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# Embarking on and Persisting in Scientific Fields of Study: Cultural capital, gender, and curriculum along the science pipeline

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RESEARCH REPORT

# Embarking on and Persisting in Scientific Fields of Study: Cultural capital, gender, and curriculum along the science pipeline

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In this paper, we examine the nature and extent of participation of Canadian young women and men in science-based academic fields. Informed by Bourdieu's theory of cultural reproduction, we focus on three key stages—senior secondary school, the transition to post-secondary studies, and the post-secondary completion stage—to determine whether and how the interrelationships of gender, cultural capital, course completion in senior secondary school, timing of decisions, and initial participation in post-secondary education lead to the completion of science-related undergraduate degrees. Through correspondence analyses of 10 years of longitudinal data with 1,055 respondents, we extend the findings of cross-sectional studies that examine only one aspect of this longitudinal story by showing how the intersection between organisational structures (institutional and disciplinary) and cultural capital transmitted by the family shapes the opportunity structures of access to scientific fields of study by young women and men.

## Introduction

The imagery of the "leaking science pipeline" is often used to describe the attrition of women from the fields of science and engineering. This gender-related phenomenon in science manifests itself early, starting with elective subjects in high school (Cleaves, 2005), continuing through undergraduate and graduate studies (Ayalon, 2003; Hanson, 1996; Kahle, 1996; Mendick, 2005), and finally leading to the widely discussed under-representation of women in academia, industry, and even science education (Bradley, 2000; Davis & Rosser, 1996; Fox, 1996; Graham & Smith, 2005; Ramirez & Wotipka, 2001; Rayman & Jackson, 1996). Although attrition can affect

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all those attempting to embark on science-related careers, it appears to be particularly problematic for women. In Canada and worldwide, these persistent attrition patterns raise concerns about equitable access to science-based education and careers.

In 2004, 61% of all Canadian bachelor's degrees were earned by women. However, the proportion was as low as 43% in mathematics and physical sciences, and only 23% in engineering (Statistics Canada, 2006a). For women generally, declining completion rates continue along the university degree pipeline. Whereas almost two-thirds of those earning bachelor's degrees in 2004 were women, for the same year this proportion was 52% at the master's level and 42% at the doctoral level. In engineering and some science fields, the rates of graduate enrolment, and hence degree completion, by women are considerably lower. For instance, in 2004 the proportion of master's degrees earned by women was 39% in mathematics and physical sciences, and 24% in engineering. The proportion of doctoral degrees earned by women in 2004 was 21% in mathematics and physical sciences, and only 16% in engineering, which shows the net decline of science credentials earned. Analyses of trends over time reveal that women have made only slight gains in these fields (Andres, 2002b; Andres & Adamuti-Trache, 2005).

Similar patterns are observed in other industrialised countries, suggesting that the leaking science pipeline is a global phenomenon. In the United States, for the year 2004, the proportion of women earning bachelor's degrees in mathematics and physical sciences was 44% and in engineering was 21%. At the master's level, women earned 42% degrees in mathematics and physical sciences, and 21% in engineering. The proportion of doctoral degrees earned by women was 26% in mathematics and physical sciences, and 18% in engineering (National Science Foundation, 2006). In Great Britain, in 2004, the proportion of women (UK domiciled) earning bachelor's degrees in mathematics and physical sciences was 42%, and increased slightly to 44% at the master's level. However, the proportion of doctoral degrees earned by women in mathematics and physical sciences was 33% (UK Office of Science and Technology, 2005). In engineering, the completion rates by women increased from 15% at bachelor's level, to 18% at master's level, and 20% at doctoral level; as such, under-representation of women in this field is comparable with Canada and the United States. Fuchs, von Stebut, and Allmendinger (2001) ascertain that women's participation in science was slightly improved in Germany during the past decade. In 1998, women represented about 43% of university graduates and 33% of doctoral degree recipients. This brief cross-national comparison of educational attainment in specific fields of study suggests that attrition patterns by women in science and engineering fields are not confined to Canada.

Over the past 20 years, research has been directed at identifying factors that influence the experience of women in science, as well as attempting to develop plausible models aimed at explaining gender differences at various stages along the science pipeline. In this paper, by employing a longitudinal data-base, we follow a cohort of high school graduates 10 years after high school graduation and focus on three key stages: senior secondary school, the transition to post-secondary studies, and the post-secondary completion stage.

The first stage of interest occurs in high school and entails embarking on science-based trajectories by completing advanced mathematics and science courses. It is well documented that influences in the early years of schooling, especially those exerted by parents, impact students' views toward subsequent school course work. However, it is in the senior secondary years where specific curricular choices allow for certain post-secondary opportunities to become possible. We intend to explore whether parental transmission of cultural capital is instrumental in students' choices of science courses at this stage. According to Bourdieu and Passeron (1979), an educated parent has "the eye for a good investment which enables one to get the best return on inherited cultural capital in the scholastic market or on scholastic capital in the labour market" (p.82). Science education is likely to be such an investment. Either by envisaging careers in science or engineering, by believing that scientific backgrounds create skills possessed by only selected groups of individuals, or simply by establishing reliable strategies to ensure their children enter the post-secondary system, educated parents may encourage their children to study mathematics and science in the senior secondary years.

Embarking on a science or mathematics trajectory is a necessary but not sufficient condition leading to science-based careers. Persistence is required to ensure the successful transition to the second stage, and completion of the third stage, post-secondary studies. Little research has documented (1) the relationship between cultural capital and specific academic choices, and (2) the long-term impact it has on educational enrolment and attainment at the post-secondary level by young women and men. Only by employing longitudinal data will it be possible to articulate useful theoretical accounts of the dynamic nature of these factors over time and to examine the complexity of relationships that occur across these three major stages.

The research presented in this paper is conducted within the Canadian socio-educational context in which science-related educational trajectories are shaped. In this paper, we adopt a socio-structural approach to examine the patterns of educational choices made by young people. Research adopting this perspective seeks to examine the extent to which social structures such as social class, family background, gender, academic achievement, and educational opportunities condition transition experiences and eventual life-chances (Andres, Anisef, Krahn, Looker, & Thiessen, 1997; Furlong & Cartmel, 1997; Jones & Wallace, 1992; Krahn & Lowe, 1999).

By following respondents from senior secondary school through the post-secondary system, we answer the following main questions: What are the educational trajectories for women and men who have completed a constellation of science and/or mathematics courses during their senior high school years? How do these trajectories compare with those of students who have not completed science and/or mathematics-based courses of study? Through the examination of 10 years of panel data on British Columbian young women and men's educational pathways, we examine whether and how cultural capital (i.e., specific attributes transmitted by the family that influence one's educational achievements) and academic capital (i.e., curricular choices and subsequent credentials) contribute toward earning formal qualifications in a competitive field like science.

Although we acknowledge that other forces such as social capital[1] may be at play, in this study we delimit our analysis to the role of cultural capital, for, according to Bourdieu (1986), “the transmission of cultural capital is no doubt the best hidden form of hereditary transmission of capital, and therefore receives proportionately greater weight in the system of reproduction strategies” (p. 246).

## Review of the Literature and Theoretical Framework

Unlike many European systems of education (Matějě & Straková, 2005), in Canada curricular differentiation is not the result of early and rigid selection and sorting schemes. Instead, when students are in Grade 10 they choose—hopefully with the help of parents, counsellors, and teachers—courses most suited to their interests, abilities demonstrated to date, and planned educational paths as formulated by this point in their high school careers. During the final two years of secondary school (Grades 11 and 12), depending again on the successful completion of courses and evolving educational and career interests and disinterests, programmes of study are followed, modified, or completely abandoned. For Canadian high school graduates, rather than being a set trajectory, curricular differentiation is an outcome of courses completed in high school. For example, whereas some students may choose to study physics in Grade 11, they may or may not take physics in Grade 12. For those who did not take physics in Grade 11, they may choose to study this subject in Grade 12, but will not be able to complete Physics 12 (unless they choose to extend their high school studies by 1 year). Some students graduate from high school with an incomplete set of physics course work, and this may disqualify them for enrolling in post-secondary programmes for which these courses are pre-requisites. Within this structural context, it is relatively easy for students—and especially girls—to leave science pathways as early as the senior years (i.e., Grade 11) of secondary study. Hence, disproportionate participation in certain disciplines within the higher education by women and men may actually be exacerbated by secondary educational systems with few mandatory requirements and relatively unfettered individual options (Bradley, 2000; Organization for Economic Co-operation and Development, 1986).

Similar to many states in the United States, in British Columbia, Canada there are many routes into the post-secondary system. With the requisite course work and competitive grade point averages, students can enrol directly from high school into university. Typically, students who enter university science programmes will have completed senior level courses in mathematics, and at least two science subjects (e.g., physics, chemistry, biology), while some will have taken supplemental calculus. Non-university institutions such as community colleges, university colleges, and institutes have a variety of prerequisites, depending on the programme of study. Academic programmes (e.g., those transferable to university after the completion of a certain number of credits) have admission requirements similar to, although usually less rigorous than, universities. Prerequisites for terminal programmes (i.e., those that end with a community college certificate or diploma) depend on the nature of and demand for the programme. Students enrolling in non-university programmes may be able to complete bachelor's degrees in some applied fields at these institutions.

Again, similar to many United States systems, the British Columbia post-secondary system is an articulated (sometimes called "seamless") system in that it is possible for students who enter non-university institutions to eventually complete baccalaureate degrees. For example, if a student wishes to pursue a bachelor's degree in science, but has not completed the required course work in high school, she or he may do so at a community college and then enrol in an academic (i.e., university transfer) programme. With considerable forethought about course choices, careful academic planning, and the completion of course work at a high academic level, such a student is able to transfer to a degree-granting institution to complete the requirements for a bachelor's degree. Yet, university education remains the main path toward careers in science and engineering.

Science education research addresses issues of social class by highlighting the role that parents can play in transmitting educational values and practices to children, and hence facilitating their acquaintance with mathematics and science learning. Educated parents are likely to possess adequate knowledge and dispositions to offer direct help with school activities and to stimulate their children's interest in school, and eventually their expectations for further education (Jacobs & Bleeker, 2004; Jacobs & Harvey, 2005; Reay, 2004; Zady & Portes, 2001). As demonstrated by Jacobs and Harvey, parental education and aspirations for their children's education become strong determinants of students' school achievement. In some cases, educated parents became instrumental in supporting school environments that "push" students toward high achievement, in that such environments reflected their own backgrounds and the high post-secondary aspirations and expectations they held for their children. In addition, several research studies demonstrate the relationships among parental education, social class, high school course choices (i.e., science or non-science paths), and post-secondary orientations of students (Blickenstaff, 2005; David, Bali, Davies, & Reay, 2003; Dick & Rallis, 1991; Dryler, 1998). However, few studies are informed by theoretical perspectives in the sociology of education literature to account for the inter-relationships among social class, gender, and participation and completion of degrees in science. From a cultural reproduction perspective advanced by Bourdieu (1986, 2000), the transmission of capital, in the form of cultural as well as economic resources, occurs at the level of the family. That is, parents transmit capital in the form of dispositions, habits, and attitudes to their children, resulting in the reproduction of the dominant culture through which background inequalities are converted into differential academic attainment and eventually social status. According to Bourdieu and Passeron (1979), "social origin exerts its influence throughout the whole duration of schooling, particularly at the great turning points of a school career" (p. 13). Students from different socio-economic backgrounds have access to:

> unequal knowledge about courses and the careers they lead to, the cultural models which associate certain occupations and certain educational options … with a particular social background, and the socially conditioned predisposition to adapt oneself

> to models, rules, and values which govern the school system. (Bourieu & Passeron, 1979, p. 13)

In the case of science, an early understanding of the educational trajectories that lead to careers in science disciplines is essential (Vetter, 1996). By virtue of not having completed the necessary prerequisites, the objective chances of pursuing such studies at university level will have already been eliminated, thus narrowing the range of career opportunities. Bourdieu and Passeron note that the "relegation of working-class or lower-middle-class students to certain disciplines" (1979, p. 2) remains a more covert form of educational inequality.

The lack of requisite credentials is simultaneously a direct and indirect form of exclusion. Students who do not possess the prerequisites for entry into specific post-secondary programmes are simply denied entry (Ayalon, 2003). However, unequal knowledge about the current and future worth of academic credentials, which according to Bourdieu (1984, 1990) is one of the most valuable types of information transmitted through inherited cultural capital, may well be the result of indirect forms of exclusion (Bourdieu, 2001; Bourdieu & Passeron, 1979; Cleaves, 2005; Lamont & Lareau, 1988). That is, students eliminate themselves from the full range of educational opportunities or are relegated to less desirable academic programmes.

Female students who complete high school science courses and then enrol in undergraduate science courses tend to be above-average achievers in science (Adamuti-Trache, 2004; Sadler & Tai, 2001). University enrolment data indicate that female students are most likely to choose biological and chemical sciences, and to a lesser extent physics, mathematics, astronomy, computer sciences, and engineering (Statistics Canada, 2006b). For the young women who do escape initial exclusion from certain academic programmes, their persistence in certain disciplines—and in particular, mathematics and physical science—often declines. Constrained by individual self-assessment of competence (Correll, 2004), gender socialisation barriers in science departments (Etzkowitz, Kemelgor, & Uzzi, 2000), or both, women may conclude that university level science programmes are "not for me".

For all students, the undergraduate years represent a crucial time when career decisions are made. The major influencing factors are related to institutional structures and to the culture of each scientific discipline (Clark, 2001). Many studies discuss the effect of academic cultures and structures on the rate of attrition of female students from science programmes, as well as on women's persistence in the scientific field. The culture of the scientific community is often described as masculinist (e.g., an aggressive, competitive, or indifferent milieu as reflected in teaching and research styles; distance from social concerns); hence, feelings of exclusion experienced by women are intensified (Erwin & Maurutto, 1998). As Bourdieu (2001) cautions, even:

> when external constraints are lifted and formal liberties granted—the right to vote, the right to education, access to all occupations …—are acquired, self-exclusion and 'vocation' (which acts as much negatively as it does positively) take over from explicit exclusion. (p. 39)

In other words, although young women may have had the requisite cultural and academic capital and related dispositions to allow them to embark on university science programmes of study, it may not be enough to ensure that they persist and complete such programmes. According to Le Hir (2000), this form of self-censorship leading to "the striking underrepresentation of women … in certain academic disciplines" is the result of a form of symbolic violence "that can be as efficient a form of violence as oppression, but it is much more difficult to detect" (p. 136).

In this paper we explore the relationship between participation in science education and science education attrition rates by different social classes of young women and men across time. However, rather than positing that cultural capital alone will have the greatest influence on disciplinary choice and eventual earned educational credentials, we take up McCall's (1992) challenge to consider gendered dispositions as a critical form of capital and to examine the "interaction of gender with class distinction through the lens of embodied capital" (p. 839). Although some researchers claim that gender is neglected in sociology of education research in general, and in studies of the transmission of cultural capital (Dumais, 2002; Jacobs, 1996), we concur with McCall that Bourdieu's work is "a powerfully elaborate conceptual framework" (1992, p. 837) to examine the relationships among capital, gendered dispositions, high school orientation, and post-secondary outcomes.

## Research Design

### *Purpose of Study, and Research Questions*

As emphasised in the literature, each moment along a scientific career may influence educational and professional outcomes, while each moment may also be determined by many prior factors. Moreover, especially in "hard" sciences and engineering, there are critical points along a career path that may change it dramatically, and this effect appears to be more evident in the case of women than in that of men.

The study aims at addressing the following specific research questions: (a) Is there a relationship among family background, gender, and the completion of specific courses in senior secondary school? (b) Is there a correspondence among high school preparation, gender, and parental background and initial post-secondary participation? and (c) How do family background, high school curricular differentiation, and academic capital correspond to educational destinations 10 years following high school graduation? These questions cannot be adequately addressed by analysing outcomes at isolated moments in time. Analyses of longitudinal data through the relational technique of correspondence analysis (Bourdieu & Wacquant, 1992) will reveal the ways various academic stages are connected. Given that the science pipeline appears to be a system with only one entry point but many exit points, only longitudinal research containing information of individual paths over time can provide relevant information from the perspective of both theory and practice.

*Data Collection and Sampling Procedure*

This research uses three waves of questionnaire data from the Path on Life's Ways Project. This study is the only comprehensive longitudinal research project on the transition of youth to adulthood in British Columbia, and one of the few longitudinal studies of young adults in Canada. The research, spanning 10 years,[2] provides a detailed account of individuals' lives, choices, and post-secondary education and work experiences across different points in time since high school graduation and in relation to changing social and cultural conditions. The Path on Life's Ways Project is comprised of longitudinal data collected by mail-out questionnaires in 1989, 1993, and 1998 (Andres, 2002a). These data are linked with senior high school course selection and achievement records.

The baseline 1988 data-set consists of a selective random sample of 10,000 students and their corresponding demographic administrative records (e.g., grades, provincial examination results, geographic location), representing over 40% of the British Columbian high school graduate population at that time. Three follow-up surveys (1989, 1993, and 1998) were conducted by mail-out questionnaires sent to the respondents of each previous survey. Each survey had a response rate of about 50%, leading to a sample of 1,055 subjects in 1998 (59% female and 40% male), which constitutes the basis for this study. Although there has been considerable sample attrition over time, the overall representativeness remains sound (see Andres, 2002a, for details of the sample). Demographic data and specific information on respondents' year-by-year post-secondary educational histories have been selected for this study. The variables used in this analysis are described in the Appendix and operationalised below.



*Research Sample and Variables*

The research sample used in this study is the 1998 longitudinal sample with a total of 1,055 respondents, of whom over 800 have completed some science and/or mathematics course work in the last year of high school. For the purpose of this study, respondents are grouped by their participation in high school science and mathematics courses, as reflected in the type and number of courses taken for graduation. Based on upper secondary school courses, namely Grade 12 biology, chemistry, mathematics, and physics, four high school profiles were developed. The rationale for this classification is that, in Grade 12, students enrol in courses that reflect their future post-secondary plans (institution and programme admission requirements), academic abilities (grade requirements for high school graduation and post-secondary admission), and perhaps their career interests. The four high school profiles are as follows: non-science (NS), mathematics (MA), life sciences (LS), and physical sciences (PS). This classification[3] has been used in previous research on this topic (Adamuti-Trache, 2002, 2004; Adamuti-Trache & Andres, 2002). Students in the non-science profile group (NS) did not complete any Grade 12 mathematics and science courses, or in a few cases (1.3%) they completed one physics or chemistry course. Since these few respondents did not complete Grade 12 mathematics to ensure a solid foundation for the physical sciences, they were included in the non-science group. The mathematics profile group (MA) contains students who took mathematics but no science courses for graduation. The life sciences profile group (LS) contains students who took biology (with or without mathematics or chemistry), but no physics courses. Those in the physical sciences profile group (PS) have completed courses that include mathematics in combination with at least one of the chemistry or physics courses. The physical sciences high school profile corresponds to the most intensive and the broadest science-related preparation. Based on the above classification a high school profile variable is described in the Appendix.

Separate analyses of the life sciences and physical sciences groups are crucial in revealing the actual situation of under-representation of women in sciences. Since participation by women in life sciences disciplines has improved recently (Luckenbill Edds, 2002), an "all science" category gives the false impression that participation by women in specific science fields has improved. In reality, despite the fact that women are now better represented in biological sciences and medicine, there is still a large numerical gender discrepancy in mathematical and physical sciences and engineering, where women continue to be an obvious minority.

Table 1 presents the distribution of students in the research sample ($n$ = 1,055) by their high school academic orientation (i.e., described by the four high school profiles) and their academic performance (i.e., assessed by the average final Grade 12 marks). The sample size is fairly large for most subgroups, except the mathematics high school profile; for this subgroup, findings will be interpreted with caution. The research sample contains a large proportion of students who have completed science courses at the senior secondary level. According to Table 1, the highest final average mark in Grade 12 corresponds to the physical sciences category, the group with the broadest science-oriented preparation. This group contains a large number of high achievers: about 38% of students have final grades over 80, and 7% of students have final grades over 90 (Adamuti-Trache, 2002).

That parental education is a strong determinant of children's post-secondary participation and their orientation toward college or university education is well documented (Andres & Krahn, 1999; Knighton, 2002; Sullivan, 2001). Andres and

Table 1. Academic orientation and achievement by gender and high school profile

| | Number (%) of students | | | Grade 12 final average mark | | |
|---|---|---|---|---|---|---|
| High school profile | Female | Male | Total | Female | Male | Total |
| Non-science | 135 (22) | 90 (21) | 225 (24) | 67 | 66 | 67 |
| Mathematics | 62 (10) | 28 (7) | 90 (8) | 72 | 68 | 71 |
| Life sciences | 323 (52) | 92 (21) | 415 (39) | 72 | 72 | 72 |
| Physical sciences | 102 (16) | 223 (51) | 325 (29) | 77 | 76 | 76 |
| All | 622 | 433 | 1,055 | 72 | 73 | 72 |

Grayson (2002) demonstrated the relationships among educational backgrounds of parents, access to and completion of post-secondary education, employment, and job satisfaction; and Dhalla et al. (2002) found that parental background was related to their children's choices of expensive and long university programmes, such as medicine.

For the purpose of this paper, we employ parental education as the indicator of cultural capital. Various studies use several measures to assess the cultural capital in one's possession, including knowledge about and attendance at various culture events and activities (DiMaggio, 1982; DiMaggio & Mohr, 1985; Katsillis & Rubinson, 1990). However, this study focuses on the transmission by parents of cultural capital and not cultural capital itself (Robinson & Garner, 1985), which makes parental education appropriate as an indicator. We could have included mothers' and fathers' occupational levels and status as additional indicators. However, preliminary investigations employing correspondence analysis demonstrated that parental occupation and educational variables correspond closely with each other. Inclusion of parental occupational levels does not contribute substantively to the results, and makes the analyses more difficult to present. Also, whereas the respondents in our study were more likely to have reasonably accurate knowledge of their parents' education, measures such as income levels of parents are often either missing or considered unreliable when reported by children (Andres & Krahn, 1999; Guppy & Pendakur, 1989).

The 1989 survey contains variables measuring the highest levels of education for both parents. In this analysis we use a two-category parental education variable: one or both parents with a university degree, or no parent with a degree (see Appendix). The available sample size is slightly reduced ($n$ = 988) since a few respondents did not give information regarding the education of their parents. In the ensuing analyses, the sample is organised either by combining gender and parental education (i.e., four-category classification) or high school profile with gender and parental education (i.e., 16-category classification).

We employ several other variables in the analyses. Inclusion of a variable measuring timing of the decision to attend post-secondary education corresponds with Bourdieu's (1986) contention that "the precondition for fast, easy accumulation of every kind of useful cultural capital, without wasted time, [occurs] only for the offspring of families endowed with strong cultural capital" (p. 246). Correspondence among the timing of decisions, cultural capital as transmitted by the family, gender, and high school orientation will provide insight into what counts as capital and how it is transmitted. The variable—post-high school orientation in 1989—is included to assess the degree to which the various levels of post-secondary study selected by students correspond with parents as sources of cultural capital, gender, and high school academic orientation. Post-secondary completion status in 1998 is a measure of the enduring nature of capital—including gendered capital—over time. Finally, we focus only on those young women and men who completed a university degree by the university field of study in 1998, in relation to parents as sources of cultural capital and high school orientation. These variables are described in detail in the Appendix.

*Correspondence Analysis Method*

Since this study aims to describe patterns and reveal structural relationships among categorical data, it is appropriate to use correspondence analysis (CA). This is a multivariate technique that summarises information in two-way contingency tables and provides an informative visual representation of data distribution; that is, row and column profiles based on the two-way contingency table turn into points displayed in a two-dimensional space (Greenacre, 1994). This method of data analysis was favoured and employed by Bourdieu. He states:

> if I make extensive use of correspondence analysis, in preference to multivariate regression, for instance, it is because correspondence analysis is a relational technique of data analysis whose philosophy corresponds exactly to what, in my view, the reality of what the social world is. It is a technique that "thinks" in terms of relation. (Bourdieu & Wacquant, 1992, p. 96)

We provide a short description of the method to guide the reader through the interpretation of CA maps.

The CA method relies on geometry and concepts from mechanics. Row and column profiles are created as proportions that show the distribution of responses in a two-way contingency table. Each profile is assigned a weight (called a *mass*) proportional to the number of respondents in the corresponding row (or column), which is used to compute the chi-square coordinates of points in a multi-dimensional space. A chi-square distance based on the profiles determines the separation of two points and is used to calculate the total *inertia*, which is "a measure of the dispersion of the profiles in multidimensional space" (Greenacre, 1994, p. 12). More variability of data distribution in the two-way contingency table leads to higher *inertia*. The CA map is defined by two directions of the multi-dimensional space (i.e., principal axes) that carry the largest amount of *inertia* in all the row and column profiles. This is similar to factor analysis, where factors measuring the largest variance in all the variables are selected. In this paper, we will use SimCA (Greenacre, 1990)—a computer program that produces the chi-square coordinates for the CA maps and the statistical tests of the analysis.

Symmetric CA maps plot row and column profiles, and show how they are relatively distributed with respect to each other. This allows interpretation of the principal axes using either set of points, in a similar way to factor analysis. Either the row or the column profiles aligned along principal axes give information about which data characteristics (latent "hidden" variable) contribute to explain the amount of the total inertia along each axis. The other set of profiles is then positioned with respect to the principal axes to reflect a structural relationship with the latent variable. This is called *dimensional* or *factor-analytic* interpretation. In general, the first axis that explains the largest amount of inertia has a more substantive meaning, while interpreting the second axis is more subtle. Categories described by sets of points that are close in space are similar (i.e., profiles are produced by comparable data patterns in the two-way table), while points corresponding to dissimilar categories are situated far apart.

## Study Findings

The study contains a series of analyses following the longitudinal flow of events along respondents' educational pathways. In the first analysis, we explore the distribution of high school profiles across the four categories of gender combined with parental education. The next four analyses employ variables that combine high school profiles, gender, and parental education to explore distribution patterns of variables such as the timing of post-secondary education decisions, post-school status 1 year after high school graduation, post-secondary completion, and field of study 10 years after high school graduation. Correspondence analysis symmetric maps are obtained for each of the above analyses, but only Analyses 1, 2, 4, and 5 are presented in detail. Due to space limitations, the CA map is not shown for Analysis 3 and it is reviewed more briefly by highlighting the relevant associations among variables.



### *Analysis 1: High school profiles, gender, and family background*

Is there a relationship among family background, gender, and the completion of specific courses in senior secondary school? The CA map (Figure 1) is based on a two-way contingency table with columns represented by the four high school profiles and rows represented by the four categories of gender and parental education. The *factor-analytic* interpretation of the CA map focuses on the positioning of row profiles with respect to principal axes to identify the meaning of latent variables (if any), while the relative position of the column profiles provides information about the structural relationships.

The horizontal axis opposes the two gender groups, with female profiles to the left and male profiles to the right side of the map, which also matches the separation of life sciences (left) and physical sciences (right). This gender preference in science is acknowledged by science education research. It also suggests that gender is strongly associated with the level of mathematics difficulty in academic courses, with boys selecting the more mathematical disciplines (i.e., physical sciences). The other two high school profiles—non-science and mathematics—are more evenly situated with respect to the gender axis. This axis accounts for 92% of the average total inertia (profiles distribution).

The vertical axis opposes the physical and life sciences profiles that are based on science courses from mathematics and the non-science profiles that do not involve any science-related preparation. This axis accounts for only 8% of the total inertia and can be interpreted as "science vs non-science disciplines". The association with the vertical axis is numerically lower, but it suggests that students with more educated parents select science-related disciplines (the top of the map) while students coming from families where no parent has a university degree are inclined to take no science courses in their final year of high school.

The clear separation of column and row profiles in the CA map and the chi-square statistic ($\chi^2 = 182.6$, $df = 9$, $p < .001$) shows that the distribution of respondents

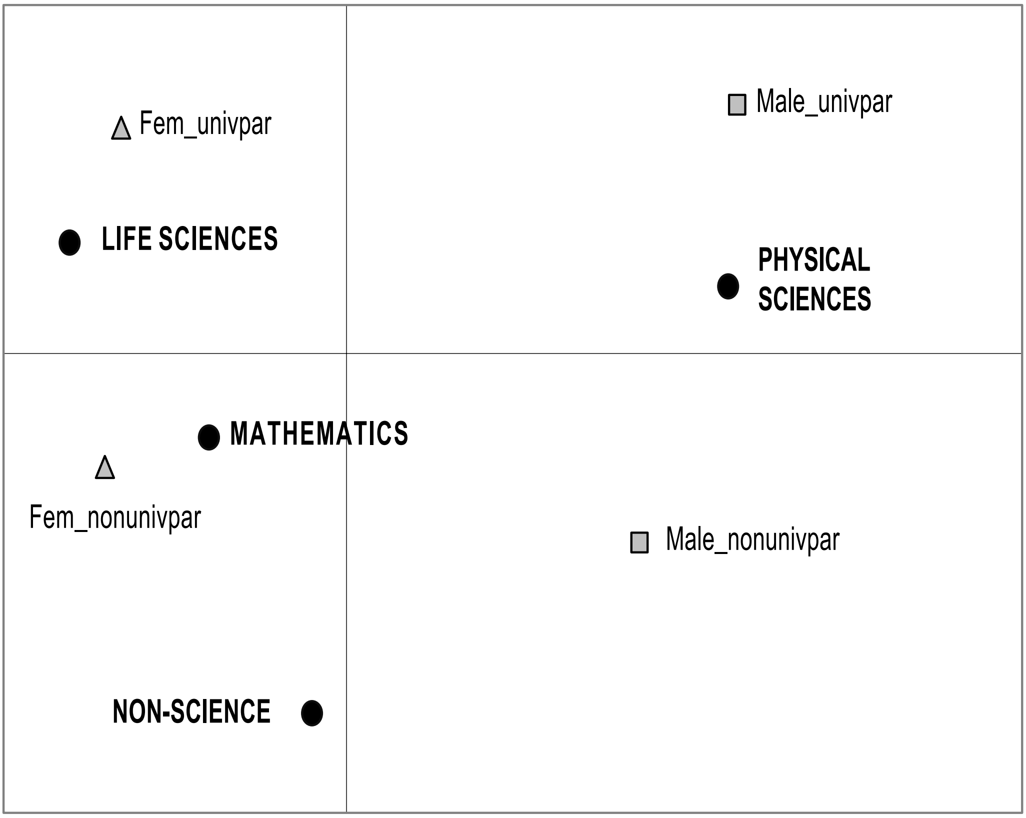


Figure 1. High school profiles by gender and parental education. *Note*: fem, female; univpar, parents with university education; nonunivpar, non-university-educated parents



across high school profiles is highly associated with gender and parental education. Gender appears to be a more relevant factor, being associated with the horizontal axis that explains the largest part of inertia. Boys are more attracted toward physical sciences and girls toward life sciences. Parental educational attainment relates to the number of science courses students take for graduation. The relative positions of column and row profiles show that physical sciences and life sciences profiles attract students with university educated parents. The non-science profile is mostly related to male and female students from families where neither parent attended university. Mathematics preparation (i.e., the typical route toward business and commerce) is relatively highly associated with groups of female students, especially from families with no university education.

*Analysis 2: Timing of decisions regarding post-secondary education*

Analysis 2 explores if and how the "timing of post-secondary decisions", operationalised in a six-category variable (Appendix), corresponds to the 16 row profiles that combine high school preparation, gender, and parental education.

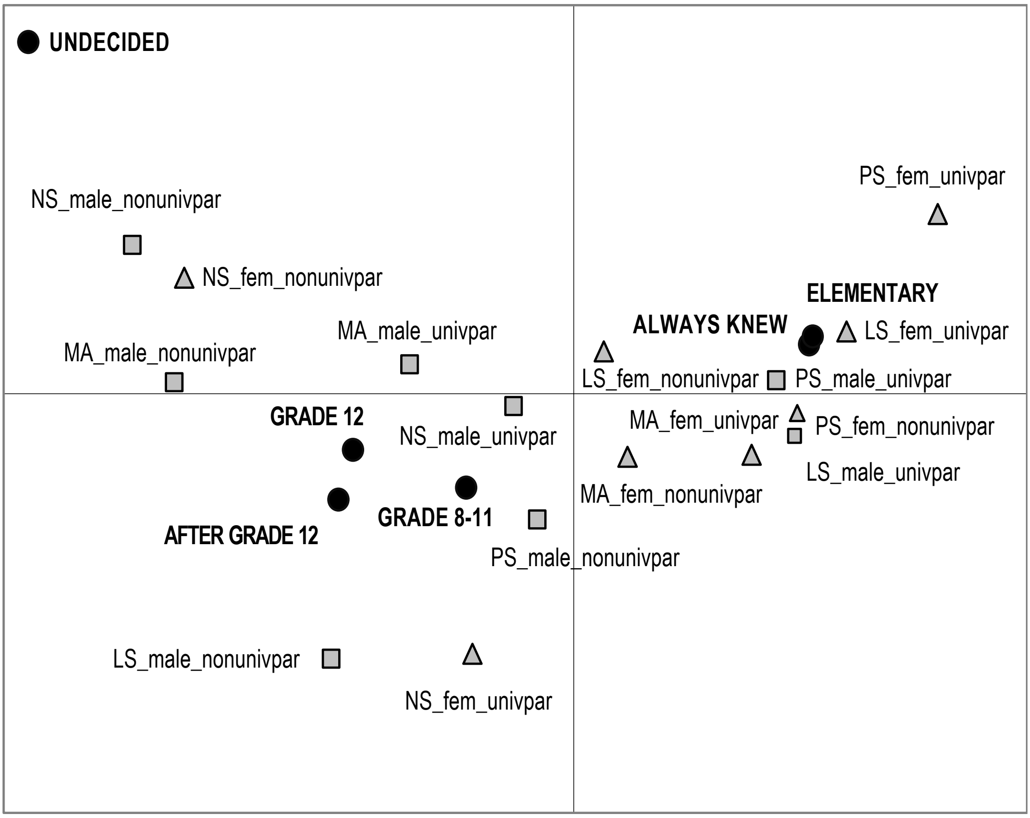


Figure 2. Timing of decisions regarding post-secondary education. *Note*: fem, female; univpar, parents with university education; nonunivpar, non-university-educated parents

In Figure 2, the horizontal axis opposes the undecided group to the left versus the early decision groups to the right side of the map, and accounts for 71% of the average total inertia. The placement of row profiles, with more non-science and mathematics groups to the left (toward undecided respondents) and more physical and life sciences groups to the right (toward early decided respondents), suggests that "undecided vs decided" column profile orientations match well with the direction of "non-science vs science" row profiles. The *factor-analytic* approach allows us to identify a relationship between the time when respondents decide to continue post-secondary education and their high school science course choices. The early timing of decisions regarding post-secondary education is related to having educated parents as sources of cultural capital. Profiles defined by less preparation in science and parents with less cultural capital are likely to correspond to "high school and after" timing of decision profiles. The correspondence analysis reveals that high school science preparation and university parental education are highly associated with making early decisions about post-secondary education ($\chi^2$ = 235.3, $df$ = 75, $p$ < .001). Although this analysis shows that gender categories are less dissimilar, almost all female groups tend to make early decisions about post-secondary education; male groups are more likely to make these decisions during high school years.

*Analysis 3: Post-school choices one year after high school graduation*

One year after high school graduation, respondents made various educational choices, as described by a three-category variable associated with the following post-school profiles: no post-secondary attendance (non-participant), enrolment in institutions other than university (non-university participant), and university enrolment (university participant). The CA (map not shown) describes the distribution of post-school status profiles across the 16 row profiles that combine high school preparation, gender, and parental education. High school preparation is highly associated with post-school status, with physical sciences groups oriented toward university participation and non-science groups toward non post-secondary participation ($\chi^2 = 207.1$, $df = 30$, $p < 0.001$). Parental education and gender groups bring specific contributions to each post-school profile. Both female and male university participants are mainly from the categories of respondents with university educated parents. Non-university participants are mainly female and male respondents with parents possessing less than university education. Non-participants are mainly male respondents. Also, the analysis demonstrates that females and males from the physical sciences profile with non-university parents are likely to become university participants. This suggests that more science preparation can lead to direct university entrance, independent of family background.

*Analysis 4: Post-secondary completion status 10 years following high school graduation*

Post-secondary completion status 10 years following high school graduation indicates whether respondents in the study completed various forms of post-secondary instruction. Previous analyses reveal that only 6% of all respondents never attended post-secondary institutions, and that the proportion of those who never participated in post-secondary education is higher for men than for women. Another 12% of all respondents attended, but did not complete, a post-secondary programme, and again the proportion of men in this category is higher than that of women. About 28% of all respondents have completed only non-university studies, with a larger proportion of women than men in this category. Finally, about 54% of all respondents in the study have completed university instruction, with a slightly larger proportion of women in this category (Andres, 2002a).

The CA map in Figure 3 shows the points corresponding to the four column profiles that correspond to the post-secondary completion categories (Appendix) surrounded by the 16 groups comprised of high school orientation, gender, and parental education.

The horizontal axis accounts for 84% of the average total inertia, and opposes the university graduates group (more education) to the right and the groups with less education to the left side of the map. The placement of row profiles show most

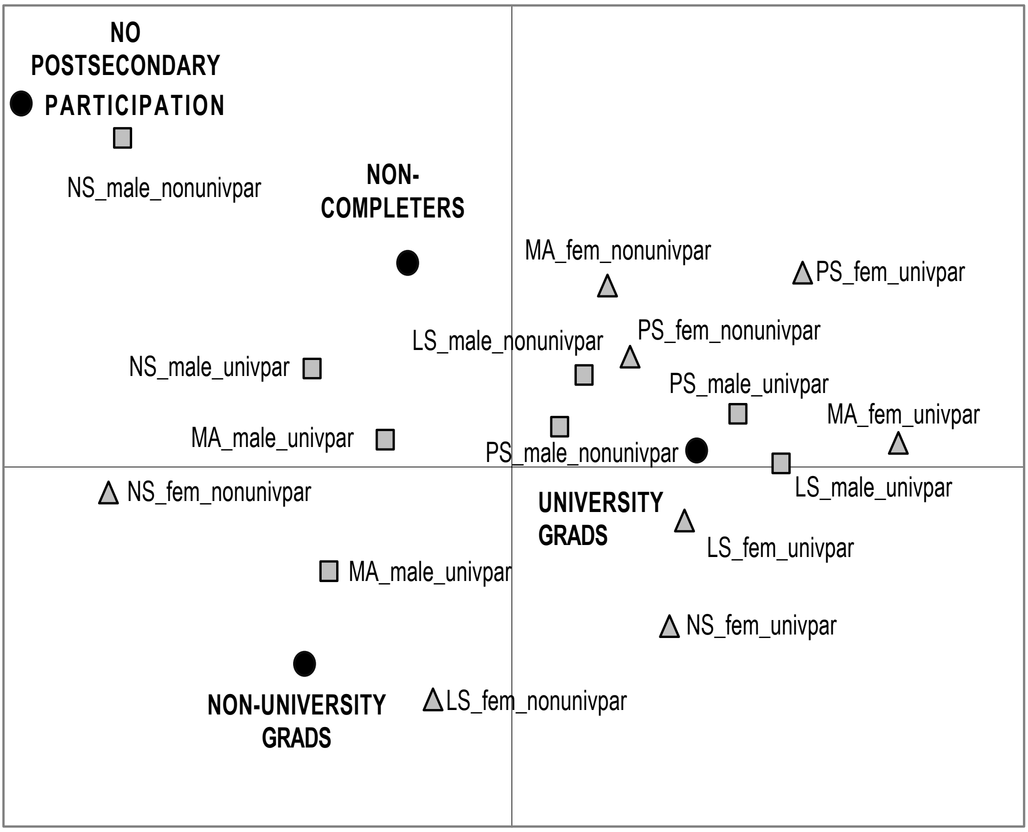


Figure 3. Post-secondary completion 10 years after high school graduation. *Note*: fem, female; univpar, parents with university education; nonunivpar, non-university-educated parents

physical and life sciences groups (more science) to the right and most non-science and mathematics groups (less science) to the left side of the map. Parental education is also well matched along the horizontal axis, opposing most groups with university educated parents to the right and non-university educated parents to the left. It is notable that almost all female groups are also situated on the right side of the CA map along the "more education" direction. Hence, the "more education vs less education" column profiles correspond to the direction of "science vs non-science", "university educated vs non-university educated parents", and "female vs male" row profiles.

The vertical axis accounts for 11% of the total inertia, positioning column profiles with completed education toward the bottom (university and non-university graduates) and profiles with no completed education toward the top of the map (non-completers and no post-secondary participation).

This analysis indicates that high school orientation, parental education and gender are highly associated with the post-secondary completion status 10 years after high school graduation ($\chi^2 = 208.4$, $df = 45$, $p < .001$). Row profiles oriented toward university participation (more education) correspond to groups with more science preparation and more educated parents. More female groups are also very likely to complete university education. Holders of non-university credentials, non-completers, and those who did not attend any post-secondary institution are mainly respondents from families where neither parent had attended university, suggesting that cultural capital is enduring in that continues to differentiate post-secondary educational pathways over the years. Also, those respondents who did not attend or complete post-secondary studies are likely to belong to groups with non-university educated parents, or of non-science and mathematics high school profiles. Conversely, respondents who have strong science-oriented academic capital seem to be able to translate it into favourable post-secondary outcomes.



### *Analysis 5: Choice of university fields of study*

A total of 565 respondents in the study (54% of the research sample, $n$ = 1,055) completed at least one university programme between 1988 and 1998, and obtained university degrees at the bachelor's level. Many respondents also completed graduate studies (mostly after 1993) as well as university professional degrees (e.g., teaching or language certificates) or various non-university credentials. In 1998, about 23% of university graduates were still enrolled in post-secondary studies and were completing additional degrees. Due to the complex educational pathways of respondents, determining the specialisation field of university graduates was not an easy task. Students reported the first and second academic programmes in which they participated year by year. Their choices combine arts and science, business and engineering, science and health, as well as academic and vocational destinations. The fields of study were assessed based on the dominant academic programmes attended by students over the years and the type of the degrees acquired. The classification we have adopted is as follows:

- *Agriculture & Biological Sciences* includes graduates holding bachelor's degrees in agricultural and biological science with or without further graduate degrees.
- *Mathematics & Physical Sciences* includes graduates holding bachelor's degrees in mathematical and physical science with or without further graduate degrees.
- The *Education* group includes graduates holding bachelor's degrees in education, or a combination of teaching certificates with bachelor's degrees in arts or science.
- The *Engineering* group includes graduates holding bachelor's degrees in engineering or applied sciences.
- The *Health* group includes graduates with bachelor's degrees in nursing or other medical degrees based on undergraduate science degrees.
- The *Humanities* group includes graduates holding bachelor's degrees in arts.
- The *Business* group includes graduates with degrees in law, commerce, or business.
- The *Behavioural & Social Sciences* group includes graduates with bachelor's degrees in arts or science in appropriate fields (e.g., psychology, social work, sociology, anthropology).

In this section we analyse how gender, academic capital, and cultural capital are associated with the field of study chosen by university graduates. The correspondence analysis map in Figure 4 shows the distribution of the eight specialisation fields across the 16 groups defined by high school profiles, gender, and parental education.

The horizontal axis separates the more mathematical disciplines to the right from the less mathematical disciplines to the left side of the map. This axis accounts for 54% of the average total inertia, and also opposes male physical sciences groups to the right and female life sciences and non-science groups to the left side of the map. High school orientation and gender match nicely the direction of the horizontal axis, opposing groups with mathematics and science preparation, especially men, to the right and those possessing less mathematics and science preparation, especially women, to the left. The separation of Agriculture & Biological Sciences from Mathematics & Physical Sciences is crucial in reinforcing the gender effect of



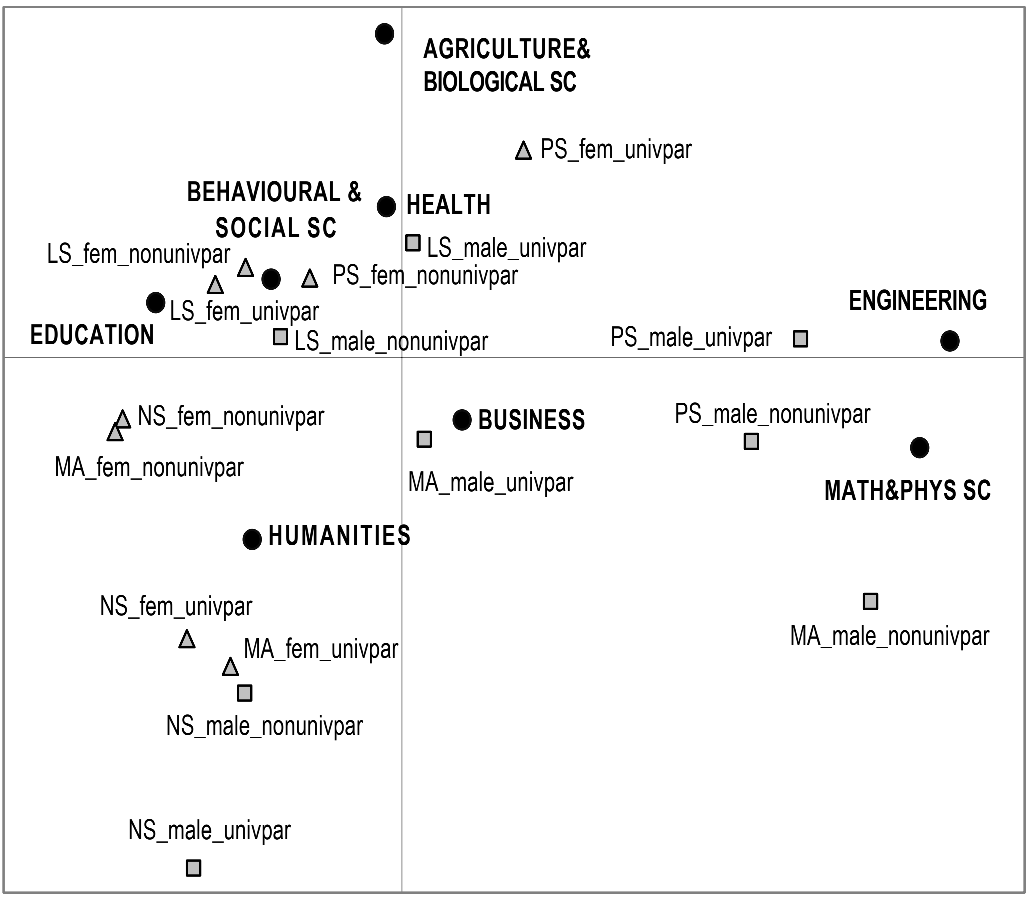


Figure 4. Fields of study for university graduates 10 years after high school graduation. *Note*: fem, female; univpar, parents with university education; nonunivpar, non-university-educated parents

participation in science fields. While male groups with high school science preparation are clearly oriented toward Mathematics & Physical Sciences and Engineering, female groups are oriented toward Agriculture & Biological Sciences. Structural relationships cannot be identified along other axes.

The *factor-analytic* interpretation of the CA map in Figure 4 reveals that choice of fields of study appears to be related to high school orientation and gender, while patterns of association between fields of study and parental education are less defined ($\chi^2 = 303.3$, $df = 105$, $p < .001$). Respondents without high school science preparation tend to complete university programmes in non-science fields. Those with science preparation tend to complete both science and non-science university programmes, and gender differences are visible in their choice of science-based fields of study.

Row profiles oriented toward more "hard" science-based fields (Engineering and Mathematics & Physical sciences) correspond to male groups with more mathematics and physical science preparation. It is interesting to notice how the choice of applied fields is associated with parental education for the male groups. For example, male groups with university parents are likely to go into Engineering if they have physical science preparation, into Business if they have mathematics preparation, and into Health if they have life science preparation. Conversely, male groups with non-university parents more often choose pure science fields such as Mathematics & Physical sciences. This suggests that cultural capital plays a role in the orientation of male students toward occupations that are well rewarded in the labour market (Adamuti-Trache, Hawkey, Schuetze & Glickman, 2006).

Female groups with science orientations are very likely to earn university credentials in "soft" science-oriented fields (Agriculture & Biological Sciences, Health, Behavioural & Social Sciences). The group of females in physical sciences with university parents is more likely to go into Agriculture & Biological Sciences and Health; however, this group also has an above-average contribution toward the hard-sciences fields such as Mathematics & Physical Sciences and Engineering. This suggests that cultural capital may play an important role in ensuring participation by young women in male-dominated fields.



## Discussion

In this paper, by employing longitudinal data to examine the educational trajectories over a period of 10 years, we are able to illuminate the culminating effects of gender, cultural, and academic capital on ultimate post-secondary completion status and, in the case of university graduates, specific fields of educational specialisation. In doing so, we extend the findings of cross-sectional studies that examine only one aspect of this longitudinal story.

Not unexpectedly, we have found that, during the senior high school years, girls and boys tend to complete different types of science courses. That is, female students are more oriented toward life sciences and male students toward preparation in the physical sciences. Parental education plays a determinant role in senior high school course choices made by respondents, in that there is a noticeable correspondence between students with university-educated parents and the completion of science courses in high school. Conversely, course selection made by respondents from families where neither parent attended university corresponded with non-science high school orientations. In addition, we found that students with university-educated parents had well-defined, early plans to continue post-secondary education. Early decisions provide an advantage to those who have the ability and interest in pursuing science-related careers that require long and focused trajectories.

Our research also demonstrates that high school graduates make post-high school choices that correspond with senior secondary academic profiles. Students with stronger mathematics and science orientations (e.g., physical sciences group) were more likely to go directly from high school to university and those with non-science high school profiles were more likely to not attend any post-secondary institution in the first year after school graduation. Those with life sciences and mathematics high school profiles tended to enrol in non-university institutions. Post-high school destinations are further influenced by parental educational backgrounds; the young women and men in this study who attended university directly from high school were more likely than average to have university-educated parents.

High school orientation, gender, and parental education play a significant role in the post-secondary completion of respondents 10 years after high school graduation. University graduation corresponds with high school science orientation and having university-educated parents. Holders of non-university credentials, non-completers, and those who did not attend any post-secondary institution were more likely to come from families where neither parent had attended university.

Both gender and high school orientation are related to the fields of study completed by university graduates. Men who completed mathematics and physical science high school courses were more likely than women with comparable backgrounds to complete academic studies in the fields of physical science and engineering.

According to Bourdieu (1984), knowing the current and future worth of various types of academic credentials is key in the transmission of cultural capital from parents to their children. Further research is needed to illuminate the patterns demonstrated in this study: that is, how educated parents influence their children's academic choices and, in doing so, the ways in which they push their children toward more science-oriented course work. This type of "push" may be related to parents' understandings and interpretations of current trends in the workforce in which scientific and technical careers are valued and rewarded by society. As such, parents may recognise the need for their children to have a solid foundation in mathematics and science. Conversely, parents may simply recognise the utility of exposure to courses such as physics and mathematics as academic (versus non-academic) courses that provide more academic rigour, and more interaction with exacting teachers and academically oriented and motivated classmates.

One key finding is that a background in mathematics and science at the high school level can be beneficial even for students who do not intend to follow scientific educational pathways. In the end, respondents—and especially the young women—may not have earned degrees in science or mathematics, but completion of these subjects in high school led to increased likelihood of attending a university and a much broader range of programme options at the post-secondary level.

Overall, even if it does become more diffuse over the years, cultural capital inherited by respondents exerts an influence on educational outcomes. The correspondence between timing of decisions and parental background demonstrates that, even in a non-selective system, parents clearly influence their children's academic choices. As Matjě and Straková (2005) point out, "even a unified schooling system need not be a guarantee for eradicating socially rooted inequalities" (p. 19). The structure of the Canadian secondary school system may indeed exacerbate low science and mathematics completion rates. This finding reinforces the need to address the question of equity for students coming from families with less education and the need for enhanced responsibility by school personnel to compensate for such differences. Some students are clearly disadvantaged when planning for post-secondary education, and the disadvantage is intensified in relation to the completion of prerequisites necessary to pursue science pathways at the post-secondary level. High school students and their parents need concrete information on specific careers, including information regarding formal and informal intricacies of the post-secondary system, work conditions, and career opportunities. Such information may help individuals determine early whether their personalities, goals, and intended lifestyles would fit into certain career paths. In the case of students from families with less educated parents who have reduced access to resources, high school teachers need to realise the importance of providing social capital in the form of educational and career planning guidance. When parents and school personnel fail to offer students the guidance needed in making educational decisions, individuals accumulate disadvantages that lead to large inequities in access to post-secondary education and labour market opportunities.

The need for more involvement of school personnel in providing information on post-secondary education is confirmed by Pillay (2004). In an analysis of open-ended comments of the 10 years of Paths on Life's Way questionnaire data, he concludes that common across all waves of surveys is the sentiment that high school teachers and counsellors did not prepare respondents for post-high school life. "As a result, [they] felt that they were left to their own resources and abilities" (Pillay, 2004, p. 237).

The post-secondary participation patterns by the mathematics (MA) group are somewhat anomalous in that both MA males and females with non-university parents are more likely to have attended non-university institutions directly out of high school. One reason for this finding could be related to academic achievement and specific course requirements for university admission. In Grade 12, MA students had overall lower performance levels than science students (see Table 1). Although more than 90% of this group took at least one of the major science courses in Grade 11, they did not continue with science in Grade 12. The combination of lower grades and a lack of science courses may have deemed them ineligible for university admission in some academic programmes. However, they were able to rectify this disadvantage by attending non-university institutions (e.g., community colleges). In the context of an articulated (or "seamless") British Columbian post-secondary system, by completing the necessary pre-requisites at non-university institutions, transfer to university studies was possible. And, indeed, 55% of this group did so.

In the final analysis in this paper (Analysis 5), by focusing only on university graduates, we were able to demonstrate that not even the young women with a background in physical science and with university-educated parents were likely to complete university degrees in these fields or in engineering. For men, there was a more clear correspondence between the physical sciences profile and field of specialisation 10 years following high school graduation; parental education had a diminished influence. Interestingly, in this analysis, the proportion of variation explained by the two-dimensional interpretation is quite low. This suggests the existence of more a relevant third dimension with other factors, such as institutionally specific characteristics and influences that correspond with the fields of study undertaken and eventual credentials earned by women who had in earlier levels of study excelled in science.

In light of the findings of this paper, post-secondary personnel, and in particular university mathematics and science faculty, need to examine the structure of their undergraduate and graduate programme offerings. Although individual agency is one determinant of participation in and completion of studies in science and mathematics, the structure of the system—and related policies, practices, and processes–is another determinant (Andres, 2004). Universities play a key role in creating and maintaining the image of various fields in society. As we reported at the beginning of this paper, the proportion of women holding faculty positions at universities is still low, especially in the fields of science and engineering. The final analysis in this paper confirms the persistence of the "leaking phenomenon" along the physical science and engineering pipeline, which highlights the need to shift the emphasis from students choosing science and mathematics programmes to these programmes choosing and retaining qualified students. More interest on the part of science departments toward conducting educational research on issues related to science learning, science teaching, participation in science, graduate outcomes, and faculty development would provide a wealth of information to enlighten policy-making processes and practices within science departments. According to Kemelgor and Etzowitz (2001), departments must consider their "own practices, attitudes, or culture" (p. 241) in order to determine whether they are part of the problem of retaining women in science. Such an examination could determine how, in turn, young women—and, to a lesser extent, men—who have demonstrated through earlier achievements that they are more than capable of excelling in science at the university level succumb to a form of symbolic violence that, through indirect means such as self-exclusion, "cannot function without the complicity of the oppressed to their own oppression … [while] remaining invisible to them" (Le Hir, 2000, p. 135). In other words, why is it that science departments are unable to attract and retain those who are the most qualified to excel in science education and related professions?

Finally, since this research is based on a cohort of high school graduates from 1988, a legitimate question is whether the study findings still provide useful information on current educational and career choices of young women and men. The economic, social, and educational contexts within which science education evolved in British Columbia and elsewhere in the late 1980s and early 1990s have certainly changed. The high-tech job market has expanded and information technology has penetrated a variety of fields, resulting in the creation of new science and engineering occupations. The past two decades have also been characterised by the expansion of feminist theories (Harding, 1986, 1991; Keller, 1985; Kourany, 2002; Schiebinger, 1999) within the field of science, which has led to increasing awareness of the need for inclusive classroom practices, the implementation of affirmative action policies in the United States, and employment equity policies in Canada. In addition, the demographic context has also changed dramatically since immigration in British Columbia has led to an increase in the school population of over 70% during the past 15 years. Large numbers of immigrants coming from Eastern Europe and Asia have brought their own perspectives, interests, experiences, and needs regarding equity issues in education and labour force.

In an analysis of participation in Grade 12 mathematics and science provincial examinations by British Columbian young women and men between 1991/92 and 1999/2000, Adamuti-Trache (2004) documented that participation rates in these subject areas had not increased for both girls and boys, and gender differences continue to be pronounced and largely unfavourable for girls. Hence, the findings and related implications and recommendations reported in this paper remain current. The issue of under-representation of women in science and engineering cannot begin to be resolved as long as starting conditions are unchanged.

## Acknowledgements

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## Notes

1. According to Bourdieu (1986), social capital consists of social obligations or “connections”. Two criteria determine the volume of the social capital a given agent has at her or his disposal: first, the size of the network of connections that the agent can effectively mobilise; and, second, the volume of capital (economic, cultural, or symbolic) possessed by each of those to whom the agent is connected. Coleman (1988) maintains that social capital exists in three forms: as obligations and expectations, as information channels, and as social norms.
2. A 15-year follow-up was conducted recently.
3. When possible, the full label (e.g., “physical sciences”) is used. However, when there is limited space on the maps, abbreviations are used (e.g., “PS”).

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## Appendix. Study variables

### High school academic profiles

The four high school profiles are labelled non-science (NS), mathematics (MA), life sciences (LS) and physical sciences (PS).

### Gender

The two categories of this variable are female (fem) and male (male).

### Parents as Sources of Cultural Capital

We employ a two-category derived variable that measures whether at least one parent has completed university education. This variable is based on mother's and father's education (nine-point scale from 'elementary school' to 'completed graduate degree'). The two categories are labelled non-university parents (nonunivpar) and university parents (univpar) and are used to form the four- (i.e., combined with student gender) and sixteen-category (i.e., combined with gender and high school profile) composite variables .

### Timing Post-secondary Decision

A six-category variable classifies respondents according to the time when they perceived making decisions to participate in post-secondary education. The categories are as follows: students who always knew whether they will continue or not post-secondary education; students who made decisions during Grade 7 (ELEMENTARY) or earlier (ALWAYS KNEW); students who made the decision during Grades 8–11 (GRADE 8–11), in Grade 12 (GRADE 12) or after Grade 12 (AFTER GRADE 12); and those who were still undecided one year following high school completion (UNDECIDED).

### Post-school Orientation—1989

This three-category variable indicates whether students enrolled in the post-secondary studies in 1989 and the type of institution attended. The categories include no post-secondary attendance (NON-POSTSECONDARY), enrolment in institutions other than university (NON-UNIVERSITY) and university enrolment (UNIVERSITY).

### Post-secondary Completion Status—1998

We use a four-category variable that measures the type of post-secondary completion ten years following high school: non-participant (NO POSTSECONDARY PARTICIPATION), post-secondary non-completer (NON-COMPLETERS), non-university graduation (NON-UNIVERSITY GRADS), university graduation (UNIVERSITY GRADS).

### Field of Study—1998

Field of study in 1998 is measured by an eight-category variable, derived from the highest degree reported since 1989 and the programmes of study completed, as identified by respondents. Fields of study are aggregated into the following: Sciences (AGRICULTURE & BIOLOGICAL SCIENCE and MATH & PHYSICAL SCIENCE), Behavioural and Social Sciences (BEHAVIOURAL & SOCIAL SCIENCE), Education (EDUCATION), Engineering (ENGINEERING), Health (HEALTH), Humanities (HUMANITIES), Business (BUSINESS).