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Student Success in First-Year University Physics and Mathematics Courses: Does the high-school attended make a difference?

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This paper considers school factors that contribute to a successful transition from high school to first-year university Physics courses at the University of British Columbia by employing a two-level hierarchical model. It is assumed that there is a relationship between student performance and the high school they graduated from. It is shown that school location and type affect student performance: students from public schools in the Metro Vancouver area perform better in first year compared to students from independent schools and schools in distant communities. The study also considers rankings of schools based on student performance in first-year university Physics and Calculus courses. These university-based rankings differ significantly (essentially in reverse order) from the well-known Fraser Institute rankings based on measures internal to high schools.

Keywords: *University Transition; Performance Gap; School Effectiveness; School Ranking*

Introduction

Student success and experiences in first-year university have recently received increased attention by academic researchers and administrators of post-secondary

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institutions in many countries throughout the world. Research is often framed in terms of transition from school to university and includes themes such as academic advising, curriculum issues, building a community of learners, predicting and promoting success in first-year transition (Parle, 2009). A recurrent theme is the need to bridge the achievement gap between the two educational stages. For instance, findings from the national surveys of first-year Australian students conducted every five years since 1994, consistently show that about one-third of students feel ill-prepared to choose a university course on leaving school (Krause, Hartley, James, & McInnis, 2005). Similarly, Marland (2003) reflects on the need for a UK policy on transition that would include a review of in-school preparation, as well as an analysis of university subject content and teaching methods. The author contends that 'schools must ask themselves to what extent a curriculum that provides poor preparation' (p. 202) might contribute to high drop-out rates from university. This suggests that schools are expected to take responsibility for student progression to higher-level study.

Worldwide, there is a pressure upon schools to develop and improve student outcomes (Hopkins & Reynolds, 2001), and this trend is also noticeable in the Canadian school system. In 2003, the British Columbia Ministry of Education released a report (Brownlie et al., 2003) that proposes several ways to define student achievement. A common approach is to define student success during the school years in terms of performance standards, level of satisfaction, competitiveness and growth. Another approach is to look at long-term outcomes of school education such as post-secondary and career attainments which are an indication of successful transitions from one stage of schooling to another. A recent report by the Ontario Ministry of Education (2010) makes it explicit that policies and procedures that would support students in their transition to any post-school destination (e.g. workplace, college, apprenticeship and university) are part of a province-wide School Effectiveness Framework initiative. These views suggest that student performance in first-year university provides an informative assessment outcome for the quality of secondary education and the high-school attended by students—the so called 'school effect'.

The paper draws on previous research that recommends that high school to first-year university transition should be analyzed through a subject-specific lens in order to capture aspects relevant to each subject (see, e.g. Wingate, 2007). Some studies looked specifically at the transition from school to university for students enrolled in Mathematics (Kajander & Lovric, 2005), English (Smith, 2004) or Music courses (Winterson & Russ, 2009). The primary focus of the current paper is to examine student performance in university Physics courses and the extent to which differences are associated with the high school they attended when controlling for school factors and student characteristics. We consider first-year students at the University of British Columbia (UBC), Vancouver, Canada, who graduated from high schools in the province. In order to retain the maximum influence of student high-school experience, we focus on the first Physics courses taken in the fall term of first year of university studies.

A second objective is to compare the ranking of high schools based on the performance of their graduates in university with a ranking of high schools that emphasizes success in learning as measured solely by overall performance on standardized examinations. We argue that in school rankings based solely on high-school examination results, there is no way to control for differences in students' initial levels of understanding of the subject matter which means it is more difficult to isolate the school effect. However, if the university students all start with a comparable level of subject knowledge, the most successful students will be those who are best able to mobilize what they have learned in high school in order to succeed academically at university. In other words, a successful high school to university transition is a much stronger indicator of secondary education effectiveness than the account of student performance during high school only. Since this study covers the five-year period 2002–2006 when standardized examinations were required for university admission, an important difference between our approach and school assessments based solely on the standardized examinations (e.g. Fraser Institute ranking of British Columbia (BC) high schools) is that the students in this study all met the entrance requirements for UBC.[1] We propose to measure the performance of an individual school by the fraction of their graduates who achieve 'A' grades at university, the fraction who pass the first university course, and the difference between high-school and university marks (UBC Physics Reports, 2000–2006)—a methodology first employed in the UBC Math Reports (1995–2005). The last indicator is particularly important: a smaller grade difference is a likely indicator that the high school is preparing students to enhance their potential for success at the next level.

BC Educational Context

Characteristics of BC Schools

Currently, BC has about 380 secondary schools enrolling over 60,000 Grade 12 students per year (British Columbia Ministry of Education, 2010)—enrolment that has not changed significantly over the last decade. About half of the students are enrolled in Metro Vancouver high schools. The Vancouver school district, situated in the proximity of UBC, enrolls about 10% of the Grade 12 students in the province. Some 10% of G12 students in BC are enrolled in independent schools. These schools provide a particular religious, cultural or educational approach, within curriculum and staff qualification requirement boundaries and receive partial funding from the provincial government, up to 50% of the per student funding for public schools.

Much debate in Canada addresses the issue of whether public or private education, urban or rural schools, small or large schools are more successful in preparing students. Empirical evidence suggests that school location and type are relevant to post-secondary participation and academic performance. For instance, Frenette (2004) argues that access to Canadian colleges and universities is related to distance to post-secondary institution—location affecting particularly students from low-income families. Other studies examine the effect of school type on achievement. For instance, Boerema (2009) who compares students from BC independent and public schools in Grade 12 Language Arts courses argues that private education leads to better results. The author also found a positive relationship between student achievement and the level of educational attainment in the neighborhood surrounding the school. This suggests that the effects of school location and type on school achievement and post-secondary pathways need to be examined in relation to socio-economic status (SES).

Standardized Provincial Examinations

For the years considered in this study, BC had a system of mandatory provincial examinations in Grade 12 subjects. These examinations have been optional since 2007 and finally cancelled as of September 2011, except for Grade 12 Language Arts which is still mandatory. Moreover, as of September 2009, the provincial examinations are optional for university admission. When the provincial examinations were mandatory, the school mark was combined with the provincial examinations mark in a ratio 60/40 to form a high-school grade which was officially used in admission decisions by BC universities. Although there was some school-to-school variability in school marks relative to the provincial examinations marks, particularly for small high schools, on the whole the school and provincial examinations marks were strongly correlated. However, the provincial examinations component ensured the final high-school grades provided a more uniform benchmark for assessing student ability and achievement. For the years considered in this study, a comparison of incoming first-year students who have achieved similar levels of success in their high schools allows one to isolate the 'school effect' on university performance.

School Rankings

From 1975 to 2005, the UBC Mathematics Department published reports showing how students from different high schools and different regions in BC as well as from other jurisdictions (e.g. Alberta and Ontario) performed in first-year Calculus courses (UBC Math Reports, 1995–2005). The UBC Physics Department followed up on this initiative; results are presented and discussed through a high school-to-university transition perspective that includes the impact of high-school course requirements (e.g. participation in Grade 12 Physics provincial examinations) on UBC Physics course performance (UBC Physics Reports, 2000–2006). These surveys show that there is a 'school effect' on student achievement in university Calculus and Physics courses. Students from different high schools entering first year with the same high-school grades in these subjects consistently show different performance in university courses over several cohorts of students—an empirical observation that is thoroughly examined in this paper.

The UBC 'school ranking' argument is built on the assumption that first-year academic performance is an indicator of how students are going to succeed during university and further career stages. As well, a successful transition to first-year university is a first test of school effectiveness outside its own boundaries. Other widely used indicators of school effectiveness such as graduation rates and provincial examination results are less direct indicators of success at university. For example, the Fraser Institute, an independent international non-profit research and educational organization, has developed a widely publicized rating system for schools that has been applied in Canada and the USA. These ratings are not without controversy because the reasons why independent schools tend to do significantly better in the Fraser Institute rankings than public schools are not fully transparent (see, e.g. Cowley & Easton, 2007). In turn some proponents of public education view the Fraser Institute rankings as a threat to the public system. Given the high degree of public interest in the issue of public *vs.* private education, it is in the public interest to examine critically claims by various purported quantitative assessments of school performance. We propose a higher education perspective on this issue through a focussed analysis of comparing high-school and university data. This perspective is grounded in observations from annual survey data that clearly indicate performance in first-year Physics and Mathematics courses is related to the high school that a student attends (i.e. 'school effect').

Conceptual Framework

As pointed out by many researchers, transition into higher education is a major step along one's educational pathway (Reason, Terenzini, & Domingo, 2006) because it marks the stage when students are expected to become more autonomous learners, capable to critically engage with their subject area and to make purposeful educational and career choices (Wingate, 2007). First-year academic performance provides the foundation for future studies, and affects student self-confidence, satisfaction with the program and feelings of belonging to the university community. As Wingate illustrates, the first year of studies impacts on retention since the majority of students who leave the program invoke 'lack of preparation for and understanding of the type of learning that is required' (p. 392). Brady and Allingham (2007) interviewed second-year students who reported that adjusting to university work was difficult because the level of support from their instructors was reduced while the requirements to engage in independent study have increased.

There are a few studies recognizing that first-year transition should be analyzed within disciplinary boundaries because of differences in the process of learning and construction of knowledge that create specific transitional difficulties (Luk, 2005; Smith, 2004; Wingate, 2007). Some of these studies deal with university Mathematics learning and emphasize the 'gap' in Mathematics preparation of incoming students (Kajander & Lovric, 2005). Student participation in advanced Mathematics and Calculus work in high school is singled out as having positive effects on first-year achievement. A recent study shows that university students who took Calculus in high school would increase the final grade in their first-year university Calculus courses by 10 percentage points (Fayowski, Hyndman, & MacMillan, 2009).

With respect to Physics education, research is concerned with low participation in high-school Physics courses as compared to chemistry and biology, and gender issues. Nashon and Nielsen's (2007) interviews with BC science teachers and students reveal that lack of Mathematics competencies hinders many students to take Physics 12. Some respondents attribute the low enrolment in Physics 12 'to the perceived difficulty of the course content or to the "prestige" of physics' (p. 99). Female students are even more likely to avoid Physics 12 which translates into their low participation in more challenging first-year university Physics courses. A recent BC provincial report (British Columbia Ministry of Education, 2006) indicates gendered participation rates in Physics examinations between 2002 and 2006, with only 8% of female students compared to 18% of male students taking Physics 12. Other studies focus on gendered choices of high-school science courses and women under-representation in university science and engineering programs (Adamuti-Trache, 2003; Ayalon, 2003; Cleaves, 2005). High-school curricular differentiation certainly reflects student interests, abilities, prior experiences and general knowledge about school subjects. However this also has an impact on further educational and career pathways.

Many factors affect student participation and performance in demanding school subjects such as Mathematics and Physics. Family background is repeatedly identified among these factors; theories of SES are used to explain school achievement in Mathematics and science (Yan & Lin, 2005) and post-secondary educational attainments in science-related fields (Adamuti-Trache & Andres, 2008). Other studies show the effect of socio-economic indicators describing the neighborhoods surrounding each school (Boerema, 2009; Ma, 2004), which supports the idea that school environments affect student performance. It is not surprising that schools are held accountable for how well students perform academically throughout their school years and beyond. Although university achievement is largely explained by individual attributes and family background, a quite significant unexplained variation is assumed to reflect the quality of the teaching and learning environments of the schools they have attended. As Pike and Saupe (2002) indicate: 'for almost 70 years, researchers have recognized that the quality and effectiveness of the sending high school also has a significant effect on students' performance during college' (p. 188).

Method

Purpose of the Study

In this paper, we approach the issue of school effectiveness from a higher education and subject-specific perspective. The paper addresses the following specific questions:

- What is the relationship between student academic performance in first-year Physics courses and student-level variables such as high-school results and gender? How is this relationship affected by school-level factors such as school type and location as well as school neighborhood indicators (e.g. level of education, home language, income) and school contextual factors such as academic (e.g. participation rates in provincial examinations)?
- Are there differences between schools with respect to socio-economic and academic indicators as well as performance gap in first-year Physics courses?

- Is there any relation between UBC 'school ranking' based on Calculus and Physics first-year results, and other rankings of schools in the province (e.g. Fraser Institute ranking)?

Conceptual Model

The antecedents and correlates of first-year Physics outcome selected for the multilevel modeling analysis consist of the variables shown in Table 1. Differences in outcome can be caused by differences among individuals as well as differences within schools and between schools. In a two-level model, student individual characteristics (i.e. prior achievement and gender) represent Level-1 factors. In order to examine the 'school effect' other kinds of contextual or Level-2 factors are proposed (i.e. school characteristics, school neighborhood SES and specific academic indicators). These factors account for the fact that individual students are 'nested' in their schools and variables at all levels probably contribute to university performance. We acknowledge the data limitations and the simplicity of assumptions regarding the school effect (e.g. the model does not take into account other school factors such as school size or classroom factors such as teacher qualifications). Since there is no direct information on family background, school neighborhood variables (based on students' home postal codes in 2001) offer a broad estimation of SES.

Data

This is an empirical study based on institutional data collected from the University of British Columbia Registrar's office that include information on student gender, graduation year, high-school attended, performance in specific first-year UBC and

Table 1. Conceptual model

Level-1 variables (student-level)	Level-2 variables (school-level)	Outcome
High-school Physics mark	School type (2-category variable)	
Gender (2-category variable)	School location (4-category variable)	First-year Physics mark
	School neighborhood	
	Percentage population with university degrees	
	Percentage population with home language other than English	
	Median family income	
	School academic profile	
	Participation rate provincial examination—Mathematics	
	Participation rate provincial examination—Physics	

Grade 12 courses, as well as data corroborated from BC school reports (e.g. participation in provincial examinations). We also use the 2001 Census data to select several socio-economic indicators (e.g. percentage of population with university degrees, percentage of population with home language other than English, median income) describing the neighborhoods surrounding each school.[2] Five years of student level data (2002–2006) were assembled for the students who entered UBC immediately after graduation from BC high schools and enrolled in the first-term university Physics courses that had Grade 12 Physics courses as pre-requisites. School names are not included and the analysis differentiates schools only by school type (i.e. public, independent) and location (i.e. Vancouver West and Vancouver East,[3] Suburban, Outside Metro Vancouver). The school location geographical areas are ordered by proximity to UBC (i.e. UBC is located within the Vancouver West area).

To examine a case study that compares ranking scales for Vancouver West and Vancouver East high schools, we created a school database including average ranks by school based on several years of data obtained from the UBC Physics and Calculus reports (UBC Math Reports, 1995–2005; UBC Physics Reports, 2000–2006), and Fraser Institute reports (Cowley & Easton, 2007). The UBC ranking methodology is described in detail in the UBC Physics report (see, e.g. 2006): it is based on the percentage of students who passed the course, the percentage who received a letter grade 'A', and by how much the average mark drops in going from high school to university. The school database includes five-year rank averages (2002–2006) for UBC Physics and four-year rank averages (2002–2005) for UBC Calculus. The Fraser Institute rankings are five-year rankings (2001–2005) of the exact overall ratings on a 10-point scale for the Vancouver schools included in the case study.

Research Sample

Most first-year UBC Physics courses have as pre-requisites high-school Physics 12 and Mathematics 12, which were both provincially examinable courses for the period covered by this study. About three-quarters of first-year Physics students have these pre-requisites. Those who did not take high-school Physics 12 but only Physics 11 (and Mathematics 12) could enroll in an Introductory Physics course as a pre-requisite for further Physics courses. Gender differences are significant when comparing enrolment in the two groups of courses with and without the Physics 12 pre-requisite: women represent about one-third of students in the first group of UBC Physics courses and about two-thirds in the Introductory Physics course. This distribution is a result of low participation in Physics 12 by female students—a persistent issue in BC high schools (Adamuti-Trache, 2003). Although women represent about 40% of the first-year Physics students at UBC, since our analysis is focussed only on Physics courses that require Physics 12, the research sample contains 34% women and 66% men.

The research sample contains 4,569 students from 110 BC high schools with at least 10 students enrolled in UBC Physics courses over the five-year period 2002–2006. Table 2 shows descriptive statistics of the variables used in this study. The

Table 2. Descriptive statistics of variables used in the model ($N = 4{,}569$)

Variable name	Categories	Percent/ mean	SD
UBC Physics mark	Continuous (0–100)	73.88	13.41
High-school Physics mark	Continuous (0–100)	87.26	7.67
Gender	Male	65.9	na
	Female	34.1	
School type	Public	93.6	na
	Independent	6.4	
School location	Vancouver West	19.3	na
	Vancouver East	10.5	
	Suburban	63.8	
	Outside Metro Vancouver	6.4	
School SES[a]			
Average % population with university degrees	Continuous (0–100)	25.39	12.18
Average % population with HL other than English	Continuous (0–100)	22.08	14.62
Average median family income ($ thousands)	Continuous	60.33	12.56
School academic indicators[b]			
Average participation rate—Mathematics provincial examinations	Continuous (0–100)	45.93	12.46
Average participation rate—Physics provincial examinations	Continuous (0–100)	23.93	8.41

[a]School SES indicators are based on 2001 Census data provided by the BC Ministry of Education; indicators are derived from the entire 2001 student population in each school by taking into account students' home postal codes.
[b]Participation rates by school are percentage of high school graduates not of the entire student cohort. Average estimates are based on BC Ministry of education school reports for years 2001–2006.
Abbreviation: HL, HL, home language.

grades drop significantly when comparing average results in high-school and university Physics courses (i.e. 87.26 → 73.88). As to be expected, school performance is more homogeneous than university performance across the student population (SD: 7.67 *vs*. 13.41) because all university students have high-school grades above the admission cut-off.

School type and school location are the design variables for this study. Students included in the study come from high schools across the province, with 19% from Vancouver West, 11% from Vancouver East, 64% from Suburban and 6% from Outside Metro Vancouver schools. Most students graduated from public schools (94%) and only 6% from independent schools.

Students enrolled in UBC Physics courses came from schools with slightly higher SES compared to the province. Census 2001 data (BC Stats, 2001) indicate that 17.6% of the BC population had university degrees as compared to 25.4% for the neighborhoods where students in the study reside. Median family income in the province was $54,840 while the average median income for the sample is $60,330. The percentages of population with home language other than English were closer: 21.7% in BC as compared to 22.1% for the research sample. However, it is important to note that first-year Physics students at UBC are coming from schools that had higher participation rates in Mathematics 12 and Physics 12 examinations compared to the province as a whole. For instance, between 2001/2002 and 2005/2006, participation rates in Mathematics provincial examinations were 34% for all BC students compared with 46% for schools sending students to UBC; participation rates in Physics provincial examinations were about 14% for all BC students compared with 24% for schools sending students to UBC (British Columbia Ministry of Education, 2006).

Findings

Multilevel Analysis

We develop a series of multilevel (hierarchical) models to assess the effect of Level-1 and Level-2 variables on first-year Physics achievement (dependent variable). The models are described below: the individual-level variables are indexed by *i* whereas the school-level variables are indexed by *j* (Raudenbush & Bryk, 2002). A summary of results is presented in Table 3.

Unconditional model. Model 1 is testing whether there is any effect of school clustering on the dependent variable. The intercept parameter β_{0j} is treated as a random parameter assuming a deviation (u_{0j}) of the school mean from the overall mean (γ_{00}).

$$Y_{ij} = \beta_{0j} + r_{ij}, \tag{1}$$

$$\beta_{0j} = \gamma 00 + u_{0j}. \tag{2}$$

The parameter estimate for the intercept (γ_{00}) is 73.29 which indicates the fixed effect for this simple model. The intra-class correlation (ICC) ratio indicates how large the intercept random effect is. Denoting the student-level variance of r_{ij} as σ^2 and the school-level variance of u_{0j} as $\tau 00$, the variation in the dependent variable attributable to schools is

$$\text{ICC} = \frac{\tau 00}{\sigma^2 + \tau 00} = \frac{6.97}{6.97 + 174.00} = 0.04.$$

This result shows a small 'school effect' with only 4% of the variance in outcome being accounted by clustering students in schools.

Model 2. The Level-2 model examines specific school and neighborhood factors that account for the 'school effect'. The intercept Equation 2 is modified when controlling

Table 3. Summary of parameter estimates for two-level models of first-year university performance—UBC Physics mark ($N = 4{,}569$ students, $n = 110$ schools)

Parameter	1. Unconditional model		2. Level-2 model (school level)		3. Level-1 model (student level)		4. Full model	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Fixed effects								
Intercept (γ_{00})	73.29***	0.34	76.04***	2.85	72.03***	0.41	70.33***	2.85
School type (ref = public) IND (γ_{01})			−2.14*	1.07			−0.48	1.06
School location (ref = Vancouver West)								
VE (γ_{02})			1.60	1.63			3.60**	1.68
SUB (γ_{03})			0.72	1.37			2.14	1.40
OMV (γ_{04})			−1.36	1.85			0.85	1.83
School SES								
EDU (γ_{05})			0.14**	0.05			0.17**	0.05
HL (γ_{06})			−0.04	0.03			0.03	0.03
INC (γ_{07})			−0.12**	0.04			−0.07	0.04
School academic indicators								
MAEX (γ_{08})			0.05*	0.03			0.01	0.02
PHEX (γ_{09})			−0.01	0.04			−0.03	0.03
PHYS (γ_{10})					1.09***	0.03	1.09***	0.03
Gender (male = ref)								
FEM (γ_{20})					1.98***	0.35	1.96***	0.34
Random effects—variance estimates								
Within school variance (σ^2)	174.00***	3.69	174.08***	3.69	114.90***	2.47	114.73***	2.46
Intercept variance (τ_{00})	6.97***	1.83	4.56**	1.49	12.78***	2.30	8.03***	1.75
High-school Physics mark variance (τ_{11})					0.04**	0.01	0.04**	0.02

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.001$.

Abbreviations: SE, standard error; VE, Vancouver East; SUB, suburban; OMV, Outside Metro Vancouver; EDU, percentage with university degrees; HL, percentage with home language non-English; INC, median family income; MAEX and PHEX, participation rates in Grade 12 Mathematics and Physics examinations; PHYS, high-school Physics mark; FEM, female students.

for these factors (see notations in Table 3):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}{}^{*}\text{IND} + \gamma_{02}{}^{*}\text{VE} + \gamma_{03}{}^{*}\text{SUB} + \gamma_{04}{}^{*}\text{OMV} + \gamma_{05}{}^{*}\text{EDU} \\ + \gamma_{06}{}^{*}\text{HL} + \gamma_{07}{}^{*}\text{INC} + \gamma_{08}{}^{*}\text{MAEX} + \gamma_{09}{}^{*}\text{PHEX} + u_{0j}. \tag{3}$$

Results show a significant negative effect on UBC mark for independent schools. Although none of the regression coefficients is significant, students from Vancouver East and Suburban schools are doing better than students from Vancouver West, while those from Outside Metro Vancouver are behind. An index of the variance explained at Level 2 by the set of variables included in the model is obtained by comparing the intercept variance across Model 2 and Model 1 is as follows:

$$\frac{\tau 00,_{\text{Model 1}} - \tau 00,_{\text{Model 2}}}{\tau 00,_{\text{Model 1}}} = \frac{6.97 - 4.56}{6.97} = 0.35,$$

which indicates that 35% of the 'school effect' is due to school and neighborhood characteristics.

Among the SES indicators, level of education and income have significant effects: each percent increase in the proportion with university degrees increases the UBC mark by 0.14 points and each increase by \$1,000 in average income decreases the UBC mark by 0.12 points. There is a slight positive effect of participation rate in the Mathematics examination: each percent increase in the rate increases the UBC mark by 0.05 points.

Model 3. This is a Level-1 random coefficient model (Equation 4) which includes student-level variables (i.e. Grade 12 Physics mark centered around the grand mean, gender), assumes random effects of the intercept caused by between school differences, random effects of the slope introducing the Grade 12 Physics mark due to within school differences in achievement, and fixed effects for gender.

$$Y_{ij} = \beta_{0j} + \beta_{1j}{}^{*}\text{PHYS} + \beta_{2j}{}^{*}\text{FEM} + r_{ij}, \tag{4}$$

$$\beta_{0j} = \gamma_{00} + u_{0j}, \tag{5}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}, \tag{6}$$

$$\beta_{2j} = \gamma_{20}. \tag{7}$$

Table 3 shows that female students obtain about two points more in the UBC mark, which also increases by more than one point for each additional point in the Grade 12 Physics mark. As compared to Model 1, there is a clear drop in the within-school variance which suggests that the UBC mark is largely predicted by student-level variables. The proportion of the variance explained at Level 1:

$$\frac{(\sigma^2_{,\text{Model 1}} - \sigma^2_{,\text{Model 3}})}{\sigma^2_{,\text{Model 1}}} = \frac{174.00 - 114.90}{174.00} = 0.34.$$

Model 4. Finally, we construct a full model by adding school-level variables to Model 3. The model takes into account only the main effects by school-level and student-level variables. It assumes random effects of the intercept and the slope of Grade 12 Physics mark, and fixed effects for gender when controlling the between school variability by school factors. Model 4 is based on Equation 4 where β_{0j} is modeled by Equation 3, β_{1j} by Equation 6 and β_{2j} by Equation 7.

In explaining the UBC outcome, school location is definitely more important than school type. The average UBC mark is only 0.48 points less for students from independent schools compared to those from public schools. However, as compared to students from Vancouver West schools, those from Vancouver East, Suburban and Outside Metro Vancouver schools obtain UBC marks that are 3.60, 2.14 and 0.85 points higher, respectively. Among the control factors, student-level variables have the most significant effect and their estimates are practically unchanged in Model 4 compared to Model 3. Neither the strong relation between university and high-school grades nor the gender effect is surprising. When student and school variables are included, the school neighborhood SES control effects are only slightly changed. School academic indicators do not contribute to the model. However, the combined effects of factors highlight the significance of school location, originally proposed to examine the 'school effect'. When controlling for all variables, Vancouver East students score highest in UBC Physics courses (i.e. the grand mean of 70.33 is significantly increased by 3.60 points).

The 'School Effect': Performance gap and school-level factors

Since the modeling exercise shows a relatively small school effect, it is important to explore in more detail how achievement profiles differ by school location and type—a common basis for comparison in research and reporting. We also discuss the performance achievement gap which is an important aspect of a successful educational transition. We take a socio-economic approach to illustrate that SES differences between schools can be associated with differences in the student performance gap in Physics.

Socio-economic factors differ across BC high schools (Table 4(a)). Vancouver West schools have the largest university-educated population (44%), as compared to the other geographical areas: Suburban (22%), Vancouver East (19%) and Outside Metro Vancouver (14%). On the other hand, Vancouver East schools have the highest proportion of the population with a home language other than English

Table 4. School characteristics ($N = 4{,}569$ students, $n = 110$ schools)

	Vancouver West			Vancouver East			Suburban			OMV			BC		
School type	Public	Independent	All	Public	Independent	All	Public	Independent	All	Public	Independent	All	Public	Independent	All
(a) Socio-economic and academic indicators															
Percentage population with university degrees	44	47	44	19	22	19	22	21	22	12	22	14	25	33	25
Percentage population with home language non-English	27	19	26	46	34	45	19	15	19	7	3	6	22	17	22
Median family income ($ thousands)	65.7	76.9	67.3	43.8	45.9	43.9	61.6	63.5	61.6	51.8	61.7	53.1	59.8	67.7	60.3
Average participation rate—Mathematics provincial examinations	53	57	54	46	40	46	44	49	44	35	57	38	45	53	46
Average participation rate—Physics provincial examinations	28	25	28	22	13	22	24	20	24	17	40	19	24	24	24
(b) Academic grades of students attending UBC															
N	752	132	884	452	27	479	2,820	95	2,915	252	39	291	4,276	293	4,569
n	9	5	14	9	2	11	61	7	68	15	2	17	94	16	110
Average UBC Physics mark	75.31	72.85	74.95	75.46	73.04	75.32	73.65	71.87	73.59	71.57	68.64	71.18	74.00	71.99	73.88
Average school Physics mark	86.75	86.53	86.72	85.48	89.41	85.70	87.57	86.69	87.54	89.01	86.33	88.65	87.29	86.82	87.26
Percentage drop in marks[a]	13.19	15.81	13.57	11.72	18.31	12.11	15.90	17.10	15.94	19.59	20.49	19.71	15.23	17.08	15.33

[a]This is defined as (average UBC mark − average school mark)/(average school mark) × 100.

(45%) compared to Vancouver West (26%), Suburban (19%) and Outside Metro Vancouver (6%) schools. Differences between Vancouver West and East school neighborhoods are also very pronounced in terms of median family income ($67,300 *vs.* $43,900), with the other two geographical areas situated in between. For each region, there are socio-economic differences between public and independent schools. These differences are most pronounced in Vancouver (both West and East areas) and Outside Metro Vancouver schools, and are minimal in Suburban schools. There is also some variability in exam participation rates, especially in Mathematics, higher rates being associated with more affluent neighborhoods with higher proportions of university educated people and to some extent, larger proportions of immigrants. We should also note that the average participation rates in provincial examinations are significantly higher for the schools included in the study compared to all BC high schools. Thus, between 2001/2002 and 2005/2006, average participation rates in the province were 34% in Mathematics and 13% in Physics provincial examinations (British Columbia Ministry of Education, 2006) as compared to 46% and 24% for all schools considered in the study. These differences show that students who attended UBC came from schools that were more likely to motivate students who take Grade 12 Mathematics and Physics courses, to help them succeed in these subjects and ultimately gain university admission in prestigious science and engineering programs.

Table 4(b) shows the average UBC Physics grades for students who attended UBC and the corresponding average school Physics grades, and can be interpreted in relation to the school contextual factors presented in Table 4(a). Overall, we notice some decrease in UBC Physics performance when moving from Vancouver East and West schools to Suburban and Outside Metro Vancouver schools. Overall, students from public schools perform better than those from independent schools (74.00 *vs.* 71.99), and students from Vancouver East obtain the best results (75.32) as compared to those from Vancouver West (74.95), the Suburban (73.59) and Outside Metro Vancouver schools (71.18). There is significant variability in UBC grades across schools ranging from 68.64 for independent schools Outside Metro Vancouver to 75.46 for public schools in Vancouver East. However, with respect to high-school Physics grades, one can notice a variation in the opposite direction with lowest Physics 12 grades obtained by students from Vancouver East (85.70) and the highest by students from Outside Metro Vancouver high schools (88.65). This leads to a performance gap (i.e. the relative drop in grade when transitioning from high school to university) that varies between the lowest 11.72% for Vancouver East public schools to the highest 20.49% for independent schools Outside Metro Vancouver.

By inspecting Table 4(a) and (b), one can infer that the better performance in UBC Physics courses can be either associated with more educated and affluent school neighborhoods or with larger proportions of immigrants. However, it is noteworthy to mention that the highest UBC average grade (75.46) is not associated with schools from the wealthiest and the most educated neighborhoods (i.e. Vancouver West), but with public schools from the neighborhoods with the largest percentage of immigrants and by far the lowest median family income (i.e. Vancouver East). These students experience the lowest change in grades (11.72%), which may suggest an accurate high-school grading and a solid preparedness for university work. It is also possible that students from immigrant communities are more highly motivated to succeed.

Although high-school performance is often associated with high SES which leads to ranking independent schools higher than public schools (see, e.g. Cowley & Easton, 2007), this relationship does not appear to carry forward to university performance, especially in Mathematics and Physics. For instance, this socio-economic advantage is not reflected in UBC performance which is higher for first-year students from public schools.

The trends suggest that coming from a remoter community may not in itself be a reason for lower performance. A weaker performance at the university level could be the result of poor high-school preparation due to a shortage of academic specialists to teach senior level Mathematics and Physics courses, especially outside the Metro Vancouver region. It may also reflect the loss of support systems inherent when moving away from home and the difficulty to adjust socially to a new environment in the metro area.

The Meaning of School Ranking

As presented in the Background section, our inquiry into the issue of school effectiveness and student success in Physics is grounded in the practice of annual 'school rankings'. In this paper, we have postulated that success at the next educational level should be a criterion for assessing school effectiveness and thus 'ranking'. In particular, we adopt a higher education perspective and suggest that the effectiveness of a school in a specific subject should be measured by the performance of its students in their first-year of university studies in that subject or related subject. To illustrate the consistency of our approach, we evaluate the correlation between school rankings in first-year Physics and first-year Calculus courses, and compare them with the Fraser Institute ranking over the same period of time. While UBC school ranking is exclusively based on the academic performance (either Mathematics or Physics) of first-year UBC students in relation to their school performance in each subject, the Fraser Institute ranking is based on the entire student population in each school regardless of their destination.

To illustrate that 'school ranking' changes according to the employed criteria, we contrast three school rankings based on UBC Physics performance, UBC Calculus performance and the Fraser Institute evaluation of schools. We present a case study that compares these rankings for Vancouver West and Vancouver East schools in order to reduce the bias of geographic proximity to a university that may impact student choice. Table 5 contains the average ranks for Vancouver public and independent schools and the paired correlations of rankings.

There is a significant positive correlation between the two UBC rankings, but remarkably they are both negatively correlated with the Fraser Institute ranking.

Table 5. Mean ranks by school type and correlation of ranking (Vancouver schools)

	Mean ranks		
	Public ($n = 17$)[a]	Independent ($n = 7$)	Correlation coefficients
UBC Physics ranking	10.88	15.29	UBC Physics—UBC Mathematics $r = 0.545^{**}$
UBC Mathematics ranking	9.38	15.02	UBC Physics—Fraser Institute $r = -0.252$
Fraser Institute ranking	14.81	5.00	UBC Mathematics—Fraser Institute $r = -0.334$

Note: Lower mean rank values correspond to higher ranking on the performance scale.
[a]Only 24 Vancouver schools have mean ranks available over the period of study in all reports.
$^{**}p < 0.05$.

Furthermore, the independent schools are near the top in the Fraser Institute ranking (mean for independent schools is at the 21st percentile), whereas they are significantly below the average (63rd percentile) in the UBC Mathematics and Physics rankings.

The UBC rankings measure the success, in first-year Physics or Calculus courses, of graduates from different high schools in order to inform teachers in these two subjects how successful they are in preparing their high-school students for UBC. The rankings only include students attending UBC and penalize schools that do not give students a realistic evaluation of their potential for success in university level courses. The Fraser Institute ranking includes all students attending a particular school, targets parents, and penalizes schools that have fewer students in academic programs. Accordingly, in the Fraser Institute rankings, independent schools rank higher than public schools and Vancouver West public schools rank higher than Vancouver East public schools. In UBC rankings, public schools rank considerably higher than independent schools and there is no apparent difference between the rankings of Vancouver East and Vancouver West public schools, contrary to popular opinion. The UBC school rankings offer a higher education perspective on how to assess school effectiveness in preparing their students to succeed academically at the university.

Conclusions

Summary and Discussion

Since our analysis includes only students who graduated from high school in the same year they enrolled at UBC, and only participation in the first term Physics courses is considered, we claim that our findings are illustrative for the high school to university transition in Physics-related programs. The subject-specific perspective employed in the study emphasizes particular aspects relevant to success in this academic discipline such as prior preparation in the subject, gender, as well as school academic and socio-economic contextual factors. Mathematics and Physics are subjects that require continuous effort by students, as well as a school environment challenging them to work hard and be persistent in these subjects.

The main results of our multilevel analysis is that university performance in Physics is largely determined by high-school performance (and gender), although a 'school effect' is noticeable. We describe the 'school effect' in relation to school type and location, which is often the basis for comparison in research and reporting (see, e.g. Boerema, 2009; Cowley & Easton, 2007; Frenette, 2004). Our study shows that, with respect to Physics and Mathematics, BC public schools are more effective than BC independent schools in preparing students for success at university. One step further in understanding achievement during school years and beyond is to account for school contextual factors. The current study shows that school SES contributes to some extent explaining students' achievement in first-year Physics courses. We should, however, recognize that the administrative and institutional data employed in the study allow for an interpretation of a 'school effect' exclusively in terms of specific structural and social school-level factors. As Reay, David, and Ball (2001) argue 'a school effect' or 'institutional habitus' should be understood as the culture of the school, as well as relational issues and priorities that have a significant impact on high-school students and their higher education plans and future success. While research based on large-scale institutional data reveals systemic patterns observed in the school to university transition, additional information on the quality of teachers, teaching methods and resources, course and career advice, higher education aspirations would likely help to better understand the observed 'school effect'.

Equally important is for students to experience a smooth transition into university studies and to maintain or enhance their performance levels in the subject (Kajander & Lovric, 2005; Wingate, 2007). A performance gap is not unusual when students enter a new educational phase; however, a significant drop in grades may indicate their inability to cope with more challenging knowledge, as well as lack of discipline and study habits for pursuing higher education. Our findings suggest that more accurate student assessment in the high-school subject (Mathematics, Physics) leads to better performance in related university courses. Neither the strong relation between university and high-school grades nor the gender effect is surprising. Our findings show that female students have a better performance than male students in first-year Physics courses.[4] Similar gender effects are obtained for student performance in university Mathematics courses (Fayowski et al., 2009). Other studies show that, in general, female students outperform male students during the first-year of university (Win & Miller, 2005). However, Hazari, Tai, and Sadler (2007) demonstrate that female students underperform in introductory university Physics courses once controlling for academic background (i.e. female students who come into university with higher grades do not perform significantly better) and especially for the high-school Physics curriculum and affective variables (e.g. father encouragement, family's belief that science leads to a better career).

Our study is based on the assumption that school environments that encourage students to take upper-level Mathematics and science courses, and classroom environments that stimulate learning in such demanding subjects are essential factors of participation, performance and persistence along science-related educational trajectories. Therefore, we expected that school participation rates in Physics 12 and Mathematics 12 would be more significant in modeling first-year Physics achievement. Although the model does not provide evidence in support of this matter, the descriptive analysis shows that schools with higher participation in Mathematics and Physics provincial examinations, which meant that more students were taking Mathematics 12 and Physics 12 courses, are associated with more affluent neighborhoods with higher proportions of university educated people, higher median income, and to some extent, larger proportions of immigrants. It is from these ethnic diverse neighborhoods that first-year students with higher performance in Physics courses are recruited: better performance in UBC Physics courses resulted from highly educated neighborhoods (i.e. Vancouver West) and/or neighborhoods with larger proportions of immigrants (i.e. Vancouver East). Students who enroll in schools situated in more affluent geographical areas are likely to come from wealthier and more educated families, and/or have peers with such backgrounds. Since more educated parents are more likely to understand the benefit of solid Mathematics and science preparedness, they may influence schools in challenging students to participate in provincial examinations. Similarly, many immigrant students are inclined to take Mathematics and science courses in high school, thus their representation in a school may affect the school's receptiveness toward these subjects (Garnett, Adamuti-Trache, & Ungerleider, 2008).

Study findings illustrate that the rankings of schools based on student performance in first-year university Physics and Calculus courses are correlated; however, these university-based rankings differ from other quantitative school performance measures internal to the high schools, for instance, the Fraser Institute rankings consistently indicate that better school performance is associated with higher SES which leads to ranking independent schools higher than public schools. Since this relationship does not appear to carry forward to university performance, especially in Physics and Mathematics, we question the Fraser Institute ranking methodology and we contend that success at the next educational level should be a better criterion for assessing high-school effectiveness. Our conclusion supports recent initiatives in the USA to create an integrated data system that could provide high schools with timely information about their graduates' actual college outcomes. As noted by Kirst and Venezia (2010), 'high schools ... are not connected to their local postsecondary institutions, and policies such as disconnected standards perpetuate the divide between the systems' (p. 1). The UBC school rankings are essentially feedback reports that inform high schools on how effectively they have prepared their students to succeed at university in particular subjects.

Implications for Policy and Practice

A major policy implication that emerges from this study is that it is important to consider the role of provincial examinations on students' university achievement. Until recently, all students from BC who wished to attend university had to write provincial examinations. For instance, between 2001/2002 and 2005/2006, average participation rates for all BC students were 34% in Mathematics provincial examinations and 13% in Physics provincial examinations (British Columbia Ministry of Education, 2006). Participation rates in provincial examinations dropped significantly in the years following the implementation of a new high-school graduation program where students receive full credit for Grade 12 courses (except in Language Arts) even if they do not write provincial examinations. As of September 2009, it was also no longer mandatory for students to write provincial examinations (except in Language Arts) for university admission. As a consequence, the proportion of Grade 12 BC students who wrote provincial examinations in Principles of Mathematics 12 (required for admission to UBC Science, Engineering and Business programs) was 31% (examinations written during the school year 2006/2007), 26% (2007/2008) and 15% (2008/2009). Significantly lower percentages of students wrote Physics 12 provincial examinations: 11% (2006/2007), 9% (2007/2008) and 5% (2008/2009) (British Columbia Ministry of Education, 2009).

There is undeniable evidence that writing a provincial examination in a particular subject and being realistically evaluated during senior high-school years has a positive effect on student performance in first-year university courses (Bluman & Smith, 1977). As demonstrated in this study, participation and good performance in examinations gives a good indication of student academic preparedness for first-year university courses. On one hand, preparing for an examination requires constant and systematic studying. On the other hand, assessment outcomes give students a sense of academic success along educational trajectories. Needless to say that it also helps teachers and university instructors identify gaps between prescribed and achieved learning outcomes, and supports policies made by high-school and university administrators.

For the years considered in this study, the final high-school grades included a provincial examination component. This uniform benchmark for assessing student ability and achievement prior to university and program admission could be a reason why the 'school effect' on first-year university performance was relatively low. The recent policy change that completely eliminated Grade 12 provincial examinations in Mathematics and Physics will likely have implications for school and university practices. On one hand, schools and teachers may feel less restricted in terms of following standardized curriculum which may hopefully allow for creativity in employing new teaching resources and methods. On the other hand, one can expect that the absence of standardized provincial examinations will enhance the school-to-school variability in preparing students in demanding subjects like Mathematics and Physics with consequences on students' first-year university transition. In addition, universities are expected to develop new and fair admission requirements in order to reduce the effect of inevitable school grades inflation. Since student assessment is a major area of interest for higher education research, policy and practice, it will be interesting to see how student transition from high school to university will be approached in BC in a post-standardized provincial examinations era. Especially, in the absence of provincial examinations, research should be more explicitly directed toward understanding what are successful schools (or some teachers) doing in order to motivate students, support their learning in a particular subject and prepare them for success at the next educational level.

Notes

1. All students considered in this study started off with a more or less common minimum level of preparation in the subject matter since provincial exams were required.
2. The 2001 census indicators are based on school headcounts and the home postal codes of students attending each school (data provided by the BC Ministry of Education).
3. We examine Vancouver West and East separately because we noticed differences in UBC performance over time.
4. Same result is obtained without controlling for high-school physics grades and for school-level variables.

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