Educational and Counselling Psychology
McGill University

Dr. Nathan Hall, Associate Professor
Department of Educational and Counselling Psychology
McGill University

McGill University is located on land which has long served as a site of meeting and exchange amongst Indigenous peoples, including the Haudenosaunee and Anishinabeg nations. McGill honours, recognizes and respects these nations as the traditional stewards of the lands and waters on which we meet today.

Appendix D

Questionnaire Items

[Demographic Information]

In this part of the survey, we ask for some factual information about you. Your answers to all of the questions are **confidential**.

Do you wish to be provided a brief report of the study findings by email upon completion of this study phase?

Yes

No

Do you wish to be informed by email of opportunities to participate in additional related studies conducted by the researchers?

Yes

No

Which year of undergraduate studies are you in?

1

2

3

4

5+

Please select the subject(s) that best represents your current or intended major. If you have not yet chosen a major, what subject are you most strongly considering majoring in? If you are considering a double major, please indicate both fields.

[All participants who select a major highlighted in grey will be redirected to an ineligibility page]

--- Agriculture (Agro-Environmental Sciences, Agricultural Economics)

--- Architecture

--- Biological Sciences (e.g., Physiology, Microbiology, Environmental Biology)

--- Biochemistry

--- Chemistry

--- Cognitive Science

--- Computer Science

--- Earth Sciences (e.g., Geography, Earth System Science, Atmospheric Science)

--- Engineering (e.g., Mechanical, Biomedical, Electrical)

--- Environment

--- Mathematics

--- Neuroscience

--- Nutritional Sciences (e.g., Nutrition, Food Science)

--- Occupational Therapy

--- Pharmacology

--- Physical Therapy

--- Physics

--- Planetary Science

--- Psychology

--- Sustainability, Science & Society

---My major is not related to science or engineering (e.g., education, music, history)

--- Other <please specify>

What is your gender?

Female

Male

Gender variant/Non-conforming

Other, please specify: ___________________

What is your age in years? _______

What is your race/ethnic background? <drop-down menu>

Caucasian (European)

West Asian (Iran, Israel, Iraq, Turkey, Saudi Arabia, etc.)

South Asian (India, Pakistan, Sri Lanka, Afghanistan, etc.)

Southeast Asian (Philippines, Singapore, Thailand, Vietnam, etc.)

East Asian (China, Japan, N/S Korea, Taiwan, Hong Kong, etc.)

Latin, Central, South American

Pacific Islander

Caribbean

African

Indigenous (Inuit, First Nations, Métis, etc.)

Other, please specify: ____________

What was your average (%) in your last year of schooling prior to starting university (high school/ CEGEP)? _____

Did you attend/graduate from CEGEP?

Yes

No

[For students who select they attend or graduate from CEGEP]

In CEGEP, were you in a STEM (science, mathematics, engineering, technology) program?

Yes

No

How many credits are you enrolled in this semester at McGill?
(Note: A one-semester course is normally worth three credits) _______________

Are you registered as an international student?

Yes

No

[Social Support – Frequency & Quality]

Source: Maymon, R., Hall, N. C., & Harley, J. M. (2019). Supporting first-year students during the transition to higher education: The importance of quality and source of received support for student well-being. *Student Success*, *10*(3), 64–75.

Instructions: In the last month, ***how often*** have you received support from each of the following sources?

Response Format: 0 = Never; 1 = Almost never; 2 = Sometimes; 3 = Fairly often; 4 = Very often

Friends
Family
Faculty/staff
Your institution (e.g., university programs, events)

Instructions: How would you describe the ***quality*** of support received from each of the following sources in the last month?

Response Format: 1 = Very poor; 2 = Poor; 3 = Average; 4 = Good; 5 = Very good

Friends
Family
Faculty/staff
Your institution (e.g., university programs, events)

Instructions: The following questions ask about additional ***types of support*** you would ***like to receive more of*** from sources in your life. Please read the questions carefully and select all options that apply.

What types of support would you ***like to receive more of*** from ***your friends***? Select all that apply.

- ☐ Emotional support (e.g. a listening ear, encouragement)
- ☐ Practical support (e.g. academic resources, help with an assignment)
- ☐ Informational support (e.g. advice, information sessions)
- ☐ Social Companionship (e.g. do activities together, writing groups)
- ☐ I already receive all these types of support
- ☐ Other (please specify)

What types of support would you ***like to receive more of*** from ***your family***? Select all that apply.

- ☐ Emotional support (e.g. a listening ear, encouragement)
- ☐ Practical support (e.g. academic resources, help with an assignment)
- ☐ Informational support (e.g. advice, information sessions)
- ☐ Social Companionship (e.g. do activities together, writing groups)
- ☐ I already receive all these types of support
- ☐ Other (please specify)

What ***types of support*** would you ***like to receive more of*** from ***university faculty or staff***? Select all that apply.

- ☐ Emotional support (e.g. a listening ear, encouragement)
- ☐ Practical support (e.g. academic resources, help with an assignment)
- ☐ Informational support (e.g. advice, information sessions)
- ☐ Social Companionship (e.g. do activities together, writing groups)
- ☐ I already receive all these types of support
- ☐ Other (please specify)

What ***types of support*** would you ***like to receive more of*** from ***the university***? Select all that apply.

- ☐ Emotional support (e.g. a listening ear, encouragement)
- ☐ Practical support (e.g. academic resources, help with an assignment)
- ☐ Informational support (e.g. advice, information sessions)
- ☐ Social Companionship (e.g. do activities together, writing groups)
- ☐ I already receive all these types of support
- ☐ Other (please specify)

[Self-Determined Motivation]

Revised Academic Self-Regulation Questionnaire (17 items)

Source: Vansteenkiste, M., Sierens, E., Soenens, B., Luyckx, K., & Lens, W. (2009). Motivational profiles from a self-determination perspective: The quality of motivation matters. *Journal of Educational Psychology*, *101*(3), 671–688. https://doi.org/10.1037/a0015083

AND

Litalien, D., Guay, F., & Morin, A. J. S. (2015). Motivation for PhD studies: Scale development and validation. *Learning and Individual Differences*, *41*, 1–13. https://doi.org/10.1016/j.lindif.2015.05.006

Instructions: The following questions measure your motivation for studying STEM. Please indicate how important each of the listed motives ***is for you to do well in your STEM courses*** by selecting a number between 1 (*Not important at all*) and 5 (*Very important*).

Response Format: 1(Not at all important), 5 (Very important)

I am motivated to do well in my STEM courses…

1. Because I'm supposed to do so.
2. Because I want others to think I'm smart.
3. Because I can improve my skills in my field of study.
4. Because my studies are consistent with my values (e.g., interests, morals, etc.).
5. Because I am highly interested in doing this.
6. Because that's something others (parents, friends, etc.) pressure me to do.
7. Because I would feel guilty if I didn't study.
8. Because of the opportunities to advance my knowledge in my field of study.
9. Because my studies are a fundamental part of who I am and my identity.
10. Because I enjoy doing it.
11. Because others (parents, friends, etc.) obligate me to do so.
12. Because I would feel ashamed if I didn't study.
13. Because it will help me better prepare for a career I am interested in.
14. Because my studies meet my goals and objectives in life.
15. Because it's fun.
16. Because that's what others (e.g., parents, friends) expect me to do.
17. Because I want others to think I'm a good student.
18. Because it's an exciting thing to do.

[Burnout]
Maslach Burnout Inventory (emotional exhaustion subscale, 7 items)

Source: Maslach, C., Jackson, S. E., & Leiter, M. P. (1996). *Maslach burnout inventory manual* (3rd ed.). Mountain View, California: CPP, Inc.

Instructions: Please read each statement below concerning ***your experiences in your STEM courses***. If you have never had this experience, please select "Never". If you have, please select a response that best describes how frequently you feel that way.
Response Format: 0 = Never, 1 = A few times a year or less, 2 = Once a month or less, 3 = A few times a month, 4 = Once a week, 5 = A few times a week, 6 = Every day

1. I feel emotionally drained from my studies.
2. I feel used up at the end of the day.
3. I feel fatigued when I get up in the morning and have to face another day of studying.
4. I feel burned out from my studies.
5. I feel frustrated by my studies.
6. I feel I'm working too hard on my studies.
7. I feel like I'm at the end of my rope.

[Creative Thinking]

Self Description Questionnaire (Creative Thinking/Problem Solving subscale, 9 items)

Source: Marsh, H. W., & O'Neill, R. (1984). Self Description Questionnaire III: The construct validity of multidimensional self-concept ratings by late adolescents. *Journal of Educational Measurement*, *21*(2), 153–174.

Instructions: For each question, please select the number that best indicates how true the statement is of you ***in your STEM courses***.

Response Format:

1 = Definitely False	5 = More True Than False
2 = False	6 = Mostly True
3 = Mostly False	7 = True
4 = More False Than True	8 = Definitely True

1. I am never able to think up answers to problems that haven't already been figured out.
2. I am good at combining ideas in ways that others have not tried.
3. I wish I had more imagination and originality.
4. I enjoy working out new ways of solving problems.
5. I am not much good at problem solving.
6. I am not very original in my ideas, thoughts, and actions.
7. I am an imaginative person.
8. I would have no interest in being an inventor.
9. I can often see better ways of doing routine tasks.

[Future STEM Intentions]

Instructions: The following items ask about your intentions to continue within a STEM field. Please read each statement carefully and respond to it using the scale provided.

[Science Career Plans]

SPIRES Survey (Science Career Plans subscale, 3 items)

Source: Skinner, E., Saxton, E., Currie, C., & Shusterman, G. (2017). A motivational account of the undergraduate experience in science: Brief measures of students' self-system appraisals, engagement in

coursework, and identity as a scientist. *International Journal of Science Education*, *39*(17), 2433–2459. https://doi.org/10.1080/09500693.2017.1387946

Response Format: (1) Not true at all to (5) Totally true

1. For the career I want, I need a degree in science (+)
2. I am planning on a job that involves science (+)
3. Science is important for my future career (+)

[Open-ended] Has COVID-19 impacted your motivation to pursue a STEM major/career?

To ensure anonymity of responses, please refrain from including specific identifying information about yourself or others, such as specific course numbers or instructor names.

[Open-ended] Please use the space provided for any additional comments or feedback you have regarding this study. To ensure anonymity of responses, please refrain from including specific identifying information about yourself or others, such as specific course numbers or instructor names.