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by Katherine Wall

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Persistence and representation of women in STEM programs

by Katherine Wall

Overview of the study

The underrepresentation of women in STEM (science, technology, engineering, and mathematics and computer science) has attracted considerable attention, and many have wondered whether women are more likely than men to quit STEM programs at university. Using data from the Education and Labour Market Longitudinal Platform (ELMLP), this study follows a cohort of students who enrolled in a STEM program in 2010 over a number of years, in order to see the extent to which women and men persist in and eventually graduate from STEM programs.

- Women made up 44% of first-year STEM students aged 19 or less in undergraduate degree programs in 2010, whereas they accounted for more than 64% of students in BHASE, or non-STEM, programs (including business, humanities, health, arts, social science and education, among others).
- Among those who were first-year students in a STEM undergraduate program in 2010, 66% of women and 72% of men remained in a STEM program (as students or graduates) as of 2015. About 23% of women and 12% of men transferred from a STEM to a BHASE program, and 11% of women and 16% of men left undergraduate studies.
- Some women who were initially in a BHASE program also switched into a STEM program; as a result, the proportion of women among STEM graduates or sixth-year students in 2015 was similar (43%) to that of first-year STEM students in 2010 (44%).
- Women who transferred from a STEM to a BHASE program generally chose BHASE fields related to their initial STEM major: for example, transferring from biological sciences to health care, or from mathematics and related studies to finance.
- Persistence varied across STEM programs. About 82% of women and 77% of men in engineering remained in the same program over the period. This compared with 9% of women and men in general and integrated sciences, where many students eventually moved to a more specific STEM program or a BHASE program.
- Women graduated faster than men from STEM programs, regardless of field of study. For example, 27% of women and 16% of men who started out in computer and information sciences completed a STEM degree within four years.

Introduction

Given the need for people with a scientific background in the labour force, the underrepresentation of women in STEM (science, technology, engineering, and mathematics and computer science) fields of study and occupations has attracted considerable attention over the last several decades. In 2016, women made up 34% of STEM bachelor's degree holders and 23% of science and technology workers among Canadians aged 25 to 64.[1] The shortage of women in STEM is widely recognized as detrimental to women, since science and technology occupations, particularly in engineering and computer science, are among the highest-paying[2] and fastest-growing occupations.[3] Additionally, numerous analyses have found that greater diversity strengthens innovation and performance.[4]

While women make up the majority of degree-holders in the biological sciences, occupations relating to the life sciences are typically lower-paying than those relating to other areas of STEM.[5] Women's representation is lowest in the engineering and computer science fields, where the large majority of science and technology jobs are concentrated.[6]

Despite extensive research and a high degree of policy concern, Canada's progress on improving women's representation in STEM has been uneven. In 2016, women's representation among Canadian-educated STEM bachelor's degree holders was 36% for 30-year olds, similar to the 37% share for 40-year-olds, though both figures were higher than women's 22% share for 65-year-olds.[7] This suggests earlier progress in improving women's representation, but little change in more recent years. In addition, administrative data from Canadian universities and colleges found that women's share of enrolments in STEM degree programs remained relatively stable between 2010 and 2015.[8]

The issue of how women's representation in STEM changes over the course of their education and career has been extensively discussed in the literature.[9] A commonly used metaphor is that of "leaks" in the STEM "pipeline," with women being lost from the pipeline at various different points: between high school and undergraduate studies; over the course of undergraduate studies; between undergraduate and graduate studies; and between degree completion and the workforce.

While women are typically underrepresented throughout the STEM pipeline, their representation decreases as they progress from high school to postsecondary studies and from there into the labour market. Women's self-identification with math and sciences is lower than that of men, and even women who report strong self-identification with math and sciences are less likely than men to intend to pursue a major in those fields.[10] These disparities increase between university and the labour market. Among Canadian-educated workers aged 25 to 34, 54% of women with a bachelor's degree in computer and information sciences worked in science and technology occupations,[11] compared with 74% of men. Likewise, women with degrees in mathematics and related studies or physical and chemical sciences were less likely than men in those fields to work in science and technology occupations, by 10 percentage points or more.[12]

One area of concern in the STEM pipeline is women's progression from starting a STEM degree to completing it. There have been numerous studies on whether women are more likely to leave the STEM pipeline during postsecondary studies than men, and if so, why.[13] Some studies focusing on universities in the United States have found that women who start a STEM degree are less likely to complete it than men,[14] while others have found that women's persistence in STEM fields of study is equal to or greater than that of men.[15] One of the most common reasons for women not to persist in STEM postsecondary studies is loss of interest in the STEM curriculum, which some studies found is related to women not self-identifying as scientists, feeling isolated or out of place in STEM classes (due to being greatly outnumbered by male peers, or to unequal treatment by professors and/or peers), or not seeing STEM fields as a means to improving the lives of others.[16] Additionally, women in STEM have lower academic-self-confidence than men of equal academic ability, contributing to their departure from STEM fields.[17] Conversely, women who strongly identify themselves as scientists or engineers are more likely to persist in STEM fields and STEM careers.[18]

Numerous examples of Canadian research examining the variety of pathways through postsecondary education can be found,[19] but there has been no comprehensive examination of women's persistence in STEM over the course of the entirety of undergraduate or graduate studies in Canada.[20]

This paper fills that gap by providing a gender-based longitudinal analysis of STEM students. It examines the persistence and representation of women and men in STEM fields over the course of undergraduate degrees, beginning with an overview of trends in STEM and BHASE as a whole (the term BHASE is used for non-STEM fields, which include but are not limited to business, health, humanities, arts, social sciences and education programs). It then proceeds to a breakdown of the trends for the different STEM fields of study, discusses the graduation rates of women and men from STEM, and examines the number of years they take to complete their degrees. The article also provides a brief examination of women's persistence and representation in STEM as they relate to master's degree programs (see the section entitled "Persistence and representation of women who are pursuing a master's degree in STEM").

Persistence in STEM and representation in STEM are related but distinct concepts. Persistence refers to the proportion of women (or men) in a given field (such as STEM) who are still in that field after a number of years. Representation refers to the proportion of people in a given field who are women.

The analysis uses data from the Postsecondary Student Information System (PSIS), connected longitudinally through the Education and Labour Market Longitudinal Platform (ELMLP) (see the Data sources, methods and definitions section). PSIS provides annual information on all students at Canadian public colleges (including Quebec CEGEPs) and universities. The bulk of the analysis examines the cohort of students who entered full-time undergraduate degree studies (at either a university or a college) in 2010, and who were aged 19 and under[21] (the 2010 cohort), and tracks them longitudinally until 2015.[22] They are retained in the analysis regardless of whether they studied part time in subsequent years.

Persistence in STEM was lower for women than men, but women's representation in STEM changed little over the course of their studies

Women made up 44% of first-year STEM students aged 19 and under[23] in undergraduate degree programs in 2010,[24] whereas they accounted for almost two thirds (64%) of students in BHASE or non-STEM programs (Table 1). Women's representation differed considerably between STEM fields. They constituted the majority in both biological sciences (60%) and general and integrated sciences (58%), fields that accounted for over one-half of all first-year STEM students. Women's representation was lower in mathematics and related studies (43%) and physical and chemical sciences (32%), and lowest in engineering (19%) and computer and information sciences (16%).

Among women who were first-year students in a STEM undergraduate program in 2010, 66% remained in STEM (as students or graduates) in 2015 (Chart 1). In comparison, 72% of men persisted in STEM. The gender gap in persistence differed little between Canadian citizens (6 percentage points), permanent residents (7 percentage points) and international students (5 percentage points). However, permanent residents (landed immigrants) had higher STEM persistence rates than other students, at 70% for women and 77% for men.

Women's lower persistence in STEM was due to the fact that women who started out in STEM were almost twice as likely (23%) as men (12%) to switch from STEM to BHASE. Most of this difference (9 percentage points) was attributed to women being more likely than men to switch from STEM to health care (mainly registered nursing or pharmacy) or psychology.[25]

Table 1
Representation of women in STEM and BHASE (non-STEM) among first-year undergraduate students in 20101

STEM and BHASE major fields of study	Number of first-year students count	Proportion of first-year students who are women percent
All fields of study	**128,511**	**57.6**
STEM	**39,774**	**43.6**
Science and science technology	**25,627**	**56.0**
Physical and chemical sciences	2,833	32.3
Biological sciences	12,938	59.8
General and integrated sciences	9,856	57.8
Engineering and engineering technology	10,663	19.0
Engineering	10,498	18.7
Engineering technology	165	32.7
Mathematics and computer and information sciences	**3,484**	**27.6**
Mathematics and related studies	1,509	42.9
Computer and information sciences	1,975	15.8
BHASE (non-STEM)	**88,737**	**63.8**
Business and administration	17,928	46.4
Arts and humanities	35,932	66.2
Social and behavioural sciences	19,312	68.4
Legal professions and studies	806	63.2
Health care	6,325	80.7
Education and teaching	3,602	80.0
Trades, services, natural resources and conservation	4,832	58.5

1. Note that the number of first-year enrollees in fields such as legal professions and studies or education and teaching may be much lower than the number of graduates since many students enter these programs in the later years of their studies. Similarly, the high number of enrollees in arts and humanities is partly due to the fact that students with undeclared majors are included in the humanities.

Source: Statistics Canada, Postsecondary Student Information System (PSIS), longitudinal data, 2010/11 to 2015/16.

Women who started out in STEM were less likely to leave undergraduate degree studies (11%) than men (16%). This group included those who left undergraduate degree programs for other programs; notably, 5% of men and 3% of women left their STEM undergraduate degree program to pursue a college-level certificate or diploma.[26] For more information, see the section entitled "What happened to women and men who left undergraduate degree studies?"

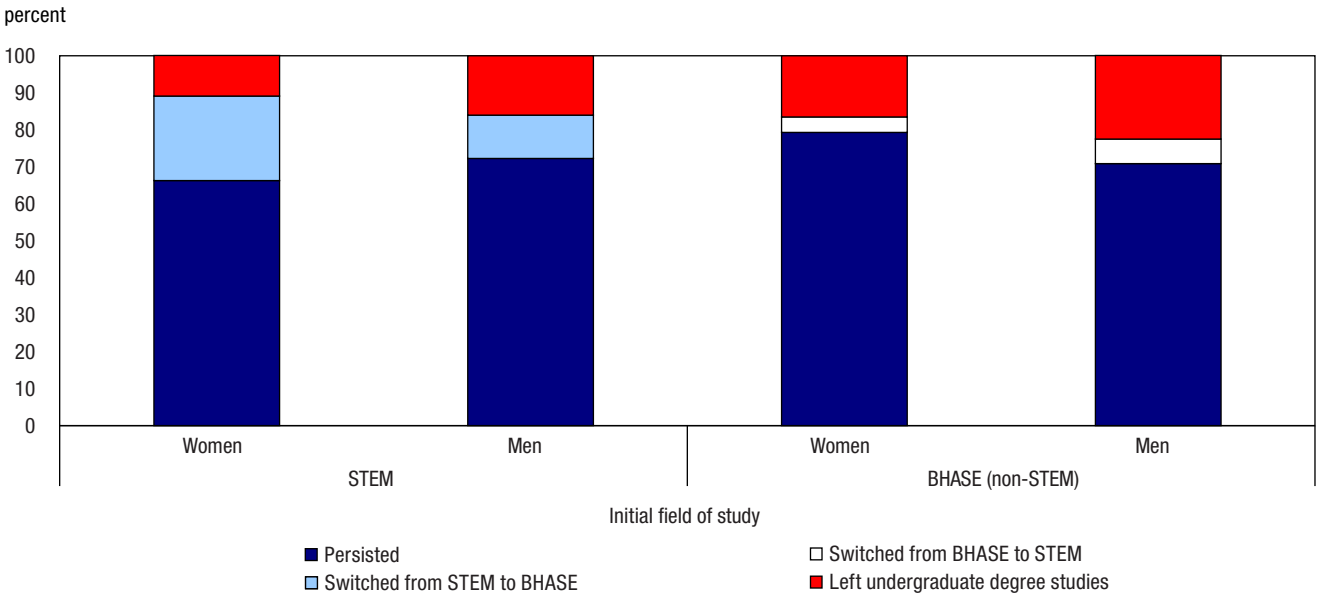
In BHASE fields of study, women were more likely to persist (79%) than men (71%). This was mainly because they were less likely to leave undergraduate degree studies, by about 6 percentage points. Women were also less likely to switch from BHASE to STEM (4%) than men (7%). Among both sexes, STEM-to-BHASE switches were more common than BHASE-to-STEM switches, while the proportion of students who left undergraduate degree studies was higher in BHASE than in STEM.

Despite women's lower persistence in STEM, women's representation in STEM did not change notably over time. Women made up 43% of people who had either graduated with a STEM degree after five years or who were continuing in the sixth year of STEM studies, similar to their 44% share of first-year STEM students.

To understand this finding, it is necessary to consider not only the students who start out in STEM and do not persist, but also the students who start out in BHASE and switch to STEM. While men who started out in BHASE were proportionally more likely to switch to STEM than women in BHASE, there were more women in BHASE than men. As a result, a larger number of women than men switched from BHASE to STEM. This increased women's overall representation in STEM enough to partially offset the effect of their lower persistence in STEM.

The loss of women from STEM fields of study over the course of an undergraduate degree is therefore not a major explanatory factor for the underrepresentation of women in STEM in Canada. Instead, the underrepresentation of women in STEM is mainly related to the majors chosen by women and men when they first enroll in an undergraduate degree program, and the careers they have after graduating from their program.

Chart 1
Persistence of women and men in STEM and BHASE after five years, 2010 cohort



... not applicable
Source: Statistics Canada, Postsecondary Student Information System (PSIS), longitudinal data, 2010/11 to 2015/16.

Most women who left STEM did so early in their studies

Most women who departed from STEM did so early on in their studies. By the start of their second year, 17% of women in STEM had either switched to BHASE or left undergraduate degree studies entirely. Between then and the start of third year, another 10% left. In the subsequent years, leaving STEM was less common. This can also be represented as a survival analysis, as shown by Chart 2. Previous studies substantiate that most students who change their field of study or leave undergraduate degree studies do so early in their studies.[27]

Women were more likely than men to leave STEM in their early years of study, while in the later years both sexes were about equally likely to leave STEM. The gender difference was related to women's higher probability of switching to a BHASE field of study since most switches happened in the early years of study.

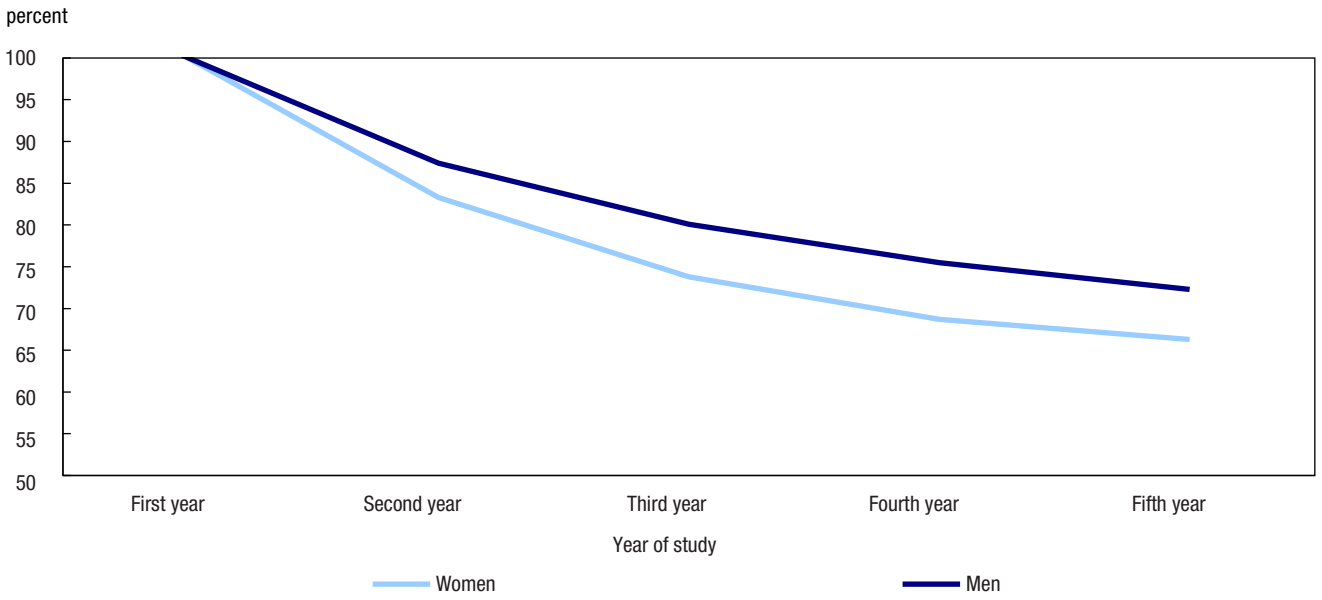
In every STEM field of study, women's persistence in their initial STEM field was similar to or higher than that of men

Examining persistence in STEM by field of study increases the number of possible pathways students can follow. They may persist in their original field of study; switch from one STEM field to another STEM field; switch from a STEM field to a BHASE field; or leave undergraduate degree studies altogether. Both persisting in the original STEM field of study and switching to another STEM field of study constitute persisting in STEM.

Women's persistence in their initial STEM field of study was consistently greater than or similar to that of men. More particularly, they were about 5 percentage points more likely to persist in engineering, and 4 percentage points more likely to persist in biological sciences. These were also the two STEM fields where students of both sexes were the most likely to persist in their original field (Chart 3).

Women's overall persistence in STEM (including both those who remained in their initial STEM field and those who changed to another STEM field) was higher than men's among students who started out in engineering; similar to men's among those who started out in biological sciences or computer and information sciences; and lower than men's in general and integrated sciences, physical and chemical

Chart 2
Persistence in STEM undergraduate degrees over five years, by sex and year of study, 2010 cohort



Source: Statistics Canada, Postsecondary Student Information System (PSIS), longitudinal data, 2010/11 to 2015/16.

sciences and mathematics and related studies. In all fields where women's STEM persistence was lower than men's, it was because women were less likely than men to switch from one STEM field to another.

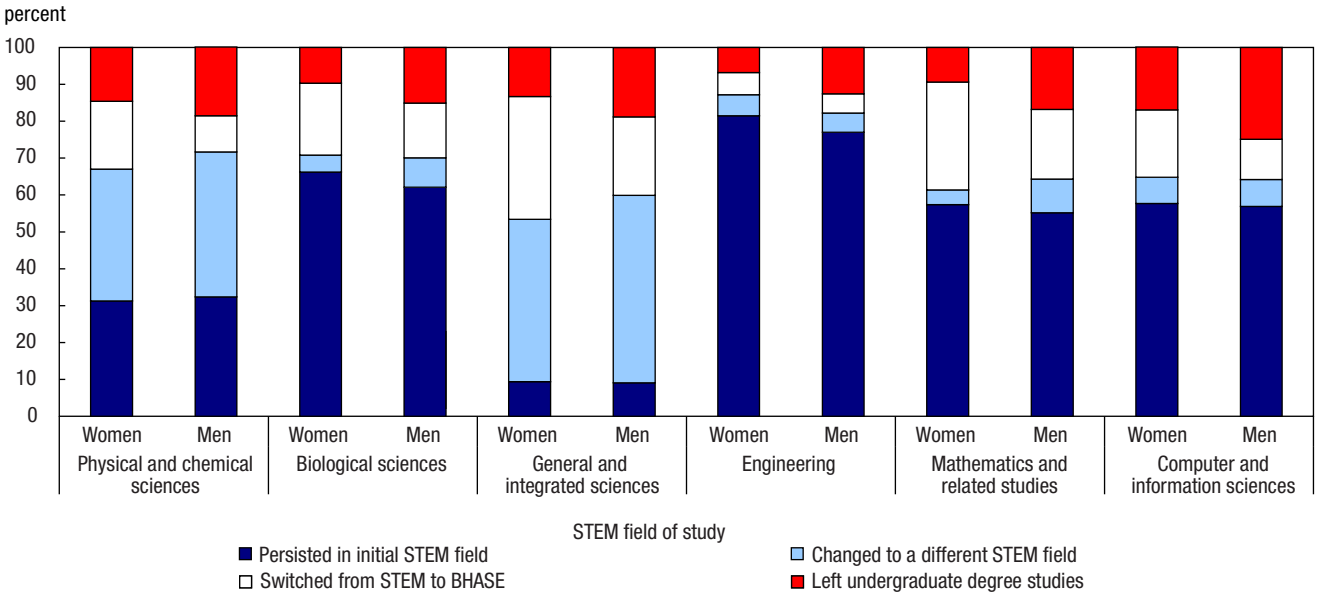
Since engineering is one of the STEM fields where women are the least represented, it is noteworthy that engineering was the field where women's persistence both in their initial STEM field and in STEM overall exceeded men's by the largest margin. This indicates that the male-dominated environment of engineering has not deterred women who do enter it from persisting in STEM overall or in engineering specifically. It runs counter to the theory that being outnumbered by their male peers makes women less likely to persist in STEM studies.[28]

Engineering students were more likely to persist in STEM than those in any other STEM field, with 87% of women and 82% of men persisting. In all other fields, less than three-quarters of women and men persisted in STEM. This is part of the reason why women's overall persistence in STEM was lower than that of men: men in STEM were more likely than women in STEM to study engineering, which increased men's overall STEM persistence rate.

In addition to being unlikely to leave undergraduate studies or switch to BHASE, engineering students were also less likely to switch to another STEM field: over three-quarters of women and men who initially enrolled in engineering stayed in engineering. There are several probable reasons for this trend. For example, the high admission requirements of engineering programs may result in these programs having more highly skilled or highly motivated students than other fields. The strong labour market outcomes of engineering graduates are also well known,[29] which may serve to motivate students.

In contrast to engineering, women's persistence in STEM was lowest in general and integrated sciences, a field where women made up the majority of students. Among women and men, 53% and 60%, respectively, in general and integrated sciences persisted in a STEM field, lower proportions than in any other STEM field. General and integrated sciences is mainly made up of students who have declared a general sciences major rather than a specialization in a specific field like chemistry or microbiology.[30] The large majority of students

Chart 3
Persistence of women and men in STEM after five years, by selected STEM fields of study, 2010 cohort



Source: Statistics Canada, Postsecondary Student Information System (PSIS), longitudinal data, 2010/11 to 2015/16.

who started out in this field later switched to a more specific field of study, either in another STEM field or in BHASE: 9% of women and men who started in general and integrated sciences remained in that field during the entire period. Students in general and integrated sciences were more likely than those in any other STEM field to switch to BHASE, which was particularly true for women (who mainly switched to psychology and health care). It may indicate that persistence in STEM is lower among students who have less specific ideas about what STEM field interests them, and higher among those who have already decided on a specific major when they start their undergraduate studies.[31] This would be consistent with research indicating that commitment to STEM is a strong indicator of persistence, while students who feel less committed to STEM are more likely to switch to other majors.[32]

Women in physical and chemical sciences, and to a lesser extent those in mathematics and related studies, were about as likely as men to persist in their original field of study, but less likely to switch to another STEM field.

Computer and information sciences had the highest proportion of students who left undergraduate degree studies, and the largest difference between women and men in this regard. While 17% of women who started out in computer and information sciences left undergraduate degree studies, 25% of men did so. Among women and men, 10% and 16%, respectively, left postsecondary studies altogether, a higher proportion than in any other STEM field. Others moved into different types of postsecondary studies, with 7% of men and 4% of women pursuing a college-level certificate or diploma. Women in computer and information sciences were more likely than men to switch to an undergraduate BHASE field (18% of women versus 11% of men) rather than ceasing their postsecondary studies or switching to a college-level program.

Students who switched from STEM to BHASE generally chose BHASE fields that were related to their initial STEM major

Women who switched from general and integrated sciences or biological sciences to a BHASE field mainly entered health care (most commonly registered nursing or pharmacy) or psychology.[33] Having previous experience in science fields can be helpful, given that health care fields often require knowledge of human anatomy and physiology, and may require knowledge of chemistry, biochemistry, microbiology and similar fields. Similarly, psychology can employ scientific experimental methods, and biological psychology relates to scientific subjects including physiology and neuroscience.

Additionally, nursing and pharmacy degrees tend to be associated with higher earnings and a higher probability of employment related to one's field of study than degrees in biological sciences and general and integrated sciences, which may provide a motivation for switching to this field.[34]

Students who switched from mathematics and related studies to a BHASE field tended to move into the field of business and related studies (including business administration, finance and accounting) or into social and behavioural sciences, particularly economics. Both business and economics have a strong mathematical component, and would enable students to continue applying their mathematical skills and interests.

The majority of those who started out in a BHASE field and later switched to STEM were students whose initial major was general studies, which is classified as a BHASE field. In other words, they had not initially selected a specific field of study. This forms a pattern with a tendency for students in general and integrated sciences (who mainly had general sciences majors) to switch from STEM to BHASE. It indicates that switches between STEM and BHASE were most common among those who had not yet chosen a specific major, and who were still investigating multiple possibilities.

This tendency was particularly evident in the sciences (biological sciences, general and integrated sciences and physical and chemical sciences), where over 60% of entrants from BHASE started out with a general studies major. Among people who switched from BHASE to mathematics and related studies, 36% were from the field of business and administration, showing that switches between math and business are relatively common in both directions.

In most STEM fields, women's representation was higher among sixth-year students and graduates than among first-year students

Each STEM field of study could gain students who switched over from other STEM fields or from BHASE fields. In most STEM fields, between 40% and 60% of sixth-year students and graduates were those who had had a different field

of study during their first year. The main exception was engineering, where 15% of sixth-year students and graduates had switched over from a different field. At the other end of the spectrum, 68% of women who were studying or had graduated from physical and chemical sciences as of their sixth year had entered it from another field, mostly from general and integrated sciences.

As a result of switches into STEM, and switches between STEM fields, women's representation in most STEM fields of study remained stable or increased between their first year and sixth year (Table 2). The increase was largest in physical and chemical sciences, where women made up 32% of first-year students, but 37% of sixth-year students and graduates, the result of women entering the field from general and integrated sciences, and men leaving the field for engineering. Women made up 16% of first-year students in computer and information sciences, but 18% of sixth-year students and graduates. The only STEM fields in which women's representation decreased were general and integrated sciences and mathematics and related studies, and in both these fields the decrease was less than 1 percentage point. These findings further support the conclusion that the loss of women from STEM undergraduate programs is not a notable cause of women's underrepresentation in STEM fields.

Women completed their STEM degrees more quickly than men

The standard length of an undergraduate program is four years in Canada outside Quebec and three years in Quebec (where it is preceded by a two-year general CEGEP program). The literature on undergraduate degrees, however, finds that it is increasingly common for students to take up to six years to complete an undergraduate degree.[35]

Overall, across all fields of study, 41% of undergraduate degree students finished their degree within four years. After five years, 66% of students had completed their degree; another 16% continued their studies for a sixth year, while 17% had left undergraduate studies.

Table 2
Change in women's representation in STEM between 2010 and 2015, by selected STEM fields of study, 2010 cohort

STEM field of study	Women's share of first-year students (in 2010)	Women's share of 6th-year students and graduates (in 2015)	Net change in women's representation from first to sixth year
	percent		percentage point change
STEM	**43.6**	**43.0**	**-0.6**
Physical and chemical sciences	32.3	37.0	4.7
Biological sciences	59.8	61.9	2.1
General and integrated sciences	57.8	57.5	-0.3
Engineering	18.7	19.9	1.2
Mathematics and related studies	42.9	42.3	-0.6
Computer and information sciences	15.8	18.0	2.2

Source: Statistics Canada, Postsecondary Student Information System (PSIS), longitudinal data, 2010/11 to 2015/16.

Women graduated more quickly than men, with 47% of women graduating within four years and 32% of men doing so. BHASE students were more likely to graduate within four years than STEM students, among both sexes.

Of students who were continuing their studies for a sixth year, 78% had either undertaken part-time rather than full-time studies for at least one year or had been absent for the fall semester in at least one year. Among those who had graduated, the opposite was the case: 75% had attended full-time studies in every year and not taken any years off.[36]

Among students who started a STEM program in 2010, over one-third (36%) of women had completed their STEM degree by the end of the fourth year, compared with 25% of men (Chart 4). After five years, 58% of women and 54% of men who started out in STEM had graduated; 9% of women and 18% of men were continuing their STEM degree, while the remainder had switched to BHASE fields or had left undergraduate studies.

Women consistently graduated from STEM programs more rapidly than men, regardless of their field of study. However, this pattern was most prominent in engineering and computer and information sciences — the two fields where women were least represented — and in biological sciences, the field where women's representation was highest. For example, 27% of women and 16% of men who started out in computer and information sciences completed a STEM degree within four years; 52% of women and 42% of men completed one within five years, while 13% of women and 22% of men continued their studies for a sixth year.

In all cases where men's persistence in STEM was higher than that of women, it was mostly because men were more likely than women to continue in their STEM studies for a sixth year. Continuing for a sixth year was most common for men in engineering or computer and information sciences, where 22% did so.

Students who switched fields of study were more likely to take over five years to complete their degree

It is also possible to examine graduation rates across different types of educational pathways. For example, among those who persisted in their initial STEM field of study, 90% of women and 79% of men graduated within five years, while the remainder continued their studies for a sixth year (Table 3).

The proportion who graduated within five years was lower for those who switched from one STEM field to another, and still lower for those who switched from STEM to BHASE, or from BHASE to STEM. Among women who switched from STEM to BHASE, one-third were still continuing their studies for a sixth year, while one-tenth of women who persisted in their initial STEM or BHASE field were doing so.

This highlights the reality that there is typically a cost associated with switching fields of study, as it lengthens the time needed to graduate.

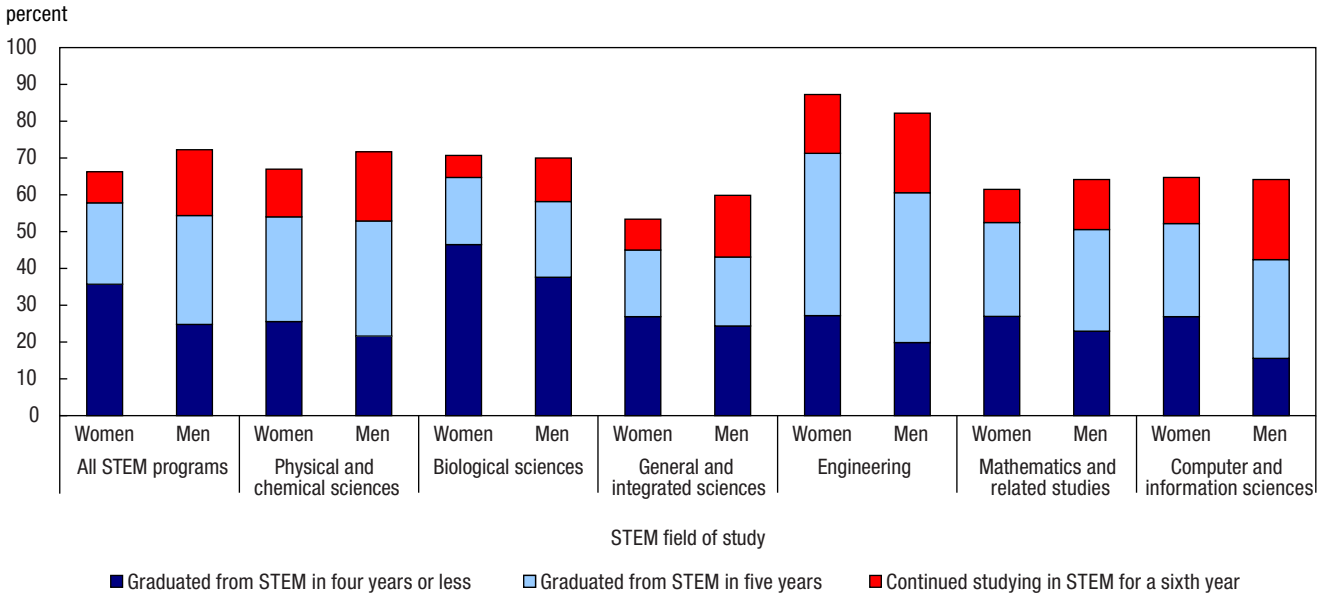
Notably, women in every pathway were more likely than men to graduate within five years. This supports the overall trend of women completing their degrees more rapidly than men.

Table 3
Proportion of undergraduate degree students who graduated within five years, by educational pathway, 2010 cohort

	Graduated within five years		Continued studies for a sixth year	
	Women	Men	Women	Men
Educational pathway	percent			
Persisted in initial STEM field	89.6	78.7	10.4	21.3
Switched between STEM fields	82.4	65.5	17.6	34.5
Switched from STEM to BHASE	66.4	54.4	33.6	45.6
Switched from BHASE to STEM	75.3	59.7	24.7	40.3
Switched between BHASE fields	75.7	69.1	24.3	30.9
Persisted in initial BHASE field	89.5	81.9	10.5	18.1

Source: Statistics Canada, Postsecondary Student Information System (PSIS), longitudinal data, 2010/11 to 2015/16.

Chart 4
Persistence in STEM by sex, selected STEM fields of study and time to graduation, 2010 cohort



Source: Statistics Canada, Postsecondary Student Information System (PSIS), longitudinal data, 2010/11 to 2015/16.

Conclusion

This study is the first to examine the persistence and representation of women in STEM over the course of an undergraduate degree in Canada. Understanding the educational trajectory of women in STEM fields allows for the identification of the points in women's education where they are most likely to leave STEM. Breaking down the analysis by STEM field of study identifies the STEM fields women are least likely to persist in, as well as the fields with the largest gender gap in persistence. This allows policies addressing women's underrepresentation in STEM to be targeted more effectively.

The study finds that, among students who started their undergraduate degree at the age of 19 or under, women's representation in STEM remained essentially stable over the course of an undergraduate degree, mainly because those leaving for BHASE programs were replaced by those who switched from BHASE to STEM programs. Thus, women's lower representation in STEM programs is largely because of lower enrolments in STEM programs at the start of their postsecondary education.

Moreover, women in each STEM field of study were equally or more likely than men to persist in their initial field of study, and completed their STEM undergraduate degrees more rapidly than men.

Women who switched to BHASE typically chose fields related to their initial STEM field. Those studying biological sciences or general and integrated sciences often switched to registered nursing, pharmacy or psychology, while those studying mathematics and related studies mainly switched to business and administration, including accounting and finance. This indicates that women who leave STEM generally continue to pursue their scientific or mathematical interests.

Future articles on the causes of women's underrepresentation in STEM in Canada could focus on the transition between high school and postsecondary studies, and the transition from postsecondary education to the labour market. For example, they could examine the reasons for women's and men's choices of major during their first year of postsecondary studies, particularly among those with strong math and science skills, since previous research has found that women with high math skills are less likely to choose a STEM major than men with lower math skills.[37] They could also investigate the reasons why women with STEM degrees are less likely to work in science and technology occupations than men with the same degrees, a trend that is particularly pronounced in computer and information sciences.[38]

The Education and Labour Market Longitudinal Platform (ELMLP) has great potential for informing future research on other factors relating to persistence in STEM over the course of a postsecondary program. As more years of data are added to ELMLP, they can be used to investigate the outcomes of different educational pathways; for example, by comparing the income trajectory of students who persist in STEM to that of students who switch to BHASE.

Katherine Wall *is a researcher with the Centre for Education Statistics at Statistics Canada.*

Data sources, methods and definitions

Data sources

The primary data source for this article is the Postsecondary Student Information System (PSIS), with its data connected longitudinally using the Educational and Labour Market Longitudinal Platform (ELMLP). This provides longitudinal data on students at Canadian public college and universities from 2009 onwards; data from certain institutions and provinces are available for earlier years.

Target populations

The target population for the bulk of the paper is students (including both Canadian and international students) who began full-time undergraduate degree studies at a Canadian public college or university in 2010, and who were aged 19 and under in 2010. It includes students even if they changed to part-time studies in later years. It excludes students who started their studies at imputed institutions (i.e., institutions that did not report their data to PSIS) and students who enrolled in multiple undergraduate degree programs in their first year; each of these groups made up less than 1% of first-year undergraduate students in 2010.

The age restriction is necessary to accurately determine when the students started their program: one previous year of data is necessary to determine when students aged 19 and under started their program, but two previous years of data are needed for students aged 20 and over. Reliable PSIS data for all provinces are only available from 2009 onwards.

When a 2011 cohort is used and students of all ages are included, women's representation in STEM is lower (40%), but the trends relating to persistence in STEM, the stability of women's representation in STEM over the course of a degree, and graduation from STEM remain the same.

In Quebec, obtaining an undergraduate degree involves a two-year general program at a CEGEP (collège d'enseignement général et professionnel), followed by a three-year undergraduate program. The Quebec students included in the study are those who began their three-year undergraduate program in 2010; therefore, the data on persistence do not account for students who began CEGEP programs in STEM and left STEM before starting their undergraduate program.

The analysis of master's degree holders uses the following three different cohorts, with no age restrictions. In each cohort, only master's degree students who studied full time in their first year are included:

- those who completed an undergraduate degree in 2010 and began a master's degree during the 2011-to-2015 period, to examine persistence in STEM between the undergraduate and master's levels;
- all those who began a master's degree during the 2011-to-2015 period, to examine women's total representation among STEM master's degree students;
- those who began a master's degree in 2011, to examine four-year graduation rates from master's degree programs.

Methodology

The article uses a gender-based longitudinal analysis to examine the persistence and representation of women and men in STEM fields of study over the course of an undergraduate degree.

The article considers students who began their undergraduate degree studies in 2010 to have persisted in STEM if they were still enrolled in a STEM program in either 2014 or 2015. Likewise, it considers them to have persisted in their original field of study if they were still enrolled in that field in either 2014 or 2015. Because it has become relatively common for students to take a year off from their studies, a single year of absence from studies is insufficient to demonstrate that the student has not persisted. Similarly, students with other non-traditional attendance patterns (e.g., taking two years off and then returning to their degree) are not considered as having left undergraduate studies as long as they attended their undergraduate program in 2014 or 2015.

Definitions

STEM: Science, technology, engineering, and mathematics and computer science fields of study.

BHASE: Non-STEM field of study, including but not limited to business, health, humanities, arts, social sciences and education.

Persistence: Persistence is defined as remaining in the same program over the course of one's undergraduate degree studies. Programs may be discussed at different levels of detail. For example, "persisting in STEM" refers to whether the student remains in any STEM program, regardless of whether they changed from one STEM field to another, whereas "persisting in one's initial STEM field" means that they did not change their specific STEM field of study.

Persistence rate: The percentage of first-year enrollees in a given program who remained in that program as of the most recent year of analysis.

Graduation rate: Graduation rates are given as the proportion of students who had graduated by a certain year of study (e.g., the four-year graduation rate is the proportion of students who had graduated by the end of their fourth year of study). This should not be confused with the total proportion of students who may have completed their degree in later years.

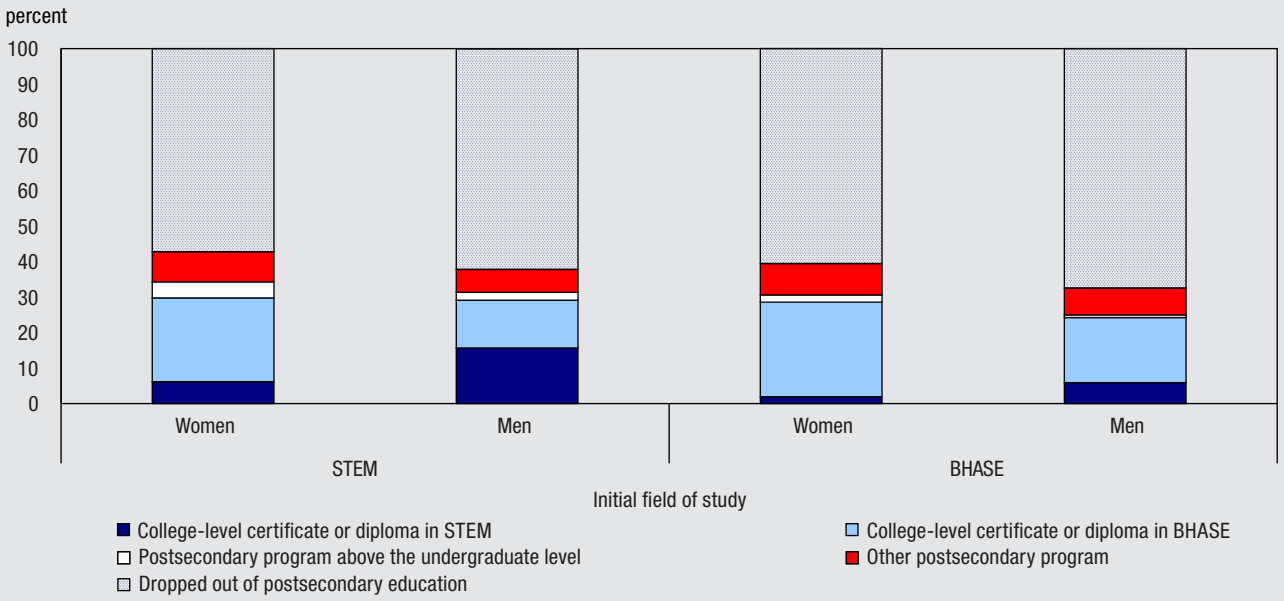
What happened to women and men who left undergraduate degree studies?

Not everyone who left undergraduate degree studies ceased their postsecondary education. As of 2014 and 2015, nearly 4 in 10 leavers were enrolled in or had graduated from some other form of postsecondary education. The most common type was a college-level certificate or diploma, chosen by about 3 in 10 women and men who left STEM undergraduate degree studies (Chart 5). Close to 5% of women who left STEM undergraduate degree studies entered a postsecondary program above the undergraduate level, almost all in pharmacy or medicine.

Most women (87%) who left STEM undergraduate degrees for college-level programs had been studying science (biological sciences, general and integrated sciences or physical and chemical sciences) at the undergraduate level, and 78% did their college-level program in a BHASE field, often in health care.

In comparison, about one-half of men who left STEM undergraduate programs for college-level programs had been studying science, while most of the other half had been studying engineering or computer and information sciences. Men who left undergraduate STEM programs for college-level programs were more likely than women to stay in STEM: the majority (54%) entered STEM programs, with many studying engineering technology or computer and information sciences.

Chart 5
Educational pathways of women and men who left undergraduate degree studies, by initial undergraduate field of study, 2010 cohort



Source: Statistics Canada, Postsecondary Student Information System (PSIS), longitudinal data, 2010/11 to 2015/16.

Persistence and representation of women who are pursuing a master's degree in STEM

Another area of women's educational pathways that that can affect their representation in STEM is the transition from a bachelor's degree to a master's degree. The ELMLP data indicate that, among Canadian citizens and permanent residents, women and men are similarly likely pursue a STEM master's degree. Out of women who completed a STEM bachelor's degree in 2010, 13% started a STEM master's degree during the 2011-to-2015 period, compared with 14% of men. Women with a STEM undergraduate degree were also more than twice as likely to pursue a master's degree in BHASE (9%) as men (4%); over one-half of the women who did so followed a bachelor's in biological sciences with a master's in a health care field, mainly occupational therapy or physical therapy.

Furthermore, women made up 42% of all Canadian citizens and permanent residents pursing a STEM master's degree during the 2011-to-15 period (irrespective of when they graduated with their bachelor's degree). This is similar to women's 44% share of first-year bachelor's degree students in STEM and their 43% share of sixth-year students and graduates with STEM bachelor's degrees. Women's representation among international students pursuing a master's degree in STEM was lower (32%).

In engineering and computer and information sciences, women's representation was higher among master's degree students than among bachelor's degree students. Women made up nearly one-quarter (24%) of engineering students and one-third (33%) of computer and information sciences students at the master's level.

Women and men were about equally likely to complete their STEM master's degree within four years. Over three-quarters (77%) of both sexes did so, while 5% continued their studies for a fifth year and 18% left their studies without completing a master's degree. The four-year graduation rates from BHASE master's degrees were higher, at 85% for women and 82% for men.

Women's four-year graduation rates were similar to or higher than those of men in all STEM fields except for general and integrated sciences, which is an uncommon field at the master's level.[39] In biological sciences, 72% of women completed their master's degree within four years, compared with 65% of men. In computer and information sciences, 86% of women and 81% of men completed their degree within four years.

The proportion of students who left their studies without completing a master's degree was higher in biological sciences and physical and chemical sciences than in other STEM fields or in BHASE. In biological sciences, over one-fifth of students (23% of women and 29% of men) left their studies without completing their degree, while in physical and chemical sciences 26% of women and 28% of men did so.[40]

Notes

1. See tables 98-400-X2016251 and 98-400-X2016257, Census of Population 2016, Statistics Canada. "Science and technology workers" refers to people with occupations in broad category 2 (Natural and applied sciences and related occupations) of the National Occupational Classification (NOC) 2016.
2. In 2015, women in science and technology occupations that generally required a university degree (NOC major group 21) had average earnings of $69,000, higher than those in any other professional occupational category except for non-nursing health professions (major group 31). Women in science and technology occupations that generally required a college diploma (major group 22) had average earnings of $50,000, higher than those of women in most other college-level occupations. See table 98-400-X2016281, Census of Population 2016, Statistics Canada.
3. According to data from the Labour Force Survey, the number of people working in science and technology occupations (NOC broad category 2) rose by 116% from 1990 to 2018, a larger increase than for any other broad occupational grouping (see table 14-10-0297-01).
4. See Phillips (2014).
5. See table 98-400-X20216281, Census of Population 2016, Statistics Canada.
6. Nearly three-quarters (72%) of people in science and technology occupations work in engineering or computer and information systems (NOC minor groups 213, 214, 217, 223, 224 and 228). Women comprise 18% of workers in these occupations, compared with 33% of workers in other science and technology occupations (see table 98-400-X2016271, Census of Population 2016, Statistics Canada). Also see Dionne-Simard et al. (2016).
7. These results are from a custom table based on the Census of Population 2016.
8. See Statistics Canada (2017a).
9. See Seymour and Hewitt (1997); Huang et al (2000); Burke and Mattis (2007); Ost (2010); Williams and George-Jackson (2014); Dasgupta and Stout (2014).
10. See Lips (2004).
11. "Science and technology occupations" refers to NOC broad category 2 (Natural and applied sciences and related occupations).

12. See Statistics Canada (2017b).
13. See Griffith (2010); Brainard and Carlin (1998); George-Jackson (2014); Ellis et al. (2016); Huang et al (2000).
14. See Sithole et al. (2017); Burke and Mattis (2007); Simon et al. (2015).
15. See Huang et al. (2000); Chen (2009).
16. See Seymour and Hewitt (1997); Blickenstaff (2005); Dasgupta and Stout (2014); Shapiro and Sax (2011).
17. See Brainard and Carlin (1998); Blickenstaff (2005); Shapiro and Sax (2011); Seymour and Hewitt (1997); Ellis et al (2016).
18. See Ayre et al (2013); Simon et al (2015).
19. Previous articles found that nearly three-quarters of students who started university had graduated from a program (either university or college) five years later (Finnie et al., 2014). They also found that overall rates of persistence in postsecondary education were higher than institution-specific or program-specific rates, since many students switch between fields of study, institutions, or levels of education. See Finnie et al. (2012).
20. Articles on women's persistence in STEM in Canada have looked at their persistence in STEM between high school and CEGEP in Quebec (Simon et al., 2015) and at the proportion of young women with STEM degrees who work in science and technology occupations (Statistics Canada, 2017b). Other research focusing on Quebec (Ntwari, 2018) has shown that women who initially enroll in STEM undergraduate programs are less likely than men to persist in and complete these programs, which contrasts with the lower persistence of men in undergraduate programs overall.
21. See the Data sources, methods and definitions section for an explanation of why the target population is restricted to those aged 19 and under.
22. While the students are tracked over a six-year period, data on graduation are obtained from the PSIS record for the year after the student graduated. Therefore, graduation rates can only be provided for the fifth year at the latest. Transfers between institutions (e.g., from an undergraduate program at one institution to the same program at another institution) are not examined and do not affect persistence.
23. When students of all ages are included and a 2011 cohort is used, the share of first-year STEM undergraduate students who are women is 40%.
24. A report on PSIS data in The Daily stated that women comprised 39% of enrolments in programs leading to a STEM degree (Statistics Canada 2017a), which differs from the Table 1 statistic: PSIS includes students at all stages of their degree rather than only first-year enrolments; includes those who started out as part-time students and those over the age of 19; and covers all STEM degrees rather than only undergraduate degrees.
25. This refers only to the subfields of psychology that are included in BHASE. Some other psychology subfields are included in STEM, and students who switched to these subfields would still be persisting in STEM.
26. 'College-level certificate or diploma' refers to a career, technical or professional training certificate or diploma in the Classification of programs and credentials. All references to these programs include only people who had graduated from or were still enrolled in such a program as of 2014 or 2015. Students who left undergraduate degree studies for a college-level program and then dropped out of the college-level program are not included in the figure.
27. See Finnie et al. (2014).
28. See Dasgupta and Stout (2014).
29. See Statistics Canada (2017b and 2017c).
30. Over 90% of students in general and integrated sciences have a general sciences major (categorized as 30.01 Biological and physical sciences in the Classification of Instructional Programs).
31. In some schools, science students are required to begin with a general science major in their first year, while entry into specific science majors in later years is restricted based on academic achievement. However, these schools tended to have a higher STEM persistence rate than other schools for students who began in general and integrated sciences. This is consistent with the explanation that low persistence is related to lack of commitment to a specific STEM field, since a general sciences major would only be indicative of lower commitment in schools where starting with a more specific science major was an option.
32. See George-Jackson (2014).
33. This refers only to the subfields of psychology that are included in BHASE. Some other psychology subfields are included in biological sciences, and students who switched to these subfields would still be persisting in STEM.
34. See Statistics Canada (2017b and 2017c); Wall et al. (2018).
35. See Zarifa et al. (2018).

36. Men were more likely than women to study part time or take a year off. However, even among students who studied full time in every year and did not take any years off, women were more likely than men to have graduated within five years.
37. See Hango (2013).
38. See Statistics Canada (2017b).
39. General and integrated sciences accounted for 308 master's degree students out of a total of 10,730 STEM master's degree students.
40. It is worth noting that since ELMLP does not cover non-Canadian institutions, it is possible that some students who appear to have left their studies without completing a degree may have moved to American or other non-Canadian institutions mid-way through their master's degree.

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