SN Soc Sci (2021) 1:253
https://doi.org/10.1007/s43545-021-00261-z

ORIGINAL PAPER

Social, economic, personal, family, and institutional influences on engineering students' choice of degree program

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Received: 20 June 2020 / Accepted: 13 September 2021 / Published online: 13 October 2021

Abstract

For this study, set in the Newfoundland Labrador context, we surveyed 151 undergraduate engineering students on demographic, social, economic, family, school-based, and personal influences relating to their decision to pursue an undergraduate engineering degree. Following Bourdieuan theoretical framework, we offer qualitative analysis of quantitative survey data. Findings show that students who pursue engineering as a field of study are primarily males, from high-income, well-educated families, and whose educational expenses are underwritten by parents or other family members. Students from lower-income families and female students were substantially underrepresented in our sample. Respondent decisions were mainly influenced by personal factors (e.g., aptitude, personal desire to work in the field), earnings potential, social value/status of engineering as an occupation, academic focus/success in STEM subjects, parental pressure to be academically competitive, and parental advice/encouragement. We argue that there is a pressing need to increase opportunities to make engineering and applied science degree programs more accessible for underrepresented groups. At the policy level, efforts should be focused on providing targeted financial support (scholarships, awards, living allowances, and other incentives) for students from low-income families and young women, coupled with improving career counseling capacity and authentic STEM experiences in schools. We also identify several areas for further research.

Keywords STEM education · Engineering education · Post-secondary decision-making · Education

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Introduction

In today's complex and uncertain global economy, Canada's capacity in STEM (science, technology, engineering, and mathematics)-related fields is considered to be a fundamental driver of economic competitiveness and productivity (Dodge et al. 2015). Although the career potential of studying in a STEM-related area is well recognized, relatively few Canadian students are inclined towards an occupation in STEM fields (Orpwood et al. 2012). In a 2014 survey of over 800 Canadian students, more than two-thirds thought that science was fun, and that STEM education offered a range of career options, however, only one in five expressed interests in pursuing science after high school, and only one in ten said they were extremely interested in a science-related occupation (AMGEN-Let's Talk Science 2014). Canada spends a higher percentage of its GDP on post-secondary education than the OECD average, but lags behind many other countries in the proportion of STEM degrees earned by graduates (Statistics Canada 2014; Conference Board of Canada 2014). Among OECD countries, Canada was given an overall D grade for the percentage of engineering graduates produced, with six provinces graded at a D-level. Nova Scotia and Newfoundland and Labrador were the top two performing provinces in the country with C grades (Conference Board of Canada 2014). Notwithstanding the establishment of government programs and initiatives to attract Canadians to STEM-related fields (Government of Canada 2018a; b), the overall number of graduates from undergraduate and advanced research programs in STEM-related programs has been declining (Conference Board of Canada 2014).

Although some observers have expressed concerns over the direction of these changes, smaller numbers of science and engineering graduates have not translated into a skilled labor shortage in Canada, since more than half of Canadian STEM-related degrees are held by immigrants (Dodge et al. 2015; Ferguson and Zhao 2013; Conference Board of Canada 2014). A major concern for government policymakers is to reshape the labor force to try and keep pace with countries such as India and China, which are producing STEM graduates at an ever-increasing rate. India and China are examples of two countries that give significant importance to STEM education, providing enough labor force capacity in STEM fields to serve both domestic and global demand. The Organization for Economic Cooperation and Development (OECD) estimates that these two countries alone could contribute more than 60% of the G20 workforce with STEM credentials by 2030 (OECD 2015).

Reasons for the relatively low numbers of Canadian science and engineering graduates, particularly female graduates, in comparison to countries such as China and India are speculative. From an achievement perspective, both male and female Canadian students appear to be well prepared to enter STEM-related diploma and degree programs. Canada is among the highest performing countries on international tests, with Canadian 15-year-old students achieving well above the OECD average on the Program for International Student Assessment (PISA) in mathematics and science (Council of Ministers of Education Canada 2019).

Other factors that may influence the decision to pursue a STEM career may relate to differences in national cultural traditions related to science and math (Cogan and Schmidt 2002; Fang et al. 2013; Stevenson and Stigler 1992), family and school emphasis on the value of mathematics and science education (Fuchs and Wößmann 2007; Sousa et al. 2012; Tsui 2005), differences in curriculum and pedagogy (National Center for Educational Statistics 2020; Orpwood et al. 2012), education system structure, and national labor market conditions (Langen and Dekkers 2005).

Several studies have investigated how students make decisions to pursue higher education generally (Eidimtas and Juceviciene 2014; Hansen and Litten 1982; Hossler and Gallagher 1987; Jackson 1982; Kotler and Keller 2009; Schiffman and Kanuk 2007); however, Canadian research focusing on decision-making patterns specific to the STEM-related fields is scarce. A number of studies has investigated academic decision-making in higher education, but there is very limited research on student choice to study engineering and applied science in the Canadian context. A recent systematic review of the literature on STEM education concluded that the current literature is strong on the social determinants of participation in general education, but weak on the social determinants of participation in STEM education (Xie et al. 2015) For example, the reasons students make decisions to pursue degrees in engineering and the sciences may well be different than the reasons people decide to study in other fields (Xie 1989; Xie and Shauman 2003; Xie and Killewald 2012). Therefore, it is worthwhile to study the factors that influence students' decision to pursue post-secondary education in STEM areas (Xie et al. 2015). Moving forward, they argue, there is a need for research to help identify contextual, institutional, familial, and individual factors that promote students' engagement with and achievement in STEM education. This includes understanding more about the factors and influences that propel students into STEM careers.

Engineers Canada acknowledged the need to learn more about the reasons why students choose to study in the field of engineering, and recently began to survey engineering students (Engineers Canada 2015, 2016, 2017). Data from the 2017 survey show that about two-thirds of respondents reported that their main reason for choosing to pursue an engineering degree was their own interest in the subject or their interest in applied science and mathematics. Other prominent reasons cited included financial/job security, the challenge of the engineering profession and the prospect of positively influencing the world/community. About a quarter of those surveyed reported family as the main influencing factor to pursue engineering degree. Although these data are useful in terms of providing a macro-level overview of motivating factors, beyond the major categories reported (e.g., job security, financial security, family influence, etc.), there are no sub-categories reported. Moreover, there are no institutional (high school) factors referenced in the Engineering Canada reports and the available demographic information does not address key financial and family-related indicators, such as family income levels, source of educational funding, parent education levels, and family size.

The purpose of this qualitative research is to investigate factors that influence students' choice of pursuing an undergraduate degree in engineering. Specifically, the research is guided by the following questions:

1. How do engineering students in Canada perceive the influence of certain family, high school, personal, social, and economic factors on their decision to pursue a degree in engineering?
2. What factors enable Canadian students to pursue a degree in engineering and what are the barriers to pursuing a degree in this field?

Literature review

In this section, we review the research literature relating to the factors that influence the transition to university study, with specific reference to engineering and STEM-based programs. We also address literature specific to the underrepresentation of women in engineering programs and the engineering profession, generally. While research that directly addresses the factors influencing student's choice to pursue a degree in engineering (and especially in the Canadian context) is more limited, decision-making in higher education, generally, has been studied by social science researchers for decades (e.g., Eidimtas and Juceviciene 2014; Hanson and Litten 1982; Hossler and Gallaghar 1987; Jackson 1982; Kotler and Keller 2009; Schiffman and Kanuk 2007).

The factors affecting students' choice of post-secondary programs are wide-ranging and varied, including personal determinants such as academic success, personal interest, and career aspirations (Cattaneo et al. 2017; Heathcote et al. 2020; Moote et al. 2020); school-related factors, (Greene et al. 2004; McKenzie and Schweitzer 2010; Moogan and Baron 2003; Nathan et al. 2010); economic and occupational factors (Balloo et al. 2017; Hazelkorn 2014; Moogan et al. 1999; Pitt and Zhu 2019); social and cultural factors (Boudon 1974; Bourdieu 1986; Bourdieu and Passeron 1990; Bowles and Gintis 1976; Cheung 2007; Wentzel and Caldwell 1997; Wentzel et al. 2004); proximity of programs/post-institution to home (Frenette 2004); and family-related factors (Bers and Galowich 2002; De Broucker and Lavallée 1998; Finnie et al. 2004; Henderson-King and Smith 2006). A number of studies have also examined and posited various theories to explain women's systemic underrepresentation in engineering and other STEM-related pro-secondary programs (Barone and Assirelli 2020; Blickenstaff 2005; Cattaneo et al. 2017; Kamphorst et al. 2015; Moote et al. 2020; Rohde et al. 2020; Vrcelj and Krishnan 2008).

Personal determinants

Multiple personal factors bear on the decision to pursue higher education and particularly the decision to study engineering. Several studies have tagged academic performance in school as a key factor in determining educational aspirations (Bishop 1977; Cheung 2007; Hossler et al. 1999; Jackson 1978; Sharp et al. 1996; Tuttle 1981). In one large-scale US study, Nicholls et al. (2010) used longitudinal demographic, attitudinal, experiential, and academic performance data covering a 12-year period to model the probability that eighth graders would go on to earn a STEM degree. The model showed that students who are academically strong by eighth grade are already well prepared for future university-level STEM degree programs. Similarly, students who are struggling in mathematics by the eighth grade are less likely to be able to keep up with math courses taken by STEM-learning high school students. The most valuable predictors of STEM degree attainment were found to be mathematics, science, and reading ability; variables that indicate academic commitment; and variables that measure family support for academic achievement. This is consistent with earlier research indicating that students who show high levels of academic performance tend to be encouraged, through tangible and intangible means, to pursue higher education (McDonough 1997; Weis 1990). Another related theory—self-efficacy theory—refers to an individual's confidence or belief in their capacity to executive the behaviors necessary to achieve certain tasks (Bandura 1977). As Betz and Luzzo (1996) note, low self-efficacy leads to avoidance of behaviors, while high self-efficacy leads individuals towards certain behaviors. When applied to educational decision-making, high self-efficacy in school would be expected to lead students towards additional learning, for example, in the form of post-secondary study. Correspondingly high self-efficacy in STEM subjects might be expected to propel students into university programs in STEM fields.

Educational aspirations are also mediated by personal interest (Holmegaard 2015; Vulperhorst and Rijst 2020) and academic self-confidence and peer influences (Cheung 2007; Falsey and Heyns 1984; Russell 1980; Wentzel et al. 2004). Choices about future educational and careers choices begin to be formed as early as the end of primary school and continue during secondary and tertiary education as students think about who they want to become, based on their interests (Sharp and Coatsworth 2012). Social interactions and friendships are also positively associated with higher academic outcomes, and students without friends tend to show lower academic outcomes (Wentzel and Caldwell 1997; Wentzel et al. 2004). Students tend to be positively influenced by social interaction with other students who, themselves, have plans to attend college (Falsey and Heyns 1984; Russell 1980; Tillery 1973). Correspondingly, negative peer influences have been shown to negatively affect post-secondary educational aspirations (Cheung 2007).

Moote et al. (2020) examined aspirations of schoolchildren with respect to careers in science and engineering and found gender to be the main factor relating to the desire to pursue an engineering degree. Based on data from more than 20,000 English students, the authors reported that the desire to study engineering was evident in boys from age 10. Ohland et al. (2008) studied several indicators of student engagement in engineering programs using data from US institutions and also reported a dearth of female engineering students.

School-based determinants

The decision to pursue to higher education is also influenced by school-related elements such as career counseling, instructional focus, co-curricular involvement, and teacher beliefs (Hossler et al. 1999; Moogan and Baron 2003). According to Greene et al. (2004), teachers play an important role in motivating students to prepare for post-secondary entry. Students are inclined towards pursuing educational paths that are deemed to be desirable by their teachers and counselors (Human Resources and Skills Development Canada 2004). McDonough (1994, 1997) argues that teachers and counselors have a strong influence on student decisions about post-secondary institutions with the strongest effects being seen in private schools, reportedly due to lower student-to-counselor and student-to-teacher ratios. Some researchers, however, have criticized the role of high school guidance counselors in preparing high school students for the transition into post-secondary education, suggesting a weak relationship between students' educational aspirations and their interaction with teachers or counselors (Boyer 1987; Hossler et al. 1999). Cruz and Kellem (2018) compared the experiences of post-secondary engineering students most of whom had transferred into engineering from another degree program. Students were found to be very limited in what they knew about engineering education or what is involved in the study of engineering as a professional field. The authors concluded that prospective students need to be better positioned to decide what aspects of engineering are appropriate for them, and would benefit from interactions with advisors, teachers, and peers in the field. A stronger understanding of the college decision-making process and better understanding of college options have been suggested as ways guidance counselors can provide improved and effective services to high school students and their families (Hossler et al. 1999; Orfield and Paul 1994).

Other research focuses on instructional aspects of schooling. Munro and Elsom (2000) argue that high school students are expected to make crucial subject area choices at the time when they are losing interest in science subjects. School-level interventions such as high-quality instruction and science classroom experiences providing enriched school-based educational activities and offering career education and guidance were suggested as having positive effects on sustaining interest in STEM subjects. Brophy et al. (2008) present several instructional models for teaching engineering in K-12 classrooms as examples of how engineering can be integrated into the curriculum. While the introduction of engineering education into K-12 classrooms presents a number of opportunities for STEM learning, it also raises issues regarding teacher knowledge and professional development, and institutional challenges such as curricular standards and high-stakes assessments. Fantz et al. (2011) investigated the long-term effectiveness of secondary-level programs—pre-engineering classes, multi-day programs, engineering hobbies, working in an engineering environment, extra-curricular engineering programs, and single-day field trips—on the self-efficacy of students choosing to pursue engineering studies. Significant differences were found in the self-efficacy of first-year engineering students who had participated in pre-engineering classes and engineering hobbies in relation to those who did not have these experiences.

This work is consistent with evidence that participation in co-curricular activities during high school increases the likelihood of pursuing higher education (Hossler and Stage 1992; Stage and Hossler 1989). In one recent study, Martin and Betser (2020) involved students in maker space (design and build) projects and found that this was effective means of stimulating student interest and skill in engineering design. The authors show that maker spaces can serve as a context for discourse around engineering education "including explorative imitation of engineering discourse routines within hands-on learning environments" (p.

194). The study also concluded that engaging professional engineers as mentors in such settings can play an important role in youth learning. Similarly, Sheppard and Anderson (2016) noted that that schools could improve students' awareness of STEM career options by highlighting the work of those in STEM-based careers and their contribution to society and refocus "on [the] depth [of] math, science, and computer literacy in senior years to address the lack of preparation for technical fields like engineering" (p. 42). To increase the proportion of STEM degrees, Nicholls et al. (2010) recommended a three-pronged approach: (1) improve the educational preparation of elementary students, especially in the core areas; (2) engage students in scientific and quantitative fields of study so that they are on the appropriate trajectory for STEM careers and engage in post-entry retention programs to increase persistence and prevent STEM degree candidates from migrating to other degree programs.

Several school-based factors have been associated with gender disparity in the engineering profession, including girls' lack of academic preparation for a science degree; gender biased science curricula and pedagogy; girl's negative experiences with science; and an unwelcoming climate for girls/women in science classes. Barone and Assirelli (2020) reported that the systemic gender segregation observed in higher education, whereby women are overrepresented in social sciences and the humanities, is substantially explained by choice of curricular track, at the secondary level. Preference for particular school subjects was found to mediate two-thirds of the gender difference in access to the humanities and social sciences and one-third of the gender difference in access to engineering and ICT program.

Working in the US context, Gottfried and Plasman (2018) showed an engineering education gender gap in high school and pointed to the need for many more girls to complete engineering career and technical education programs. They also observed a clear difference across genders; women who completed high school-level engineering career and technical education showed greater benefits than men, in terms of completion of an engineering degree**.** In a later study, Naukkarinem and Bairoh (2020) analyzed gender differences among more than 9000 applicants to Finnish science and engineering undergraduate degree programs and concluded that efforts to encourage more women to enter the engineering profession must also include engineering career and technical education coursework in high school.

The orientation towards engineering as a gendered career option is evident as early as kindergarten. Capobianco et al. (2011) investigated elementary students' conceptions of engineers and found that Grade 1–5 students assigned gender stereotypes to their drawings and working conceptions of engineers. In another study, Aguirre-Muñoz and Pantoya (2016) studied teacher interventions through engineering-centered learning resources and pedagogy as a means to enhance female kindergarten students' engagement with engineering content and participation in discussion. Taken together, engineering-centered literature and academic conversations were found to be effective in broadening meaningful participation in engineering-related education.

Economic and occupational determinants

Science and engineering-based occupations are considered to be high-status careers that reward participants with both higher incomes and elevated social standing (Rothwell 2013; Xie and Killewald 2012). Income levels for those working in science-based industries remain high and graduates who are transitioning into the labor market with a degree in science or engineering typically command higher starting salaries (Rothwell 2013). In a large-scale study of elementary and secondary schoolchildren, Moote et al. (2020, p. 45) found that compared with their peers, students who aspired to become engineers were "more likely to be motivated to earn a lot of money, to make a difference in the world and to create things."

Degrees in STEM fields, in particular, have also been associated with social mobility, whereby socially underprivileged individuals can improve their socioeconomic standing, as measured by objective criteria (Xie 1989; Xie and Killewald 2012). In terms of social status, Gibson and Hutton (2017) recently surveyed Canadians about their impressions of the engineering profession and found that 82% hold a favorable impression of the engineering profession, 83% trust the engineering profession, and 85% respect the engineering profession across Canada.

Cattaneo et al. (2017) examined the university choices of Italian students over a nine-year period (2003–2012) and found gender differences associated with labor market conditions. In the post-financial crisis period (2009–2012), when labor markets were more constrained and competitive, male students were found to be more career-oriented in their university choices, focusing more on future employability prospects. By contrast, female students made decisions that emphasized the educational experience rather than credentialing and preparation for a competitive job market. The authors draw on human capital theory, signaling theory, and preference theory to argue that the urgency of acquiring credentials to be successful in a competitive labor market is more salient for males, who assume a traditional career-centered family role. Females are thought to be more adaptive in adjusting their lifestyles, which potentially places them at a disadvantage in the labor market and in society, generally.

Other research highlights access to the job market as a barrier to female engineers. Vrcelj and Krishnan (2008) working in the Australian context surveyed undergraduate and postgraduate students to identify obstacles and supports for female students in a civil engineering degree program. Female students identified access to the job market as a barrier. They also identified a need for more female academics in engineering, guest lectures from prominent engineers, greater promotion of the successes of female engineers.

Social and cultural determinants

Other research on higher education and occupational outcomes has centered on social and cultural constructs, such as prevailing beliefs, socioeconomic advantages, cultural background, and gender. Nathan et al. (2010) investigated the extent to which teachers' beliefs and expectations about engineering influenced student advising. Although teachers reported that students' socioeconomic status was not influential, when asked explicitly, using fictional student advising scenarios their beliefs were shown to influence situated decision-making tasks. Rohde et al. (2020) used a longitudinal interview methodology to examine the perspectives of 20 students about becoming an engineer and found that participants' descriptions of who can 'do' engineering were at once both open and exclusionary. Impressions of the culture of engineering were seen to be consistent with the values and practices of models—faculty and practicing engineers—indicating that existing cultural values are upheld and reified by undergraduate engineering students.

There is a wealth of literature that situates higher education as a mechanism through which social and economic advantages or disadvantages are transmitted across generations (Blau and Duncan 1967; Bourdieu 1986; Bourdieu and Passeron 1990; Giroux 1994; Raftery and Hout 1993; Sewell et al. 1969). The dominant discourse considers education as an investment in human capital and directly related to future income, prosperity, social status, and life expectancy (Card 1999; Becker 1975; Kaplan et al. 2014; Mincer 1974). However, social- and culturally based perspectives reject rational theories (e.g., human capital theory) because they do not adequately explain career decisions and accessibility to post-secondary participation (Briggs and Wilson 2007; Cattaneo et al. 2017; Heathcote et al. 2020), which are often ambiguous and subject to personal and family influences, beliefs, historical allegiances and social, cultural. and economic factors (Bourdieu and Passeron 1990; Hart 2012, 2019; Krahn and Barron 2016). According to Cattaneo et al. (2017, p. 779), the complexity of the process of post-secondary choice "requires analyses that adopt a holistic approach that can encompass all of the factors and that recognise that decision-making is often affected by … cultural dictates." Cultural customs, family background, and social class are all examples of factors that influence the schooling experience and its resultant educational attainment (Boudon 1974; Bowles and Gintis 1976; Brand and Xie 2010; Xie et al. 2015).

Bourdieu (1986) theorized that the educated classes are able to accumulate and transfer cultural capital to their children, thereby bestowing competitive advantages in various direct and indirect ways (Bourdieu 1986; Bourdieu and Passeron 1990; Symeou 2007). This class-based stratification then enables some groups to take advantage of educational opportunities for their children, while lower socioeconomic groups do not enjoy the same advantages (Autor et al. 2008). Consistent with Archer et al. (2007), Moote and her colleagues argue that career aspirations are socially constructed—shaped by identities and inequalities such as gender, social class, and ethnicity, and driven by cultural capital and beliefs about personal agency (Moote et al. 2020). They argue that efforts to influence student perceptions and increase participation in engineering programs by women may gain greater purchase by challenging the elitist culture and practices associated with the profession, rather than focusing on changing student aspirations directly. Rohde et al. (2020) used a longitudinal interview methodology to examine the perspectives of 20 students about becoming an engineer and found that participants' descriptions of who can 'do' engineering were at once both open and exclusionary. Impressions of the culture of engineering were seen to be consistent with the values and practices of models—faculty and practicing engineers—indicating that existing cultural values are upheld and reified by undergraduate engineering students.

While acknowledging no one factor as the singular cause, Blickenstaff's (2005) systematic review of the literature listed a range of contributing explanations for the relative lack of women in STEM careers, including biological differences; an absence of female role models in the field of science and engineering; a negative attitude towards science among girls; cultural pressure for women to take up traditional occupations; and an "inherent masculine worldview in scientific epistemology (pp. 371–372)."

Family determinants

Parental influence has a substantial overall effect on the desire to enroll and complete a post-secondary program (Bers and Galowich 2002; Cabrera and La Nasa 2000a, b, 2001; Choy et al. 2000). Post-secondary participation in Canada is strongly associated with both parental value for post-secondary education and socioeconomic status (Statistics Canada 2015). Parental encouragement has a stronger net effect on a child's post-secondary prospects as compared to socioeconomic status and the personal attributes of an individual (Horn and Chen 1998; Human Resources and Skills Development Canada 2004; Paulsen 1990). Academic discussions between parents and children have been shown to encourage children to pursue higher education and the influence of parents tends to increase in the high school years (Bers & Galowich 2002). According to Galotti et al. (2006), adolescents who receive parental encouragement to pursue university studies also tend to trust the information provided by them. Youth perceptions of their parents' aspirations for a university education are also influential in post-secondary decision-making—more influential than their peer and teacher aspirations (Davies and Kandel 1981). Conversely, those students who do not experience parental involvement in post-secondary choices tend to trust the resources available at school.

Other parental factors associated with the choice to pursue higher education include parental education, parental income level, and family structure. Students with at least one university educated parent are three times more likely to attend university as compared to those students whose parents do not have a high school qualification (De Broucker and Lavallée 1998; Finnie et al. 2004). High parental income is also positively associated with high educational achievement among youth, although parental income is less robust as a predictor of a child's educational accomplishments than parental education (Drolet 2005; Finnie et al. 2004). In addition, some research suggests that students who grow up in two-parent families and who live with two parents during high school are more likely to attend post-secondary institutions, as compared to those who raised in families with different structures (Finnie et al. 2004; Lambert et al. 2004). Other researchers, however, have reported that family structure (two parents versus single parent) has little effect on educational aspirations and status attainment (Cheung 2007; Seabrook 2013).

Theoretical perspective

This study is conceptualized with reference to a Bourdieusian theoretical framework. Bourdieu and Passeron (1990) theorized that individuals (social actors) operate in fields—essentially representing spaces where actors operate to produce, circulate, appropriate and exchange goods, services, knowledge, or status. In society, actors hold competitive positions and through their actions (habitus) they attempt to accumulate and monopolize different kinds of power resources (capitals), for example, social and cultural capital. Societal inequalities and the stratification of social classes are reproduced (passed on from one generation to another) through the actions of the dominant classes. This reproduction of social inequality in also propagated through educational institutions, whereby schools reward students who exhibit the traits characteristic of the dominant habitus and devalue the cultural capital of those who occupy a position of lower status, often exemplified through economic status and position in society. Bourdieu argues that the education system "acts as a 'classificatory machine' that imposes authorized modes of segregation and incorporation" based on acceptance of the cultural capital (of the dominant classes) that a student brings with them into the classroom, including how they speak, dress, and act, as well as their values and behaviors (Kebede 2013, p. 80).

Methodology

Epistemological perspective

The theoretical perspective underpinning the research is grounded the interpretive tradition, particularly, phenomenology. Interpretivism uses a set of interpretive research methods rooted in an epistemological stance which "start[s] from the position that our knowledge of reality, including the domain of human action, is a social construction by human actors, and that this applies equally to researchers" (Walsham 1993, p. 5). Interpretivism is based on the premise that there is no objective reality which can be discovered by researchers and replicated by others. Instead, knowledge claims are based on the representations of research participants, and the researchers are generally active participants in the research. From a theoretical perspective, the responses of research participants in this study are seen more as representations of perspectives than reports on reality (Silverman 2001). Thus, there is no objective reality which can be discovered by researchers and replicated by others, in contrast to the assumptions of positivist science.

Given the scope of this study and holding realistic expectations of how much time, we could reasonably expect of study participants at any one point in time, we utilized a questionnaire/survey as a means of collecting individual participant perspectives relating to their decision to enter an engineering program. The use of quantitative data in a qualitative study is well established as a legitimate and valuable strategy for qualitative researchers, as the inclusion of numerical data "does not inherently make the research a mixed-method study" (Maxwell 2010, p. 480).

Maxwell (2010, p. 475) addresses the issue of using quantitative data in qualitative research:

> The use of numerical/quantitative data in qualitative research studies and reports has been controversial. Prominent qualitative researchers such as Howard Becker and Martyn Hammersley have supported the inclusion of what Becker called "quasi-statistics": simple counts of things to make statements such as "some," "usually," and "most" more precise.

The use of quantitative data in qualitative research also contributes to the internal generalizability of findings within the setting or collection of individuals studied, thereby "establishing that the themes or findings are …characteristic of this setting or the set of individuals as a whole" (Maxwell 2010, pp. 478–479). Similarly quantitative data help to control for systematic bias towards uniformity of interpretation and can serve as an important check on such biases (Maxwell 2010). Finally, the use of quantitative data in a qualitative study provides clear evidence for a researcher's interpretations and offers an effective counterargument against the critique that affirming data have not simply been cherrypicked, while negative exemplars have been ignored. An important point here is that the use of quantitative data forces the researcher to present data on negative as well as supporting evidence.

Survey instrument

We used a self-developed survey instrument to measure student responses on a five-point Likert scale ("strongly agree" to "strongly disagree"). The instrument was validated through an extensive literature review coupled with pre-testing with engineering faculty members and graduate students. In creating the self-developed survey instrument used in this study, we surveyed studies in the extant literature to determine the factors deemed relevant in academic decision-making relating to the choice of post-secondary discipline (e.g., Eidimtas and Juceviciene 2014; Hanson and Litten 1982; Hossler and Gallaghar 1987; Jackson 1982; Kotler and Keller 2009; Schiffman and Kanuk 2007) as well as the aforementioned Engineers Canada survey categories (Engineers Canada 2016; Engineers Canada 2017). These factors were later categorized under the family, school, social, economic, and personal factors to form the structure of the survey instrument.

The instrument was developed in Google Forms and a web link to the electronic copy of the survey gave participants the option to complete it at their convenience.

Consistency, validity, and reliability

The survey instrument was also reviewed for face validity—readability, clarity, and comprehensiveness, resulting in some minor changes.

Internal Consistency To test the reliability of the instrument we used Cronbach's Alpha, which was calculated to be 0.837 and well within the acceptable range for this measure (Tavakol and Dennick 2011).

Face Validity We validated the questionnaire by closely surveying and repeatedly completing the survey instrument ourselves, making edits and adjustments as necessary, and by consulting with several other researchers and Ph.D. students. We asked experts to review our questionnaire for readability, clarity, and comprehensiveness, which helped to validate the content.

Pilot Testing In addition to tests for internal consistency and logical (face) validity, we also conducted a pilot test of the survey instrument. Pilot testing was undertaken to make sure that everyone in the sample of research participants not only understood the questions (and how to navigate the survey instrument), but understood them in same way (Fowler 1988). For the pilot study, we sent a link to the survey instrument to 15 engineering graduates who were not part of the main study. After they had completed the survey, we asked for their feedback on several aspects of the instrument. Data from the pilot test enabled us to adjust the survey instrument to clarify any obscure questions and to rework any questions that might lead to non-response bias. The pilot test also enabled us to gauge the approximate time frame required to complete the survey (10–15 min).

Participants and recruitment

Participants were undergraduate students studying engineering at Memorial University in Newfoundland and Labrador, Canada. Based on data received from the Faculty of Engineering, there were a total of 1032 students, undifferentiated by year, enrolled in the winter semester of 2016. Of these, we able to access 497 students (136 female and 361 male) participants who were on campus. The remaining 535 were on a work term and unavailable to participate in the research. Another 83 students from the Faculty of Science who were completing courses in order to switch to the Faculty of Engineering. A total of 151 students (26%) responded to the anonymous survey.

Data collection

Three approaches were utilized for data collection:

1. *Post-Class Recruitment* Following ethics approval, we contacted the Faculty of Engineering and Applied Science. We requested and received assistance in data collection. Faculty members in the Faculty of Engineering and Applied Science agreed to permit us to distribute survey instruments to undergraduate engineering students at the end of regularly scheduled class. We went in to three different classes, which gave us access to all the students in the faculty at the time of data collection.
2. *Faculty of Engineering and Applied Science Email Listserv* We also coordinated with the Faculty of Engineering and Applied Science to distribute the research

advertisement and electronic survey instrument to students through their listserv. A formal email with the link to complete the survey was sent to all the students by the faculty administration office. This email was sent every week for two months to increase participation.

3. *Sharing the Advertisement on social media* The advertisement and the link to the survey was made available on the university's Learning Management System. This gave survey access to all the registered undergraduate students in faculty of engineering and applied science.

We also provided participants with the option of completing the survey in paper form to potentially increase response rates (Cook et al. 2000; Hohwu et al. 2013; Nulty 2008). However, all students chose to complete the online version.

Data analysis

The analysis of the questionnaire/survey data is entirely limited to the determination of frequency counts and mean scores. Accordingly, we consider this work to be solely naturalistic and interpretive.

The majority of the descriptive analysis was accessed using Google Forms. To study the responses on the five-point Likert scale, "strongly disagree" and "disagree" and "agree" and "strongly agree" were combined. Thus, the five-point scale was collapsed into three categories: "disagree," "neutral," and "agree." Jacoby and Matell (1971) argue that most Likert scales can be collapsed to dichotomous or trichotomous measures without compromising reliability. Matell and Jacoby (1971) concluded that the utilization of fine rating scales does not increase the refinement of measurement over that which is obtained with coarser dichotomous or trichotomous scales. Therefore, collapsing the scale did not have a negative impact on the strength of our analysis.

Limitations, delimitations, and assumptions

In survey research, participants may misinterpret questions and respond based upon their understanding rather than what the researcher wants to know. To mitigate against this possibility, as recommended by Converse and Presser (1986), we conducted pilot testing to evaluate respondents' understanding of the concepts under study and made appropriate changes on the survey instrument. We also provided the researchers' contact information in the event that clarification of survey items was required. We assumed that all the participants would be honest in their responses; however, we realize and acknowledge that there is a risk that some of the responses may be biased by the tendency of respondents to provide socially desirable responses (Paulhus 1991).

As noted, there were multiple recruitment strategies used to increase the number of responses. However, factors like the timing of data collection (a large number of students were on work terms), unregistered email accounts, and the absence of incentives, among other factors, may have had an effect on the response rate.

Although the sample size and response rate may limit the generalizability, the participation level in this study (151) was slightly above the desired sample size of 145. The desired sample size was calculated using the *Z*-value (for 95% confidence interval) of 1.96, proportion ratio of 0.5, 10% margin of error, and 50% response rate (calculated using the pre-test).

We note that our analysis of the questionnaire/survey data is entirely limited to the determination of frequency counts and mean scores. Accordingly, we consider this work to be solely naturalistic and interpretive. Hence, our discussions are limited to the context within which the data exist.

Results

Demographic characteristics

A majority of the respondents (91%) were English first language followed by a small proportion (5.4%) who were bilingual (French and English) and less than 4% who spoke another language in addition to English. Most (91.3%) were Canadian citizens and residents of Newfoundland and Labrador with the remainder about evenly split between Canadian citizens from other provinces, and other nationalities. Almost two-thirds of the sample were male, one-third were female, and one respondent reported as non-binary. A majority of the participants (60.3%) were under the age of 20, 35.1% were between 20 and 25, and remainder were older than 25 years of age. Most (82.7%) reported being raised in two-parent families, while 8.7% came from single parent families (mother), 3.3% from single parent families (father), and 5.3% reported other as family type. Almost half (47.7%) reported family income of more than $100,000, followed by 29.1% reporting family income levels between $50,000 and $100,000, and 10.6% reporting family incomes less than $50,000. About 13% of respondents did not know or did not report their family's income (Table 1).

Almost two-thirds of the respondents said that their education was either funded by their parents/relatives (52%) or through scholarships (12.7%). The remaining participants reported that they were self-funding their education through bank loans or employment. With respect to mother's education, more than 80% of the respondents reported that that their mother had obtained some post-secondary education, and, among this group, half reported that their mothers had earned an undergraduate university degree. A quarter of those surveys reported that their mothers had earned a graduate degree. The pattern was similar for fathers. Most of the participants came from relatively small families with either one (53%) or two (27.8%) siblings.

Family determinants

More than half of those surveyed agreed that 'parental advice/encouragement' (55.6%) and 'parental pressure to be academically competitive' (59.6%) influenced their decision to pursue a degree in engineering. Almost half of the participants (47.3%) reported that 'value of science and engineering education among

Table 1 Demographic profile of respondents

Demographic factor	*N*	Responses
Residency status	150	Canadian citizen (NL resident)—77.3% Canadian citizen (Other province)—12% Non-citizen—10.7%
Gender	151	Male—66.9% Female—32.5% Non-binary—0.7%
Age	151	Under 20—60.3% Between 21 and 25—35.1% Between 26 and 30—4% 30+–0.7%
Family type	150	Mother and father living in the same household—82.7% Single parent (mother)—8.7% Single parent (father)—3.3% Other—5.3%
Parental household income	151	Less than $50,000—10.6% $50,001–$100,000—29.1% $100,001–$150,000—25.2% $150,001–$200,000—15.2% More than $200,000—7.3% Don't know—12.6%
Main source of funding for education	150	Self-funded (Work)—22% Self-funded (Student loans, bank loans, etc.)—12% Funded by parents/relatives—52% Scholarships and awards—12.7% Other—1.3%
Parental education (mother)	149	Less than high school diploma—1.4% High school diploma—15.4% Post-secondary certificate or diploma—28.2% Undergraduate degree—30.9% Graduate degree—21.5% Doctorate degree—2.7%
Parental education (father)	148	Less than high school diploma—4% High school diploma—17.6% Post-secondary certificate or diploma—30.4% Undergraduate degree—27.7% Graduate degree—16.9% Doctorate degree—3.4%
Family size (no. of siblings)	151	0–6.6% 1–53% 2–27.8% 3–9.9% 4–2.6%

family members' influenced their decision, while about a third (37.4%) felt it had no bearing on their program choice. About 22% agreed that a 'tradition of science and engineering occupations in the family' influenced their decision to pursue engineering. Similarly, less than a fifth (17.9%) of the participants reported 'advice/pressure from extended family members' as an influencing factor.

Table 2 Family determinants of the decision to pursue a degree in engineering

Influence	Disagree	Neutral	Agree	Responses (*N*)
Parental advice or encouragement	15.2% (23)	29.1% (44)	55.6% (84)	151
Parental pressure to study science or engineering	52.3% (79)	23.2% (35)	24.5% (37)	151
Tradition of science or engineering occupations in family	66.2% (100)	11.9% (18)	21.8% (33)	151
Parental pressure to be academically competitive	26.5% (40)	13.9% (21)	59.6% (90)	151
High value of science and engineering education among family members	37.4% (56)	15.3% (23)	47.3% (71)	150
Advice/pressure from extended family member	63.6% (96)	18.5% (28)	17.9% (27)	151

Overall, the three major family determinants were parental advice/encouragement, parental pressure to be academically competitive, and high value of science and engineering education among family members (Table 2).

Institutional determinants

The survey data show that most of the institutional (school-based) factors that were examined play only a minor role in the decision to study engineering at the university level. Participants were relatively evenly divided in terms of the impact of teachers on their choice of post-secondary program, with 39.1% agreeing that encouragement or advice from a teacher or another staff member was a determining factor, and 36.4% disagreeing. Similarly, fewer than one in four respondents (23.6%) indicated that the career counseling they received in high school had an influence on their decision. Co-curricular activities in science/engineering were cited as an influential factor by only about a quarter of respondents (26%). We also asked about the influence of other school- and teacher-level factors, including 'high value of science/engineering among teachers and other staff members,' 'teacher or other staff member's pressure to be academically competitive,' and 'high-school level pressure to study science or engineering.' Responses ranged from 31.1% (pressure to study science or engineering) to 42% (pressure to be academically competitive).

Overall, in consideration of the data relating to institutional influences on choice of degree, students' reliance on the advice, guidance, and values of high school teachers and counselors or pressure exerted at the school level is relatively limited (Table 3).

Table 3 Institutional (school-based) determinants of the decision to pursue a degree in engineering

Influence	Disagree	Neutral	Agree	Total responses (*N*)
Advice/encouragement by teacher or other staff member to study science/engineering	36.4% (55)	24.5% (37)	39.1% (59)	151
High school-level pressure to study science/engineering	45% (68)	23.8% (36)	31.1% (47)	151
Career counseling advice received in high school	59% (89)	17.2% (26)	23.9% (36)	151
Academic focus on science/engineering in high school	28% (42)	19.3% (29)	52.7% (79)	150
Teacher or other staff member's pressure to be academically competitive	40% (60)	18% (27)	42% (63)	150
High value of science/engineering among teachers and other staff members in my high school	34.4% (52)	26.5% (40)	39.1% (59)	151
Co-curricular school activities in science/engineering	51.3% (77)	22.7% (34)	26% (39)	150

Table 4 Social determinants of the decision to pursue a degree in engineering

Influence	Disagree	Neutral	Agree	Total responses (*N*)
General social pressure to study science/engineering	47.4% (71)	19.3% (29)	33.4% (50)	150
General information or counseling from other sources (social media, advertisement, news etc.)	46.3% (69)	26.8% (40)	26.8% (40)	149
Career seminar, career fairs, etc	50.3% (76)	25.2% (38)	24.5% (37)	151
Friends and acquaintances	32.5% (49)	21.2% (32)	46.3% (70)	151
Social pressure to be academically competitive	35.1% (53)	21.9% (33)	43% (65)	151
Social value/status of a career in science/engineering	17.2% (26)	16.6% (25)	66.2% (100)	151

Social determinants

The 'social value[1] of a career in science/engineering' seems to be an important determinant of students' decision to pursue a degree in engineering, as indicated by two-thirds (66.2%) of respondents who were surveyed in this study. Fewer than half of those surveyed agreed that 'general social pressure to study science/engineering' or 'general career information and/or career seminars/fairs' were influential in helping choose a career in engineering. The construct 'social pressure to be academically competitive' was a stronger determinant of students' decisions to pursue a degree in engineering than 'social pressure to study engineering/science.' Interestingly, almost half (46.3%) of the participants agreed that 'peer influence' played a role in formulating their post-secondary program decisions. Overall, however, the 'social value of a career in engineering/sciences' was the strongest social determinant of respondent's decision to pursue a degree in engineering in Newfoundland and Labrador (Table 4).

Personal determinants

Personal determinants appear to be among the important factors in the decision to study engineering. All four of the constructs within the *Personal Determinants* category were determined to influence the decision to pursue a degree in engineering for a high proportion of participants. Three quarters of the participants group agreed

[1] Our conceptualization of the social value of an occupation is derived from the "social value of a job" model proposed in the Government of New Zealand's (2014) information paper, titled, The social value of a job. Social value refers to the extent to which an occupation accrues social advantages including monetary and health benefits; frequency, number, and nature of social contacts; and general contributions to the public good, such as the production of meaningful, safe, and environmentally positive products or services. Effectively, there are three elements to social value in this context: the pay (which extends to health benefits), the human relationships (social connections to others), and the activity itself (the good associated with the work).

Table 5 Personal determinants of the decision to pursue a degree in engineering

Influence	Disagree	Neutral	Agree	Total responses (*N*)
Personal motivation	2% (3)	7.9% (12)	90% (136)	151
Aptitude for science/engineering subject matter	3.3% (5)	6.6% (10)	90.1% (136)	151
Academic success in previous STEM-related subject matter	7.3% (11)	17.2% (26)	75.5% (114)	151
Personal desire to work as a scientist or engineer	5.9% (9)	8.6% (13)	85.4% (129)	151

Table 6 Economic determinants (earning potential) of the decision to pursue a degree in engineering

Influence	Disagree	Neutral	Agree	Total responses (*N*)
Earning potential of a career in science/engineering	6% (9)	9.9% (15)	84.1% (127)	151

that 'academic success in STEM-based subjects in high school' have a positive influence on their choice to pursue an engineering degree; however, 'personal motivation,' 'aptitude for science and engineering subject matter,' and 'personal desire to work as an engineer or scientist' were the strongest factors under the *Personal Determinants* category, with 90%, 90.1%%, and 85.4% of respondents agreeing, respectively (Table 5).

Economic determinants

The majority of the participants (84.1%) perceive future economic benefit/earning potential of pursuing a degree in engineering as a key determinant of their decision to pursue an engineering degree. The economic value of a degree in engineering was an important influence among respondents, second only to personal determinants (Table 6).

Discussion

The research findings from this study are discussed with reference to the demographic characteristics of the participant sample and the factors or determinants influencing the respondents' choice to pursue a degree in the field of engineering. Within this discussion, we integrate a number of policy recommendations that we believe could be enacted to help increase the number of graduates who choose to follow a career in engineering or the applied sciences, and particularly, the proportion of those graduates from underrepresented groups. This is followed by conclusions from the research and suggestions for further study.

Demographic considerations

Gender

Consistent with other research in the field, our findings show that only about a third of the respondents in this study were female. Although women do better academically than men in the Canadian education system (Turcotte 2011), their representation in engineering fields is significantly lower (Chubin et al. 2005; Engineers Canada 2017; Hango 2013). In engineering education, the female-to-male ratio in NL is slightly greater than the other Canadian provinces (Engineers Canada 2017), however, there is still considerable room to address this disparity.

Following on Bourdieu and Passeron (1990), we see that gender is an important factor in the observed differential access to certain post-secondary fields of study, and this was evident in the data from this study. Bourdieu and Passeron (1990, p. 228) argue that opportunities to pursue certain disciplines are not equitable or proportionate to the university population, but instead express “a systematic distortion,” whereby students from less economically affluent families tend to lean towards traditional occupations associated with their social class. Rather than pursuing those disciplines that typically open doors to higher economic and social mobility (e.g., medicine or law), women and students from less affluent are underrepresented in such occupations. Our findings suggest that, in the specific Canadian context examined in this research, engineering, as a discipline, is similarly positioned. Even though access to higher education has increased for women, some disciplines still remain out of reach. Sen (1985) argued that opportunities, for example, the mere fact that women have the chance to enter the field of engineering, in themselves are no guarantee that an individual will be able to achieve certain life goals. Applying this argument to higher education, the mere existence of an engineering school that is open to female applicants does not guarantee that women will enter the discipline and fill the ranks of the engineering profession.

We believe there is value in investing knowledge and effort into understanding the specific factors that positively influence, or act as barriers to women’s decisions to pursue engineering as a profession. Since girls show stronger academic performance than boys in the K-12 school system, in Newfoundland and Labrador, greater efforts to create opportunities for, and awareness of, engineering as a valuable career choice for young women would seem warranted. Blickenstaff (2005) asserts that the underrepresentation of women in STEM fields is a complex issue requiring innovative and multifaceted responses, where the emphasis is on “improving science and science education, rather than attempting to ‘remediate’ girls and women” (p. 384). Recommended actions by schools and science educators focus on equal access to the teacher and classroom resources; collaborative pedagogies with full gender integration; gender balance in language and learning resources; learning that emphasizes how science can improve the quality of life of living things and learning that acknowledge the political nature of scientific inquiry.

Some options could include (1) specifically identifying young women with an aptitude for mathematics and physics and providing them with opportunities to develop these skills; (2) deliberate and redoubled efforts by schools (administrators, science teachers, and counselors) to encourage girls to pursue engineering and other STEM-related careers; (3) providing opportunities for women in science and engineering occupations to talk with elementary and secondary-level girls about career options in these fields; (4) creating opportunities for schools and school districts to liaise with organizations such as Engineers Canada, which are involved in promoting engineering education, especially for young women; and (5) providing financial incentives for women to pursue university programs in engineering. In the Newfoundland and Labrador context, organizations such as Women in Science and Engineering (WISE-NL) have sponsored programs intended to increase the participation of women in science, technology, engineering, and mathematics careers, however, further government investment in scholarships and bursaries and financial incentive programs such as tuition fee remission, underwriting co-op placements and/or financial assistance for books, and resources are examples of monetary levers that may encourage more young women to choose engineering as a degree choice. A joint effort on the part of government, schools, and community organizations seems warranted to motivate young women to translate high levels of participation in high school-level science and math into engineering as a career option.

Family characteristics

Family structure

With respect to family structure, the vast majority of respondents reported being raised in two-parent families. These findings are consistent with several other studies reviewed in the literature that suggest a positive relationship between growing up in a two-parent family and post-secondary participation (Astone and McLanahan 1991; Finnie and Laporte 2003; Heard 2007; Lambert et al. 2004). Various conceptualizations have been posited for this relationship, but most relate to the impact of family structure on school engagement. Astone and McLanahan (1991) report that several engagement indicators such as grades, school attendance, and educational aspirations are negatively influenced by students living in families without both parents. Life-course theorizations argue that families with stable, long-duration trajectories (e.g., long-duration, two-parent families) where transitions to other family types are limited or non-existent, experience fewer emotional stressors that affect adolescents' ability to stay attached to school (Heard 2007). Studies of student attachment/engagement demonstrate that students who are more engaged in the schooling process show higher levels of educational attainment (Sewell and Shah 1968), while "[r]educed attainment, especially school failure, is the end result of a process of school disengagement, in which students progressively detach themselves from the goals, attitudes, and behaviors intrinsic in the educational process" (Heard 2007, p. 435).

We suggest that this finding may also be partly reflective of the capacity of families to support the cost of an engineering education. The data show that the majority of engineering students funded their education through resources provided by their parent(s). Given that two-parent families are better positioned financially to support their children's attendance at university, family composition may also be a proxy for income level. Moreover, the data show that 60% of the students in our sample had no more than one sibling. The financial capacity of families to support the post-secondary aspirations of their children decreases as the number of children in the household increases (Statistics Canada 2017). Smaller families have proportionately more disposable income from which to financially support their children (Parr 2006). Conversely, from a financial perspective, it might be expected that there would be financial barriers facing children from larger families, in terms of their ability to undertake an engineering degree.

Family income

Higher parental income is almost always associated with better outcomes for children. According to Phipps and Lethbridge (2006), this relationship holds, regardless of the measure of income used or the type of child outcome being studied. The data from the present study suggest that family income is a determinant of the decision to study engineering. Almost half of the respondents reported annual family income of more than $100,000, which is consistent with the literature showing that parental income is positively correlated with children's decisions to pursue post-secondary education (Drolet 2005; Finnie et al. 2004). Conversely, very few students from lower-income families were represented in our sample. It is therefore reasonable to suggest that consistent with other studies (e.g., Frenette 2007; Statistics Canada 2017), children from lower-income families are likely to encounter financial barriers to the pursuit of engineering programs.

Although further exploration is required to identify ways to increase participation from low-income families, certain immediate actions could help ameliorate this situation. Similar policy responses to those identified to help encourage more young women to study engineering could also be considered for prospective engineering students of all genders from lower-income families. These might involve targeting students from lower-income families who demonstrate an aptitude for math and physics and providing no-cost opportunities to further develop these skills, such as participation in STEM-based experiential learning. School administrators and counselors could also consider ways to educate students and their families on the practical and financial benefits of engineering careers, including enlisting university engineering faculty and recruitment staff to provide information sessions. Since educational funding is a prime barrier for such students, government agencies, universities, and/or their partner supporters might consider introducing targeted bursaries or scholarships for prospective students from low-income households who choose to pursue an engineering degree. Financial relief programs such as means-tested tuition waivers for high achieving students or paid pre-admission summer internships may be another monetary incentive. Financial support to purchase study material (books, computers etc.) or financial incentives to engineering-related businesses to offer co-operative placements may help support engineering students from low-income families. Engineering firms could also be encouraged to create bursaries for engineering education for students from low-income households as part of their corporate social responsibility. Print and digital media coverage of the topic of career in engineering and written articles about the value of an engineering career could also help prospective students and their families to appreciate the long-term social and economic value of an engineering degree.

Parent education level

More than 80% of the students who responded to the survey reported that both of their parents had some post-secondary education, and more than half said that their parents had at least an undergraduate degree—findings consistent with earlier work on intergenerational transfer (Cheung 2007; De Broucker and Lavallée 1998; Finnie et al. 2004). In terms of the choice to pursue a university degree, students whose parents have earned post-secondary credentials have obvious advantages over those whose parents have lower levels of educational attainment. Social reproduction theorists have long recognized the positive effects of higher parental education on children's academic attainment levels (Dubow et al. 2009; Li and Qui 2018; McDonough 1994, 1997). Bourdieu's social reproduction thesis (Bourdieu and Passeron 1990) centers on the relationships among education, family, and income/social class. Educated parents generally occupy a place among the higher income classes and are thought to transmit certain social and economic advantages to their children, while the children of lower-income families receive no such advantages. For example, Ishitani (2006) showed that first-generation college students were a 51% less likely to graduate within 4 years than students with college-educated parents. Some theorists see education as a means through which social advantages (or disadvantages) are reproduced in the next generation (Blau and Duncan 1967; Raftery and Hout 1993; Sewell et al. 1969). According to McDonough (1997, p. 8):

> Cultural capital is that property that middle- and upper-class families transmit to their offspring which substitutes for or supplements the transmission of economic capital as a means of maintaining class status and privilege across generations. Middle- and upper-class families highly value a college education and advanced degrees as a means of ensuring continued economic security, in addition to whatever monetary assets can be passed on to the offspring.

Thus, students whose parents have lower levels of education and income need financial and other educational supports to enable their transition to post-secondary programs, which have the potential to increase social and economic prospects and interrupt patterns of social reproduction. The need to account for these inequities and provide educational supports is a substantial social problem that is situated at the very center of what many educators, social reconstruction theorists, and policy decision-makers see as fundamental elements of poverty reduction strategies (Government of Canada 2018a, b; Sharma and Ford-Jones 2015). Since engineering degrees have substantial economic benefits, initiatives to foster math and physics in high school, create awareness about engineering degrees and provide financial support to pursue one, may not only help increase number of engineers but serve the broader social goal of improving equity.

Educational funding

This research is consistent with earlier studies that show family resources to have a strong relationship with university enrollment (Andres et al. 2007; Conley 2001; Sandefur et al. 2006). About two-thirds of respondents reported that financial support for their engineering program was primarily funded either by their parents or relatives, or through scholarships, while the remaining students self-funded their degrees, either by working or borrowing money. In our sample, the majority of respondents were raised by well-educated parents in smaller, two-parent families with good incomes. Collectively, these constitute the ideal conditions to establish a strong system of support. Without financial supports, students who enroll in engineering programs may be at higher risk of attrition (Geisinger and Raman 2013). Such students may have to work extended hours to pay for their education and living costs and/or incur significant educational debt, which may also influence educational outcomes in terms of performance or other long-term outcomes. While this was not addressed in this study, it is an avenue for further research. Further analysis of this variable, including a comparison with other fields of study would help determine if financial support from parents is more prevalent in engineering education than in other program areas, and if it is a significant barrier to participation.

Family influences

The findings show that family influences (parental advice/encouragement, parental pressure to be academically competitive, and the value placed on science and engineering education by family members) are perceived as enabling influences on the decision to pursue an engineering degree and are additional to tangible supports. These findings are consistent with the previous studies that underscore a substantial role for parents in whether their children undertake post-secondary studies (Bers and Galowich 2002; Cheung 2007; Galotti et al. 2006; Human Resources and Skills Development Canada 2004; Paulsen 1990). The majority of engineering students in this study indicated that parent's value for education, academic press, parental advice, and encouragement were all determinants in their decision to study engineering. We speculate that since a majority of parents were university educated, participants may have perceived the advice they received from their parents relating to university study as well-informed. Following on Cruz and Kellum (2018) and Rohde et al. (2020), it would be useful to further investigate, through qualitative inquiry, the particular types of discussions that foster Canadian student's aspiration to engage specifically in undergraduate engineering education and the ways in which students respond to such conversations.

Institutional factors

The data suggest that with the exception of *academic focus on science/engineering in high school* participants did not consider school-based factors to be important determinants of the decision to study engineering. Neither counseling/career information nor career seminars and fairs were identified as being influential in the career decision-making of the participants in our study. Although speculative, it is possible that teachers and counselors are not providing sufficient or appropriate advice or encouragement with respect to STEM-based career options. Alternatively, high schools may lack sufficient capacity to provide appropriate career advice. This is consistent with the literature that reports no substantial relationship between students' educational aspirations and their interaction with their teachers or guidance counselors (Hossler et al. 1999). The results from this research, therefore, raise questions about the effectiveness of career education and counseling in Newfoundland and Labrador schools. Given recent concerns related to the capacity of schools to address issues of student mental health and wellness in the Newfoundland and Labrador school system (Collins et al. 2017), it is possible that these priorities are hindering school counselors from offering valuable career advice to students and their parents.

School personnel should be well positioned and sufficiently knowledgeable to provide students and their families with necessary information regarding post-secondary planning. From our perspective, and based on the data reported here, schools must figure more prominently in providing the kind of assistance needed by students to help them with decision-making and financial planning for post-secondary study. Some possible actions at the school district/school level that could ignite greater interest in STEM careers might include (1) inviting engineering professionals to deliver talks about careers in engineering and applied sciences; (2) liaising with organizations like Engineers Canada and the faculties of engineering and applied sciences, which are involved in promoting engineering education among students; (3) investing in professional development opportunities for mathematics/science teachers and counselors to keep them up to date with STEM career opportunities; (4) reviewing the capacity of the current complement of school counselors to deliver career education, given their other priorities; and (5) potentially identifying career counseling as a separate and prioritized activity from other forms of counseling.

The literature we reviewed suggests that participation in extra-curricular activities is positively associated with post-secondary educational aspirations (Cheung 2007; Hossler and Stage 1992; Stage and Hossler 1989); however, only about a quarter of the respondents in this study reported that co-curricular activities influenced their decision to pursue a degree in engineering. The data suggest that students do not see co-curricular activities in science/engineering as an element of academic focus in science/engineering or as step towards a career in engineering. Further action research in this area might assist schools to develop better mechanisms to connect learners with STEM subjects. In addition, school-based experiences intended to attract students to STEM subjects may increase students' interest in STEM subjects. With respect to extra-curricular activities, further research may be able to discern the forms of extra-curricular activities that may be effective in stimulating interest in STEM fields. We know that students from lower socioeconomic background are underrepresented in engineering education, and they may not have access to meaningful career advice at home; therefore, teachers and counselors have a pivotal role to play in inspiring these children towards higher education.

Social, economic, and personal factors

Other determinants of the choice to study engineering identified in this research include social and economic factors, and personal influences. The students we surveyed placed importance on the social value of an engineering career, which aligns well with Gibson and Hutton's (2017) finding that people have a positive perception of engineering as a profession. We also found that social pressure to be academically competitive to be a strong determinant of program choice, and to a lesser extent, social pressure to study engineering/science, specifically. Almost half of the participants indicated that peer influence played a role in formulating their decisions. Together, these social interactions seem to exert considerable influence and represent an important area for further study. These data indicate that social factors including information from peers should be considered a powerful influence on the academic press and post-secondary planning of students. As Holland (2011, p. 1047) observes, from a behaviorist perspective, "[t]here are clear indications that students monitor and model the academic behavior of their peers." A concern related to this finding is that although social and peer influences may be strong motivators, the validity and scope of the information/advice available through such sources may be erroneous, incomplete, or uninformed.

Personal factors such as aptitude for science and engineering subject matter, prior academic success in STEM courses, and personal desire to study engineering were perceived as playing the strongest role in the decision to pursue an engineering degree. This finding is well aligned with the literature showing student achievement as a strong predictor of higher education aspirations (Bishop 1977; Hossler et al. 1999; Jackson 1978; Sharp et al. 1996; Tuttle 1981). Both personal desire and motivation to work as an engineer are functions of awareness about the engineering profession. We speculate that students from highly educated, high-income families are likely to be subjected to conversations and experiences that foster awareness of various professional fields; these factors may, therefore, be connected to family influences.

Consistent with Rothwell (2013) who notes that STEM career areas carry a premium in the overall job market, a large majority of the students we surveyed indicated that the earning potential of a career in engineering was an important driver of their program choice. Most of those surveyed come from high-income families, which suggests that their life experiences are rooted in this particular family milieu. From an economic perspective, being exposed to a financially secure family may be connected to their choice to study engineering. Educated parents with high income may transmit the importance of economic benefits of degrees such as engineering that tend to prepare students for high-earning jobs. Alternatively, students who come from low-income families may not be exposed to such information. Their higher education decisions are more likely to be based upon different family experiences and expectations, patterns of non-attendance, or other circumstances such as financial limitations. Many of the enabling factors discussed in previously may act in concert to develop a student's understanding of the economic and social value of higher education, in this instance, an engineering degree.

Conclusions

Our conceptualization of the findings from this study parallels the cyclic nature of social patterns theorized by reproduction theorists (e.g., Bourdieu and Passeron 1990; Hart 2012, 2019), whereby family-based influences and other complementary factors (that may be proxies for family-based characteristics) are coupled to a person's education, occupation, income level, and subsequent social and professional network. There is a clear imbalance in the socioeconomic profile of engineering students. The data from the research show that students who pursue engineering as a field of study are primarily associated with highly educated, high-income families; their decisions were influenced by parental advice/encouragement, parental pressure to be academically competitive, and high value of science and engineering education among family members, and for the most part, their educational expenses were underwritten by parents or other family members. Students from lower-income families were significantly underrepresented in our sample. We also note that gender disparity is still a considerable issue in the engineering program we studied, and this is commensurate with other national data for Canada. We believe that if we increase the number of young Canadians who choose a career in engineering and the applied sciences, there is a pressing need to increase opportunities to make such degree programs more accessible for underrepresented groups. At the policy level, efforts should be focused on funding opportunities to access targeted programs in engineering and the applied sciences. Individual financial support (scholarships, awards, living allowances, and other incentives) should be targeted towards students from low-income families and young women.

Schools also play a significant role in framing an individual's future. Teachers and counselors need to be well equipped with the kind of professional learning experiences that enable them to provide both meaningful career guidance about opportunities in the applied sciences, and authentic and meaningful STEM-based learning experiences. Moreover, there must be sufficient time and capacity to enable school counselors to focus on a renewal of career education programs. Such programs might be concentrated on promoting STEM-based careers and helping female students and students from low-income households to navigate any barriers currently keeping them from building careers in engineering and the applied sciences.

Increasing the number of engineering students is an important strategic priority for the Canadian labor market and we do not fully understand why so few Canadian students choose to pursue a STEM-related career. The present study is one small contribution towards realizing this objective.

Acknowledgements The authors acknowledge the assistance of the Faculty of Engineering and Applied Sciences, Memorial University in the conduct of this research.

Author contributions All authors whose names appear on the submission (1) made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data; or the creation of new software used in the work; (2) drafted the work or revised it critically for important intellectual content; (3) approved the version to be published; and 4) agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding The authors did not receive support from any organization for the submitted work.

Data availability The datasets generated and/or analyzed during the current study are not publicly available but may be made available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no competing interests.

Ethical approval All research on human subjects have been approved by Memorial University of Newfoundland's Interdisciplinary Committee on Ethics in Human Research (ICEHR No. 20170729-ED) and has therefore been performed in a way that is consistent with the ethical standards articulated in the Canadian Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans—TCPS 2 (2018) and the 1964 Declaration of Helsinki and its subsequent amendments and Section 12 ("Informed Consent") of the ASA's Code of Ethics. All human subjects gave their informed consent prior to their participation in the research and adequate steps were taken to protect participants' confidentiality.

Informed consent Consent to participate was sorted in light of the ethics guidelines. Both the authors give our consent for the publication.

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