Socio-economic Status and Academic Achievement Trajectories from Childhood to Adolescence

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Although a positive relationship between socio-economic status and academic achievement is well-established, how it varies with age is not. This article uses four data points from Canada's National Longitudinal Study of Children and Youth (NLSCY) to examine how the academic achievement gap attributed to SES changes from childhood to adolescence (ages 7 to 15). Estimates of panel data and hierarchical linear models indicate that the gap remains fairly stable from the age of 7 to 11 years and widens at an increasing rate from the age of 11 to the age of 15 years. Theoretical arguments and policy implications surrounding this finding are discussed.

Key words: SES, academic achievement, early adolescence, growth model

Bien qu'on sache depuis longtemps qu'il existe un lien entre le statut socioéconomique et le rendement scolaire, il reste encore à déterminer dans quelle mesure ce lien varie en fonction de l'âge. Cet article a recours à quatre points de données tirés de l'Enquête longitudinale nationale sur les enfants et les jeunes (ELNEJ) du Canada en vue de mesurer comment les différences dans le rendement scolaire attribuées au statut socioéconomique changent de l'enfance à l'adolescence (de 7 à 15 ans). Des estimations tirées de données recueillies au moyen d'un panel ainsi que des modèles hiérarchiques linéaires indiquent que les différences demeurent relativement stables entre 7 ans et 11 ans et deviennent de plus en plus marquées entre 11 ans et 15 ans. Les auteurs font l'analyse des arguments théoriques et des incidences sur les politiques entourant cette conclusion.

Mots clés : statut socioéconomique, rendement scolaire, début de l'adolescence, modèle de croissance.

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Extensive research in the sociology of education offers conclusive evidence of a positive relationship between family socio-economic status (SES) and the academic achievement of students (Sirin, 2005; White, 1982). In this research strand, it is fairly standard to define family SES as the relative position of individuals or families within a hierarchical social structure, based on their access to, or control over, wealth, prestige, and power (Mueller & Parcel, 1981), although no strong consensus exists on the conceptual meaning of SES (Bornstein & Bradley, 2003). And, a single SES variable is operationalized through measures characterizing parental education, parental occupational prestige, and family income (Gottfried, 1985; Hauser, 1994; Mueller & Parcel, 1981).

The relationship between family SES and academic achievement is referred to in the literature as a *socioeconomic gradient* because it is gradual and increases across the range of SES (Adler et al., 1994; Willms, 2002, 2003), or as a *socio-economic gap* because it implies a gap in academic achievement between students of high and low SES families. Scholars have shown that a socio-economic gap in the early school years has lasting consequences. Particularly, as low SES children get older their situation tends to worsen. Because of their relatively poor skills, they are prone to leave school early (Alexander, Entwisle, & Kabbani, 2001; Battin-Pearson et al., 2000; Cairns, Cairns, & Neckerman, 1989; Janosz, LeBlanc, Boulerice, & Tremblay, 1997; Rumberger, 2004; Schargel, 2004) and are less likely to be assigned to the college preparatory track (Condron, 2007; Davies & Guppy, 2006; Krahn & Taylor, 2007; Maaz, Trautwein, Lüdtke, & Baumert, 2008; Schnabel, Alfeld, Eccles, Köller, & Baumert, 2002). In the longer term, they are less likely to enter the labour market successfully or pursue post-secondary education (Alexander, Entwisle, & Olson, 2007; Cabrera & La Nasa, 2001; Kerckhoff, Raudenbush, & Glennie, 2001; Organisation for Economic Co-operation and Development [OECD] & Statistics Canada, 2000; Raudenbush & Kasim, 1998).

That educational and labour opportunities are unequally distributed among individuals of varying SES poses concerns and challenges in societies that value equal opportunity irrespective of socio-economic background. Therefore, a great deal of effort has gone into explaining and understanding the processes that configure socio-economic gradients.

For instance, Willms (2002, 2003, 2006) has proposed a framework to examine socio-economic gradients, which consists of three critical aspects:

1. the degree of inequalities in educational outcomes attributable to SES (the slope),
2. the extent to which variation in educational outcomes is explained by SES (the R-squared), and
3. the functional form of the relation between SES and educational outcomes (i.e., linear or curvilinear).

National and international comparative studies have applied Willms's framework with fruitful policy guidelines (OECD, 2003, 2004, 2007; OECD & Statistics Canada, 1995; Willms, 2002, 2003, 2006; Willms & Somers, 2001).

Furthermore, researchers have examined the underlying family processes that mediate the relationship between SES and educational outcomes (Chao & Willms, 2002; Guo & Harris, 2000; Hanson, McLanahan, & Thomson, 1997; Lareau, 2002; Yeung, Linver, & Brooks-Gunn, 2002; Willms, 2003); the extent to which socioeconomic gaps in academic achievement are consistent across subject areas (Ma, 2000); the school practices that can effectively reduce achievement inequalities across SES groups (e.g., Cohen, 1982; Rutter & Maughan, 2002; Scheerens, 1992); the extent to which the effect of SES on student performance varies between communities and why (OECD, 2003, 2004, 2007; Willms & Somers, 2001); and how economic and political forces act upon the relationship between socio-economic background and schooling outcomes over time (Heath & Clifford, 1990; Willms & Raudenbush, 1989).

What has been less extensively investigated is whether socio-economic gradients change with increasing age and how. Understanding this topic is crucial for policy research because it can offer insights into how and when inequalities reproduce and it can be altered over the life course. Researchers know that a gap in academic achievement between children of high and low SES families emerges early in life (Entwisle & Hayduk, 1982; Hertzman, 1994; Hertzman & Weins, 1996). But, the literature is more equivocal regarding the trajectory of the gap over the course of schooling. Evidence is inconclusive, typically hinging on limited

methodological designs, and has been interpreted differently. Despite these caveats, most research lends support to a widening gap with increasing age.

CUMULATIVE ADVANTAGE THEORY

The purported phenomenon of a widening gap with age is often referred to in the literature as the *cumulative advantage process*. Merton (1973) first invoked this term to explain increasing success in scientific careers; his research has been extended to investigate stratification in other social domains. The central claim of this process is that the advantage of one individual over another accumulates over time. The advantage in question is typically a key resource in the stratification process, for example, academic achievement for school success. The cumulative advantage process explains growing inequality when current levels of accumulation directly affect future levels of accumulation. And, an individual who is behind at a point in time has difficulty in catching up with the rest.

Psychologists and sociologists draw on the observation that inequalities between children of low SES families and high SES families tend to increase as they move from kindergarten to high school to explain that learning follows a cumulative advantage process (Bast & Reitsma, 1998; DiPrete & Eirich, 2006; Jensen, 1966, 1974). They argue that learning develops in a hierarchical fashion: more complex forms of learning build on simpler forms of learning. Therefore, inequalities at any stage create still greater inequalities at later stages. Although the cumulative advantage theory does not adopt a theoretical or explanatory notion, scholars have examined several school and non-school processes that may underlie this phenomenon.

School Influences on the Gap

Studies favouring school influences argue that because school practices are not neutral in their treatment of students of varying socio-economic backgrounds, schools tend to produce a widening gap. For example, researchers have suggested that recognition and reward of cultural resources of students from advantaged backgrounds (Bourdieu, 1977; Condron, 2007) and disproportionate assignment of low SES students to lower school tracks (e.g., Kerckhoff, 1993; Pallas, Entwisle, Alexander, &

Stiuka, 1994) lead to increasing inequalities between high and low SES students over time. Further research has shown that the effects of tracking depend in part on the way tracking is organized (Gamoran, 1992).

In the United States and Canada tracking occurs with students choosing or being assigned to classes working at different levels or covering different content (i.e., course-level grouping). Broadly speaking, under this tracking approach, high SES students are more likely in disproportionate numbers to enrol in advance courses leading to college education and low SES students are more likely to enter vocational programs (Alexander, Entwisle, & Olson, 2007; Davies & Guppy, 2006; Gamoran, Nystrand, Berends, & LePore, 1995; Hallinan, 1994; Hoffer, 1992; Jones, Vanfossen, & Ensminger, 1995; Krahn & Taylor, 2007; Schnabel et al., 2002). As a result, students taking college preparatory courses increasingly diverge from those less academically inclined in terms of their academic achievement (Gamoran et al., 1995; Hallinan, 1994; Hoffer, 1992).

Non-School Influences on the Gap

A competing argument is that non-school influences are the major gateway for increasing inequalities. For instance, Alexander, Entwisle, and Olson (2001) and Downey, von Hippel, and Broh (2004) maintain that family influences during summer vacations throughout elementary grade years lead to a widening gap in academic achievement. They found evidence that the SES gap grows faster during summer than during the school year. Thus, rather than exacerbating inequalities, these scholars maintain that schools actually play a compensatory role, which is often neglected, in mediating the effect of family SES on academic achievement because achievement is compared on an annual basis.

Goldthorpe (1996) and Breen and Goldthorpe (1997) argue that students make educational decisions by calculating their costs, anticipated benefits, probability of success, and the attractiveness of alternative options. Because these aspects vary among SES groups, the degree to which students of different socio-economic backgrounds view schooling as desirable varies as well. As low SES students get older and start to have their first serious thoughts about future careers, they may regard the prospect of exerting great effort in school as *not worth it*, given the antici-

pation of eventually paying high tuition fees for university while lacking resources to afford them. Similarly, Guo (1998) argues that students begin to understand during early adolescence how society's opportunity structure operates. They become aware that society rewards individuals of varying SES differently. Students of low SES families realize they are likely to be excluded from desirable jobs and, consequently, they go through a process of disillusionment. As a result, these scholars anticipate a widening SES gap with age due to students' being less motivated and placing less effort into their academic activities.

THIS STUDY

The present study examines the trajectory of the academic achievement gap of high and low SES Canadian students from childhood to adolescence. Focusing on mathematics academic performance, we sought to establish whether the achievement gap associated with SES widens with increasing age. We do not see this study as a test of the relative validity of the theoretical processes discussed above. Rather, we simply wish to acknowledge that a variety of theoretical arguments are offered to explain how the academic achievement gap attributed to SES may change over the course of schooling and that most of them suggest it widens. Although we do not model these processes, we do feel our study provides an initial step to address this topic in Canada, using a sophisticated and appropriate methodological design.

Prior empirical evidence stems largely from cross-sectional data, two- or, at best, three-time point longitudinal designs (e.g., Guo, 1998; Hoffer, 1992; Ross & Wu, 1996; Willms, 2002). Cross-sectional designs confound age and cohort effects; two-time point designs provide a very limited source of intra-individual variability to study change in the gap (Baltes, Reese, & Nesselroade, 1988; Bryk & Raudenbush, 1987, Raudenbush & Bryk, 2002). Instead, our study advances previous research by drawing on a four-time point longitudinal design. Additionally, we use statistical techniques well-suited to analyze longitudinal data (i.e., hierarchical linear models and panel data models) and account for potential biases that may emerge from having ceiling values in the mathematics achievement measure. Both the use of four-time point observations and

the application of these sophisticated statistical modeling techniques are more appropriate than those used in past studies.

DATA

Sample

The data stem from the first four cycles (1994-1995, 1996-1997, 1998-1999, and 2000-2001) of Canada's National Longitudinal Study of Children and Youth (NLSCY). The NLSCY followed a representative sample of Canadian children from birth to 11 years of age into adulthood, with data collected at two-year intervals. In cycle 1, a sample of 22,831 children aged 0 to 11 was selected. For cycles 2, 3, and 4, 16,903, 16,718, and 15,632 children and adolescents remained in the longitudinal sample.

Over the first four cycles, the NLSCY collected information on children, their families, health, development, temperament, behaviour, relationships, school experiences, participation in activities, among other aspects (Statistics Canada, 1999). Our study drew on the socio-economic data and the achievement data derived from the mathematics tests applied to children from grade 2 and onwards (Statistics Canada, 2001a). Our analytic sample of 6,290 students is restricted to children and adolescents aged 7-15 who were attending school, took the math test, and had a mathematics score in at least two cycles (see Table 1).

Measures

The dependent variable is mathematics achievement, which we obtained from a shortened version of the "Mathematics Computation Test" of the standardized *Canadian Achievement Test*, Second Edition (CAT/2). This version measures students' ability to do addition, subtraction, multiplication, and division operations on whole numbers, decimals, fractions, negatives, and exponents. Problem solving involving percentages and the order of operations are also measured (Statistics Canada, 2001b). The test, which included about 15 questions, was administered in school. For grade-2 students, an interviewer read the question and recorded the answers on an answer sheet. For students in grade 3 or above, students read the question and gave an interviewer the answer.

Table 1
Sample Distribution by Age

Age	Cycles			
(in years)	1	2	3	4
7	411	586	419	
8	571	690	541	
9	507	682	449	429
10	550	785	642	463
11	526	667	439	653
12		687	644	631
13		600	397	628
14			563	679
15			402	606
Total	2,565	4,697	4,496	4,089

Test difficulty varied with the school grade of the students. There were thus different test forms depending on the grade level in which a student was enrolled. These forms included a series of over-lapping items that were vertically equated such that a continuous scale was used to assess student growth. A gross score and a scaled score were calculated for each student. The gross score was obtained by adding the number of correct answers. The scaled score, the one used in this study, was derived from standards established by the Canadian Test Centre (CTC). The CTC developed these standards from a sample of Canadian children from all 10 provinces. The scaled scores, ranging from 1 to 999, were units of a single scale with equidistant intervals that cover all the grade levels.

The response rate of the mathematics test was rather low: 48 per cent, 74 per cent, 49 per cent, and 81 per cent in cycles 1 to 4, respectively. This response rate introduces a potential source of bias that is not accounted for within the model framework because of the absence of suitable instrumental variables. However, the low response rate is not simply due to attrition. In the first cycle it mainly had to do with the three-tier

process that Statistics Canada used to obtain permission to test children at school: students were tested only if permission were granted by the school district, the school principal, and the parents. The majority of non-response was attributable to school districts not granting permission, a factor that was not necessarily related to SES.

In the second and subsequent cycles, permission was required only at the school and family levels. Therefore, many children in the sample were not tested at cycle 1 but were subsequently tested at cycles 2, 3, and 4. Also, our models control for a number of demographic factors in addition to SES that may be related to response rate, and therefore the potential bias in the SES relationship may be somewhat mitigated. In fact, unreported analyzes show that SES is positively, albeit weakly, related to the non-response on the mathematics test, but age and its interaction with SES are not. Hence, although estimates of SES mean effects on test scores may be slightly biased, our findings are based on the interaction of SES with age, which is not systematically related to the response rate and therefore is less likely to be biased after controlling for other demographic factors.

Key explanatory variables are age and SES. Age is summarized in dichotomous variables at each age level and is also measured in months. Following prior literature (Dutton & Levine, 1989; Gottfried, 1985; Hauser, 1994; Mueller & Parcel, 1981), SES is a composite of family income, parental education, and parental occupational prestige. Willms and Shields (1996) calculated SES for the NLSCY by means of principal component analysis. We used the within-individual average of their SES variable across the various cycles for which data were available. The resulting time-invariant SES variable, measured in a continuous scale, was standardized to have a mean of zero and a standard deviation (SD) of one across the population of students that our sample represented. By measuring SES after, before, and at the occurrence of the mathematics outcome, the validity of a single-time point SES measure might be improved. And, we expect the bias of SES effects on mathematics achievement due to unobserved SES aspects to be reduced (Duncan & Brooks-Gunn, 1997). In another work Caro and Lehmann (2009) have shown that inasmuch as parental education predominantly drives SES, it is fairly

invariant over school years and its variation is not significantly related to academic performance.

We included other family and student characteristics in response to theoretical considerations and as control variables. These are students' sex, whether they lived in a single or a two parent family, whether the person most knowledgeable about the children (PMK) immigrated to Canada, whether the mothers were teenagers at the birth of the child, and the number of siblings in the family. We summarized the first four characteristics into dummy variables and measured the last one in an interval scale. Descriptive statistics of variables included in this study are presented in Appendix A. Missing values for the number of siblings in the family and whether the mother was a teenager at the child's birth have been imputed using the Hot Deck method (Little & Rubin, 1987).

MODEL

We evaluated the trajectory of the SES gap with a two-level model of mathematics measures (level 1) nested within students (level 2). The level 1 specification for each student i in each period or cycle j is [1]

$$y_{ij} = \pi_{oi} + \pi_{1i} age_{ij} + \pi_{2i} age_{ij}^2 + \varepsilon_{ij}\,, \qquad \ldots(1)$$

where y_{ij} is the mathematics score, age_{ij} is the age of the individual in months centred at 144 months, and ε_{ij} has the standard properties of a regression residual. The intercept π_{0i}, the initial status , represents the average mathematics achievement of person i at the age of 144 months. The linear component, π_{1i}, is the rate of change in mathematics achievement for person i at the age of 144 months. And π_{2i} captures the acceleration in each growth trajectory. The initial status and the rate of change vary depending on where the age of an individual is centred and the acceleration parameter is a characteristic of the entire trajectory.

There is a separate equation for each level 1 coefficient at level 2:

[1] Equations are numbered consecutively, with the equation number placed within parentheses and right justified.

$$\pi_{oi} = \beta_{00} + \beta_{01} C_i + \beta_{02} ses_i + \upsilon_{0i} \quad \ldots(2)$$

$$\pi_{1i} = \beta_{10} + \beta_{11} C_i + \beta_{12} ses_i + \upsilon_{1i} \quad \ldots(3)$$

$$\pi_{2i} = \beta_{20} + \beta_{21} ses_i \quad \ldots(4)$$

$$\text{with } \begin{pmatrix} u_{0i} \\ u_{1i} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \tau_{oo} & \tau_{01} \\ \tau_{10} & \tau_{11} \end{pmatrix} \right]$$

C_{ij} includes 8 variables: 5 theoretically relevant controls (i.e., sex, migration background, single-parent family, teenage mother, and siblings) and 3 time-period dummies for cycles 2, 3, and 4. The time-invariant SES measure *is* ses_i. All variables are centred at their population means. The acceleration parameter does not include a random component. This parameter needs at least four data points to be random. In our sample, however, only 13.5 per cent of students have four data points and the rest have either three- or two-time points (41.6 per cent and 44.9 per cent of students, respectively). Because only 13.5 per cent of students have sufficient degrees of freedom to evaluate whether this parameter is random or not, we decided to hold it fixed.

In equation (3), parameter β_{12} captures the effect of SES on the mathematics growth rate at the age of 12 (144 months). A positive and statistically significant estimate would indicate that higher SES students grow more rapidly in their mathematics skills than lower SES students and vice versa. If SES is positively related to mathematics achievement levels (i.e., β_{02} is positive) and higher SES students grow at faster rates, then the mathematics achievement gap associated with SES widens with age. Thus, the critical test regarding the trajectory of the gap is whether β_{12} is equal to, greater than, or less than zero.

By substituting equations (2), (3), and (4) in equation (1), the two-level model is consolidated in a combined model:

$$y_{ij} = \beta_{00} + \beta_{01} C_i + \beta_{02} ses_i + \beta_{10} age_{ij} + \beta_{11} C_i age_{ij} + \beta_{12} ses_i age_{ij} + \beta_{20} age_{ij}^{\ 2} + \beta_{21} ses_i age_{ij}^{\ 2} + (u_{0i} + u_{1i} age_{ij} + \varepsilon_{ij}) \quad \ldots(5)$$

The combined model in equation (5), which includes both fixed and random effects, is referred to in the literature as *mixed model* (Diggle, Liang, & Zeger, 1994). The fixed effects are represented by each β_s and the random effects by both u_{0i}, u_{1i}, and the level 1 residual ε_{ij}.

We estimated equation (5) by means of hierarchical linear models (Raudenbush & Bryk, 2002) and panel data models (Greene, 2004). In addition to the traditional random and fixed effects panel data models, we estimated the censored random effects models to control for ceiling values in the mathematics achievement measure. In cycle 1, 38 per cent and 16 per cent of students in grades 3 and 5, respectively, achieved the maximum score in the mathematics tests, introducing a potential source of bias in our estimates. In cycles 2, 3, and 4, the NLSCY prepared more versions of the mathematics tests, with different levels of difficulty, to offset this problem; however, this source of bias continued to a certain degree in these later cycles. Intuitively, censored random effects models counter-acted ceiling effects by accounting for the probability of scoring at or above the ceiling value within the maximum likelihood estimation algorithm (Greene, 2004). The effects of SES are thus estimated for a latent uncensored mathematics variable, rather than for the observed mathematics variable.

RESULTS

We report model estimates of equation (5) in Table 2 in terms of unstandardized regression coefficients. The nature of fixed effects models (i.e., all variables are time-demeaned within students prior to estimation) preclude estimating effects of time-invariant covariates. These models can, however, estimate effects of time-invariant covariates interacted with time-variant variables, as is the case of SES and its interaction with the age. Although it is a common practice to choose between fixed or random effect estimates, we decided to keep both, given their remarkable consistency with respect to the SES-age interaction coefficients. Next, we report effects that were consistently significant in the different regression techniques. Effect sizes are reported in relation to a SD of the mathematics achievement measure, i.e., 100 score points.

Females performed better than males in mathematics. The gender gap is negligible (about 3 per cent of a SD in mathematics achievement), and remains invariant as children get older (see nonsignificance of *Sex* × *Age* coefficient in Table 2). Children whose mothers were teenagers at their birth scored lower in math. On average, measured by the censored random effects model, they performed 11 per cent of a SD in mathematics below the other students. These differences increased as they advanced in school (see that the *Teenage mother* × *Age* coefficient in Table 2 is statistically significant). Children from immigrant families performed better than native Canadians irrespective of their family SES. The gap attributed to migration status amounts to less than 10 per cent of a SD in mathematics and remained stable with age (see nonsignificance of *Immigrated* × *Age* coefficient in Table 2).

The mathematics growth rate of students was positive and statistically significant. Children thus grew in their mathematics skills as they got older. According to the *Age* coefficient, for one month increment at the age of 12, children grew in about 3 score points in mathematics. Or, they grew in about 36 per cent of a SD in mathematics during a one-year period. The relationship between age and mathematics achievement is not constant. We found that the acceleration parameter (i.e., the Age^2 coefficient) was negative and statistically significant, indicating a curvilinear trend for the mathematics achievement trajectory of students. From the age of 12 to 15 years, students grew in their mathematics skills at a decreasing rate of change.

Figure 1 depicts the mathematics achievement trajectory for low and high SES students based on estimates of hierarchical linear models. We arbitrarily defined high SES students as those with average SES of the top SES quartile and low SES students as those with average SES of the bottom SES quartile. Figure 1 offers a simple empirical grounding of the existence of gaps across ages. Differences between SES groups tended to widen with age, favouring students of high SES families. Subsequent multivariate analysis characterizes these differences in more detail. They are expressed interchangeably in terms of the SES gap or SES effects. Given the SES original scale (M=0, SD=1), SES effects (coefficients) are equivalent to a mathematics achievement gap for an average SES gap of one SD.

Table 2

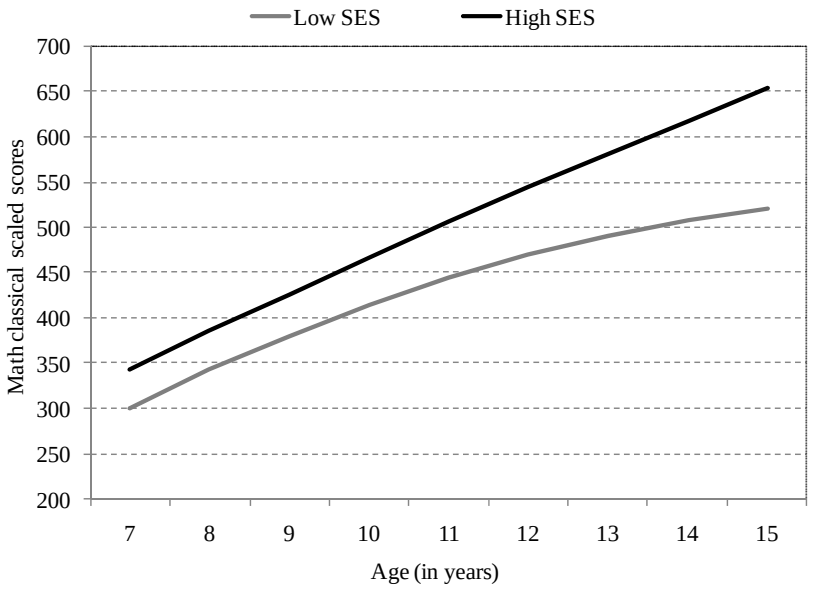
Trajectory of the Math Achievement Gap attributed to SES: Estimates of Specification 2 (*B=Unstandardized Regression Coefficients; SE=Standard Error*)

	Panel data model						HLM	
	Fixed effects		Random effects		Censored random effects			
	B	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*
Intercept	489.07*	(0.59)	515.07*	(1.60)	519.99*	(1.66)	492.87*	(0.86)
Period effects								
Cycle 2			-3.13*	(1.34)	-7.52*	(1.40)		
Cycle 3			-21.56*	(1.57)	-26.88*	(1.63)		
Cycle 4			-40.59*	(1.94)	-45.80*	(2.01)		
Control variables								
Sex (female=1)			3.31*	(1.37)	3.25*	(1.41)	4.34*	(1.56)
Teenage mother			-11.18*	(3.46)	-11.25*	(3.57)	-9.26*	(3.57)
Number of siblings	-0.50	(1.12)	-0.01	(0.68)	-0.06	(0.71)	-1.30	(0.99)
Single parent family	-0.15	(2.47)	-1.97	(1.63)	-2.15	(1.68)	-3.90	(2.54)
Immigrated to Canada			7.63*	(2.57)	7.80*	(2.64)	8.64*	(2.91)

Age effects								
Age	2.54*	(0.02)	3.18*	(0.03)	3.18*	(0.03)	2.64*	(0.03)
Age^2	-0.01*	(0.00)	-0.01*	(0.00)	-0.005*	(0.00)	-0.01*	(0.00)
SES across age								
SES			17.29*	(0.88)	17.33*	(0.91)	16.87*	(0.93)
SES × Age	0.27*	(0.02)	0.27*	(0.02)	0.26*	(0.02)	0.27*	(0.03)
SES × Age^2	0.003*	(0.00)	0.003*	(0.00)	0.003*	(0.00)	0.003*	(0.00)
Control variables across age								
Sex × Age	-0.01	(0.04)	-0.01	(0.03)	0.00	(0.03)	0.03	(0.04)
Teenage mother × Age	-0.35*	(0.10)	-0.37*	(0.09)	-0.35*	(0.09)	-0.30*	(0.09)
Number of siblings × Age	0.04	(0.02)	0.05*	(0.02)	0.05*	(0.02)	0.02	(0.02)
Single parent family × Age	0.08	(0.05)	0.11*	(0.05)	0.11*	(0.05)	0.04	(0.06)
Immigrated to Canada × Age	0.10	(0.07)	0.08	(0.06)	0.07	(0.07)	0.08	(0.07)

Note. The data consists of 6,290 individuals and 15,847 observations.
* $p<0.05$

Figure 1
Predicted Math Achievement Trajectories for Low and High SES Students (HLM Estimates)

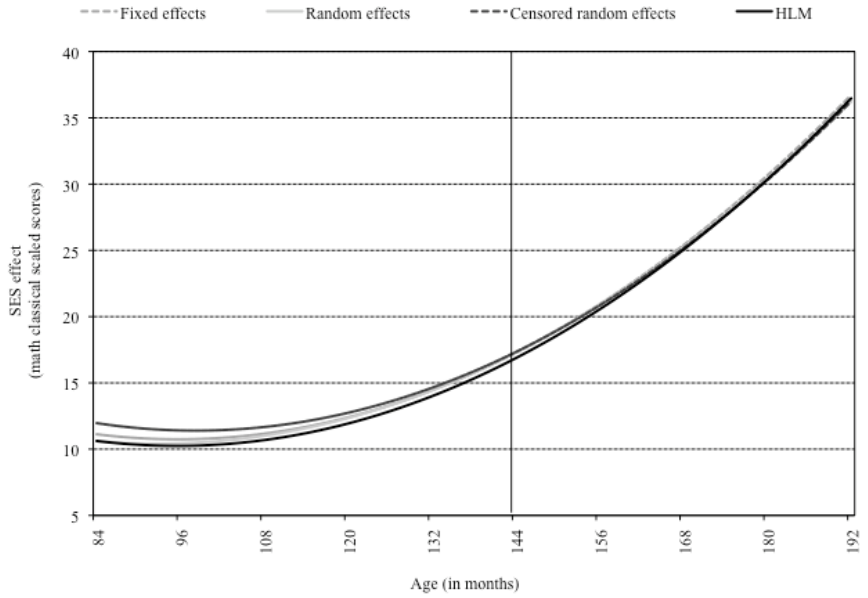


Note. Low and high SES students represent students in the bottom and top SES quartile, respectively.

The different regression techniques consistently indicate that the SES gap at the age of 12 years amounts to about 17 per cent of a SD of the mathematics measure (see *SES* coefficients in Table 2). They also lend support for a widening gap with age. The *SES x Age* coefficient amounts to about 0.3 score points, indicating that the gap widens in about 3.6 score points (0.3*12) from the age of 12 to 13 years. That is, the gap increased 20 per cent in this year period. But the SES gap did not widen at a constant rate of change. That the *SES x Age*^{2} coefficient was positive and statistically significant suggests that the gap between higher and lower SES students widened at an increasing rate of change with age.

What is most striking in Table 2 is that estimates of the trajectory of the SES gap are remarkably consistent among the different regression techniques. The magnitude of *SES*, *SES* × *Age*, and *SES* × *Age*^{2} coefficients is quite similar among panel data models and hierarchical linear models. In all cases, they indicate a curvilinear SES gap trajectory. Thus, not surprisingly, estimates of these models underpin virtually overlapping trajectories. Figure 2 presents these trajectories from the age of 7 to 15 years. The x-axis is the age of students in months and the y-axis is the mathematics achievement differences attributable to a gap of one SD in SES.

Figure 2
Trajectory of the Academic Achievement Gap Attributed to SES (Estimates of Specification 2)



Note. The fixed effects line assumes that the SES effect at age 144 months is similar to that of the random effects model.

Figure 1 and 2 suggest that the SES gap remained fairly stable during the first years and sharply increased after a particular point in time.

Table 3 offers more compelling evidence of this pattern. It reports point estimates of the SES gap at each age level and mean comparison tests of the SES gap across age levels based on the censored random effects model, the model that counteracts ceiling values in the mathematics measure.[2] The SES gap is positive and statistically significant at each age level. It is not significantly different between the ages of 7 and 11 years.

Table 3
Mean Comparison Tests of the SES Gap in Math Achievement (Estimates of the Censored Random Effects Model)

Age/Mean Gap		7	8	9	10	11	12	13	14	15
		12.41	13.28	11.48	12.65	13.75	19.66	23.02	32.07	27.20
7	12.41	0								
8	13.28	1	0							
9	11.48	-1	-1	0						
10	12.65	1	-1	1	0					
11	13.75	1	1	1	1	0				
12	19.66	1	1	1	1	1	0			
13	23.02	1	1	1	1	1	1	0		
14	32.07	1	1	1	1	1	1	1	0	
15	27.20	1	1	1	1	1	1	1	-1	0

Note. A value of 1, -1, and 0, indicates that the SES gap at the age level in the row is higher, lower, and equal from that of the column, respectively. Shadowed cells indicate statistically significant differences ($p<0.05$).

[2] Results from other regression techniques are similar and are available on request from the authors.

But, at the age of 12 years and beyond, the mathematics achievement gap between students of higher and lower SES families significantly widens (see Table 3). Therefore, the vertical line at the age of 144 months in Figure 2 marks the beginning of a widening gap.

The average gap from the age of 12 to 15 is twice as large as the average gap from the age of 7 to 11 years (26 per cent and 13 per cent of a SD in mathematics achievement, respectively). The gap increases stead-ily at an average rate of 33 per cent per year from the age of 12 to 14 years (see Table 3). At the age of 15 years, the gap seems to level off. It decreases from 32 score points at the age of 14 to 27 score points at the age of 15, but it is still significantly greater than the SES gap at the age of 12 or before (see Table 3). Also, although smaller, it is not significantly different from the gap at the age of 14 years. Data age range restrictions preclude examining whether the gap at the age of 15 announces the beginning of a new trend or not.

Overall, estimates of regression models reported in tables, figures, and mean comparison tables consistently indicate that the mathematics achievement gap associated with SES widens from childhood to adolescence. The trajectory of the SES gap fits a quadratic functional form, namely, the gap widens at an accelerating rate of change throughout this period. Particularly, it seems that the gap remains stable from the age of 7 to 11. Thereafter, students of lower SES families increasingly diverge from their higher SES peers up to the age of 15 years.

DISCUSSION AND CONCLUSION

The results of this study indicate a widening gap in mathematics achievement between students of higher and lower SES families in Canada. This finding, consistent with the cumulative advantage theory, adds to the evidence that educational disparities associated with family background tend to increase as students advance in school (Bast & Reitsma, 1998; DiPrete & Eirich, 2006; Jensen, 1966, 1974). And it suggests that children would benefit not only from intervention programs implemented early in their childhood, but also from later programs implemented when they are adolescents.

More specifically, we have found evidence that the SES gap remains roughly stable from the age of 7 to 11 years, that is, more or less between

grades 2 and 6. Thereafter, the gap widens at an increasing rate of change up to the age of 15 years, that is, from about the beginning of grade 7 to grade 10. In other words, achievement differences among students of varying socio-economic backgrounds remain invariant during elementary school and sharply widen in the transition from elementary school to middle school. Furthermore, throughout middle school years and up to the beginning of high school, the gap widens at an increasing rate of change. Ultimately, the average gap between the ages of 12 to 15 years is twice as large as the average gap between the ages of 7 to 11 years.

Our analysis on the trajectory of the gap utilizes more appropriate and sophisticated methods than in previous studies. Particularly, we advance prior research by drawing on a four-time point longitudinal design and applying regression techniques suited for the analysis of longitudinal data whereby we address the ceiling effects problem in the mathematics achievement measure. Most research relies on cross-sectional data or longitudinal data with two or, at best, three data points (e.g., Guo, 1998; Hoffer, 1992; Ross & Wu, 1996; Willms, 2002) and therefore tends to confound age and cohort effects or provides a rather limited source of intra-individual variation to study change in the gap. Instead, our study uses the first four data points of the NLSCY to estimate the trajectory of the gap in mathematics achievement, thereby increasing the validity of the trajectory of the gap (Baltes, Reese, & Nesselroade, 1988; Bryk & Raudenbush, 1987).

Furthermore, we use both hierarchical linear models and panel data models to estimate the trajectory of the gap. Panel data models produce point estimates of the gap at each level from the age of 7 to 15 and the panel data censored model accounts for ceiling values in the mathematics measure by incorporating the probability of scoring at or above the ceiling value within the model estimation algorithm. Hierarchical linear models enable estimating individual growth trajectories for higher and lower SES students as they get older. Estimates of the different regression techniques are strikingly similar with respect to the trajectory of the gap they produce, a conclusion which conveys that our results are quite robust.

Limitations

This study is not without limitations. A first limitation is the rather low response rate of the mathematics tests whereby a potential source of bias is introduced. The low response rate, however, was not simply due to attrition, but to the three-tier process that Statistics Canada used to obtain permission to test children at school, a process not necessarily related to SES. Furthermore, our models control for a number of demographic factors that may be related to the response rate and, in unreported analyses, we found that SES was related to the response rate, but the interaction of SES with age was not. Therefore, although we may have failed to estimate unbiased mean effects of SES on mathematics scores even after including controls in our models, we base our findings on the interaction of SES with age, which is not systematically related to the response rate. Thus, we expect this limitation not to seriously threaten the validity of our results.

A second limitation is that the mathematics tests included a small number of items and thus covered a fairly limited domain of mathematics skills. However, in earlier work based on a cross-sectional analysis of the NLSCY, Willms (1996) found remarkable consistency between results based on the NLSCY test and those based on more extensive curriculum-based measures. We expect that the gradients in mathematics performance may be stronger for tests that place a greater emphasis on problem solving and higher-order skills. If this is the case, then our analysis likely underestimates the strength of the socio-economic gradients for mathematics. A related limitation is the focus on the area of mathematics.

We have found a widening gap in mathematics achievement, but we cannot generalize this finding to academic achievement in other academic areas. Here, based on a meta-analysis, Cooper, Nye, Charlton, Lindsay, and Greathouse (1996) expect an even greater gap with increasing age in reading skills in light of the limited access of lower SES families to reading materials and language learning opportunities compared to higher SES families. But Gamoran (1992) suggests that inasmuch as instructional differentiation is more variable among schools in mathematics than in English, we should expect a sharper, widening achievement gap in mathematics than in English. In this case, the widening mathematics gap

reflects greater between school differences in the organization of mathematics instruction. Further research should examine how this gap evolves in different subject areas.

A final limitation is the restriction of this analysis to tests of the effects of SES without direct tests of the mechanisms that produce these results, e.g., course-level grouping practices, family influences during the summer break, and student expectations. This factor certainly limits our ability to offer guidelines for the design and improvement of educational and social policies. We certainly need more precise theorizing and more systematic empirical study of the mechanisms giving rise to a widening gap to define the foci of intervention programs. And, we need to move beyond the descriptive characterization of the gap toward a deeper understanding of the reasons why achievement trajectories diverge among SES groups. Although this information is beyond the scope of this article, earlier we reviewed studies of school and non-school influences on the gap and, drawing on them and our own ideas, we can postulate hypotheses to explain our findings and discuss their implications for policy and research.

Implications for Policy and Research

A first hypothesis is that because school practices are not neutral in their treatment of students of varying socio-economic backgrounds, they mediate SES increasing effects on academic achievement. This hypothesis is consistent with Kerckhoff's (1993) argument about institutional arrangements: socio-economically biased assignment into groups during school years produces divergent educational outcomes among SES groups (i.e., low SES children being repeatedly located in low ability groups and high SES children, in high ability groups). Even in systems that do not assign students into different schools, ability grouping within classes and/or course-enrolment patterns, as in Canada, can have the same effect (Hoffer, 1992; Schnabel et al., 2002).

If this is the case, ability grouping and course-level grouping practices are not necessarily to be abandoned, but they can be redefined in light of studies examining the effects of various grouping practices on the gap between higher and lower SES studies. Researchers need to know how these practices affect what actually happens in the classroom, for exam-

ple, teacher's pace of instruction and use of time, student participation, or class discussion. And based on this evidence, educators should encourage grouping practices that reduce the gap, without compromising the advantages of students in higher ability groups. Teachers, principals, and all educational actors involved in the definition of grouping practices should be informed of the effect of groupings and they should make decisions based on this evidence. Then grouping could perhaps be more effectively implemented.

A second hypothesis is that the out-of-school context increases disparities among SES groups. Children spend much of their time outside school and the quality of non-school environments varies widely. Thus, some scholars argue that the out-of-school context, mainly the family environment, produces divergent achievement trajectories among high and low SES students (Alexander, Entwisle, & Olson, 2001, 2007; Downey, von Hippel, & Broh, 2004). The school serves actually as equalizer. Although schools do not reduce disparities in the absolute sense, these increase less when school is in session.

If this reason explains our finding of a widening gap, policy makers should focus their efforts on improving the family environment of low SES children and increasing their exposure to schooling. Although the former alternative is less amenable to policy intervention, educational authorities can take concrete actions to increase and improve the quantity and quality of time children spend in school. Summer and after-school programs targeted at students of low SES families are the most obvious approaches. For example, Alexander, Entwisle, and Olson (2001) suggest summer enrichment programs with a strong curriculum focused on reading, it being the foundation for all that follows. They argue that educational policies that increase access to books can have an important impact on achievement, particularly for less advantaged children. Also, researchers recommend non-academic activities outside the classroom setting that support learning such as (a) visiting parks, museums, science centres, or zoos; (b) taking swimming, dance, or music lessons; (c) going to the library; or (d) practising sports during the summer break.

Another hypothesis is that mathematics success in the higher grades places greater emphasis on reading skills and involves tasks that require higher-order skills. Inasmuch as these skills are related to SES, because

the requirements for mathematics increase when students reach secondary school, then the SES-achievement gradient becomes stronger. Still another hypothesis is that the SES gap widens because low SES children are more negatively impacted by the transition from elementary school to middle school because they tend to migrate to lower SES schools compared to high SES children.

The NLSCY does not have the available data to test these hypotheses; we feel they deserve attention in future longitudinal studies. Certainly, this research needs to be done to increase educators' understanding of how and why the SES gap changes with age. This study represents an initial step to examine the trajectory of the gap with more appropriate methods than in the past. But further research should examine the mechanisms underlying changes in the gap, whether they vary for different academic areas and at different school periods, while using, of course, sound methods. Understanding these mechanisms is fundamental to provide information for the design and improvement of social policies.

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Appendix A

Table A

Unweighted Descriptive Statistics of Study Variables (N=15,847)

Characteristic	*M*	*SD*
Math achievement	458.53	106.96
Cycle 2	0.30	0.46
Cycle 3	0.28	0.45
Cycle 4	0.26	0.44
Sex (female=1)	0.50	0.50
Teenage mother	0.04	0.20
Number of siblings	1.27	0.88
Single parent family	0.16	0.36
Immigrated to Canada	0.08	0.27
Age of 7	0.09	0.29
Age of 8	0.11	0.32
Age of 9	0.13	0.34
Age of 10	0.15	0.36
Age of 11	0.14	0.35
Age of 12	0.12	0.33
Age of 13	0.10	0.30
Age of 14	0.08	0.27
Age of 15	0.06	0.24
Age in months	133.77	27.69
SES	0.02	0.90