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RUNNING HEAD: Equity in mathematics and science outcomes (Ireland)

EQUITY IN MATHEMATICS AND SCIENCE OUTCOMES: CHARACTERISTICS ASSOCIATED WITH HIGH AND LOW ACHIEVEMENT ON PISA 2006 IN IRELAND

Lorraine Gilleece and Jude Cosgrove

Educational Research Centre, St. Patrick's College, Dublin, Ireland

Nick Sofroniou

WJEC, Cardiff, Wales

ABSTRACT. Equity in education is a key concern internationally; however, it is rare that this issue is examined separately for low- and high-achieving students and concurrently across different subject domains. This study examines student and school background characteristics associated with low and high achievement in mathematics and science on the Programme for International Student Assessment. Based on the results of a multilevel multinomial model of achievement for each domain, findings indicate that a greater number of the variables examined are associated with low rather than high achievement. At student level, home language, intention to leave school early, socioeconomic status, grade level, cultural capital, and books in the home are significantly associated with achievement in mathematics and science. At school level, only school average socioeconomic status is statistically significant in the models. Significant gender differences are found in the distribution of high and low achievers, which vary across the domains. In mathematics, females are more likely to be low achievers while males are more likely to be high achievers. In science, gender interacts with early school-leaving intent whereas males intending to leave school early are more likely to be in the low-achieving group than females intending to leave early. Conclusions emphasise the need for targeting resources aimed at promoting equity in outcomes at student level as well as at school level. Future work may extend the current analyses by incorporating domain-specific variables or examining cross-country differences.

KEYWORDS: achievement, equity, Ireland, mathematics, PISA, science

INTRODUCTION

Equity in educational outcomes is of interest in Ireland and internationally. That is, equity in education will not be achieved until differences are eliminated between groups in society in terms of performance. The implication of this is that individuals experiencing disadvantageous circumstances should be targeted specifically for additional support for their education and wellbeing. Furthermore, equity in educational outcomes must be viewed in its wider context. For example, the “underperformance” of students from lower socioeconomic families necessitates an examination of their experiences of schooling, including school environment, sense of belonging, and personal meaningfulness of the curriculum. Reflecting this concern with equity, the Organisation for Economic Co-operation and Development (OECD) reports on the results of the Programme for International Student Assessment (PISA) place a relatively high emphasis on this theme (OECD, 2001, 2004).

The analyses presented in this paper examine equity, focusing on two groups of students of policy interest—those at the extremes of the achievement distribution. This is facilitated using multinomial multilevel modelling. More widely used regression methods treat the outcome as continuous (as is the case in the OECD’s treatment of achievement data in reporting) and, therefore, do not allow one to focus on these subgroups.

In the following sections, the aims and design of PISA are outlined, and Ireland’s PISA 2006 performance in mathematics and science is reviewed with particular attention given to equity. Correlates of mathematics and science achievement are then discussed, emphasising characteristics of interest in the present study. We consider the manner in which the OECD treats the theme of equity, focusing in particular on its treatment of student socioeconomic background as a composite characteristic. We argue that in the context of examining equity this approach may not be optimal for addressing certain policy issues.

Following this, we describe characteristics of the sample, variables, and analysis methods employed for the current study and present the results. Conclusions focus on commonalities across the two subject domains, implications particularly as they relate to policy on educational equity, and areas for future research.

The Programme for International Student Assessment

PISA is an initiative of the OECD (Cosgrove, Shiel, Sofroniou, Zastrutzki, & Shortt, 2005; Eivers, Shiel, & Cunningham, 2008; OECD, 2001, 2004, 2007; Shiel, Cosgrove, Sofroniou, & Kelly, 2001) that was first implemented in 2000. Through a survey conducted every 3 years, it examines the extent to which students are able to demonstrate key competencies in reading, mathematics, and science. The approach taken to measuring students' knowledge and skills is that of real-life literacy rather than a more confined curriculum-driven assessment.

Students participating in the assessment are aged 15, which is close to the end of compulsory schooling in OECD member states. In Ireland, the majority of students sampled to participate are in grade 9 (about 60%); some are also in grades 8, 10, and 11. In addition to completing a 2-hour assessment of reading, mathematics, and science, students complete a questionnaire on home background and various attitudes and activities. School principals also complete a questionnaire that examines issues such as management structures, resources, and school environment. Several school- and student-level variables drawn from the questionnaires (both nationally and internationally derived) are used in the present study to examine whether and which school and student characteristics are associated with high and low achievement in mathematics and science.

Review of Ireland's Performance in Mathematics and Science in PISA 2006

In 2006, the mean mathematics scores of Irish students (501) did not differ significantly from the OECD average score (500; Eivers et al., 2008; OECD, 2007). Ireland's rank among OECD countries was 16th. Males scored significantly higher than females on the mathematics scale in the majority of OECD countries; in Ireland, males scored an average of 11 points higher than females. Although males outperformed females in PISA mathematics, gender differences in mathematics in favour of females have been found in the Junior Certificate Examination, the Irish State examination taken at the end of grade 9 (Eivers et al., 2008).

Irish students had a mean score of 508 on PISA science, which was significantly but not substantially above the OECD average of 500 (Eivers et al., 2008; OECD, 2007). Ireland ranked 14th among OECD countries. Consistent with the majority of OECD countries, no significant gender differences in science performance were observed in Ireland. In contrast, females tend to outperform males on the Junior Certificate science examination (Eivers et al., 2008).

Gender differences in mathematics and science are, thus, not independent of the measures used. This is a complex area of research and beyond the scope of the present paper; the main point with respect to the current study is that policy interventions aimed at enhancing gender equity should not rely on a single outcome measure or, at least, be cognisant of the content and design of the measurement instrument (see Halpern et al., 2007, for a useful review of this topic).

Across OECD countries, there is considerable variation in the extent to which student achievement varies between schools. This indicator can be interpreted as a measure of the extent to which schools provide equitable outcomes for students. In PISA 2006, the percentage of achievement variation that lies between post-primary schools in Ireland was considerably lower than the OECD average. Variation in Ireland was less than 20% for both mathematics and science (19% and 17%, respectively) compared with OECD averages of 35% for mathematics and 33% for science (OECD, 2007).

In summary, it seems that the Irish students' average performances are reasonable and that the educational system is relatively equitable in terms of science and mathematics achievement, but that quality in performance could be improved. However, these claims are based on average performance for the sample participants; and the focus of this paper is to accord attention to specific subgroups of students.

Characteristics Associated with Mathematics and Science Achievement

This section focuses on characteristics identified in the international and national reports on PISA, considering Kellaghan's (2001) commentary on educational disadvantage in Ireland as a context. Using the definition of educational disadvantage set out in Ireland's Education Act (Government of Ireland, 1998)—"the impediments to education arising from social or economic disadvantage which prevent students from deriving appropriate benefits from deriving appropriate benefit from education" (Section 32, 9), Kellaghan (2001) described the three forms of capital (economic, cultural, and social) underpinning Bourdieu's work (e.g. Bourdieu, 1977; Bourdieu & Passeron, 1977; O'Brien & Ó Fathaigh, 2004) in order to propose an expanded definition of educational disadvantage. This revision has resulted in the implementation of a new national scheme of supports (Department of Education and Science, 2005), which will be discussed in the concluding section of this paper.

First, economic capital relates to the material, particularly financial, resources available to families and communities. An absence of economic capital is poverty, which is perhaps the most obvious factor when it comes to considering educational equity. Second, cultural capital—a more complex concept—is closely related to cognitive competencies and conditions involved in educational outcomes. Kellaghan (2001) argues that it is the most relevant form of capital in a consideration of educational equity. The importance of language to cultural capital is considerable. The third form of capital, social capital, is generally agreed to be embedded in relationships between individuals in informal social networks. Social capital functions by securing benefits for individuals by virtue of their network membership. It is related to shared values, norms, and sanctions and is reciprocal in nature. It is, therefore, an important force of social control and parental support; it can also become a tool of social reproduction by the dominant class.

These three forms of capital are thought to reinforce the status quo of power relations and access to resources and goods. Struggle for and appropriation of capital occurs in what Bourdieu terms *fields* (i.e., structured spaces of forces and struggles with their own regulatory rules). Individuals are more or less aware of the rules of a particular field (e.g., a school setting) and those with higher levels of capital are assumed to be better positioned to manipulate the rules for their own benefit.

In the OECD's analyses relating to socioeconomic background, the combined index of educational, social, and cultural status (ESCS) is used. It is a composite of six measures: parental occupational status (i.e., an index ranging from 16 to 90 with higher scores indicating higher occupational status, based on the higher of both parents' occupations, and derived from the International Standard Classification of Occupation; OECD, 1999), parental level of education converted to years of schooling, home educational resources, cultural resources, indicators of material wealth, and the number of books in the home (OECD, 2009). Therefore, the three forms of capital are present in the ESCS scale. The OECD (2007) uses the ESCS as a single indicator in several analyses and justifies doing so by noting that "these various aspects of socio-economic background tend to be highly interrelated, [so] most of the … report summarises them in a single index" (p. 174).

In Ireland, however, the components underlying ESCS are not strongly interrelated. Of the 15 intercorrelations (i.e., given 6 components underlying ESCS, this makes (6*5)/2 unique pairs or correlation coefficients) between the components of ESCS, 13 are of moderate strength at most, ranging from .18 to .37. The remaining two are moderate to strong correlations of .42 (between books in the home and the index of cultural possessions) and .47 (between parental education and parental occupation). It is of interest to analyse the components of ESCS separately, rather than as a single composite, since they may require different policy responses.

A consistent finding across countries is that student background characteristics, such as socioeconomic status (SES) and books and cultural possessions at home, are significantly associated with achievement in both mathematics and science (Chiu & Xihua, 2008; Hampden-Thompson & Johnston, 2006). In contrast, there is substantial variation across countries in the relationship between immigrant status and performance, and this is related to the composition of immigrant groups. For example, in PISA 2006, of the 22 OECD countries with sufficient numbers of first-generation students for analysis, the increased probability of these students scoring in the bottom quarter of the science performance distribution ranged from 1.1 to 2.7 and was 1.3 in Ireland (OECD, 2007). Cosgrove and Cunningham (in press) note that in the Irish context it is the linguistic background of students, rather than their immigrant status, that is predictive of achievement. It may be noted that immigration is an important policy area for the Irish education system given increasing immigration rates. A recent EU green paper (Commission of the European Communities, 2008) noted that in Ireland, Italy, and Spain the percentage of students born in another country has multiplied by three or four since 2000.

Secondary analyses of the PISA 2003 results for Ireland, using multilevel modelling, indicated that achievement of students on the mathematics assessment (Cosgrove et al., 2005) was significantly related to gender (with males outperforming females in mathematics), parental occupation, lone parent status, number of siblings, books in the home, home educational resources, frequency of absenteeism, and grade level. Results for science in 2006 were similar to those for mathematics with the exception of gender (Cosgrove & Cunningham, in press).

Generally, differences in achievement between schools in Ireland by sector (secondary, comprehensive, vocational) and enrolment size are no longer significant once analysed within a multilevel modelling framework. However, school socioeconomic composition remains in the models and explains around half of the between-school variance in achievement in Ireland (Cosgrove & Cunningham, in press). This finding demonstrates the presence of a *social context effect*, whereby school average socioeconomic composition exerts an influence on achievement outcomes over and above individual student social background (e.g., Raudenbush & Willms, 1995; Willms, 2002).

The association between student attitudes, engagement, self-concept, and achievement have also been examined (Chiu & Xihua, 2008; OECD, 2004, 2007). As the aim of the present study is to compare models of mathematics and science, domain-specific variables are not included in the analyses, and previous research in this area is not described in detail. Generally, self-efficacy, self-concept, and interest/engagement measures are consistently related to achievement within countries while measures relating to learning strategies, such as memorisation and elaboration, are more weakly associated with achievement (OECD, 2004; 2007). Issues in the measurement and interpretation of these constructs have been noted (e.g., Van de Gaer, Gebhardt, & Schulz, 2009; Williams & Williams, in press).

METHODOLOGY

This section considers the PISA sample design and outlines the variables used, the research questions examined, and the analytic techniques employed in the current paper.

Sample

The sample comprised students in Ireland who participated in PISA 2006 who have available data on all explanatory variables. In total, 4,585 students (49.4% male) participated.

After deletion of cases missing data, 4,184 students (48.8% male) remained in the dataset in this study. This corresponds to 91.3% of the original sample, implying quite a low rate (8.7%) of missing data. Missing data are not uniform across proficiency levels, with higher rates associated with Level 1 or below in both mathematics and science. In other words, low-achieving students were more likely to have missing data on the variables of interest. The nonrandom pattern of missing data should be borne in mind when interpreting results.

Variables

Students were categorised into low, middle, and high achievers based on PISA proficiency levels. These are defined based on international benchmarks and provide qualitative indicators of the likely skills of students at different levels of performance. There is a point on each scale below which students have less than 50% probability of answering the easiest PISA questions. For these students (4.1% in mathematics, 3.5% in science), nothing can be inferred about what skills the students *do* have and such students are said to be below proficiency Level 1. For the present analyses, students at Level 1 in each domain were combined with those below Level 1 (16.4% in mathematics, 15.5% in science) to form single low-achieving groups. The highest level in mathematics and science is Level 6 (1.6% in mathematics, 1.1% in science). Levels 5 and 6 were combined for the purposes of modelling high achievers in these two domains (10.2% in mathematics, 9.4% in science). Table 1 shows the background variables used in the present analyses. These variables were selected based on the literature review and policy relevance.

[INSERT Table 1 about here]

Although cultural capital and parental education (years of schooling) are treated as continuous variables in many of the international analyses, both were found to comprise a limited number of distinct values (e.g., just four values from the cultural capital scale accounted for the responses of 98% of respondents). These variables were, therefore, recoded into categorical variables. These correspond to, for parental education, lower secondary education and postsecondary education (with upper secondary as the reference category) and, for cultural capital, less than the 25th percentile and greater than the 75th percentile (with the 25th – 75th percentile as the reference category). Student SES, home educational resources, and school average SES have been standardised to have a mean of 0 and standard deviation of 1.

Research Questions

It was noted in the introduction that examining student performance as a continuous outcome may not be optimal to address research and policy questions surrounding equity in educational outcomes. Furthermore, conclusions that one may draw on subgroups of the population (e.g., males, females) may vary depending on the subject domain. This was the rationale for examining achievement in both mathematics and science by treating the outcome as a noncontinuous rather than a continuous variable, allowing for comparisons of the characteristics associated with high and low achievers.

The analyses aimed to address the following research questions:

1. Which school and student characteristics are associated with achievement in mathematics and science; do the same aspects predict achievement at both extremes of the distribution and in both domains?
2. Are there gender differences between high and low achievement and in the two domains; to what extent may gender differences be considered independent of the other variables considered?
3. How can the results inform national policy aimed at enhancing equity in educational outcomes?

Multinomial Analyses

A multilevel model is used for the current analyses as the PISA sample consists of students clustered within schools who tend to be more similar to each other than students sampled at random across schools. A multinomial model is used because the outcome of interest is categorical in nature rather than continuous.

A multinomial multilevel model for an outcome with three categories produces two log-odds ratios, which may be converted to odds ratios through exponentiation. The difference in the log-odds of a variable corresponds to the probability of the variable occurring in the extreme category compared to the reference category, which in the present study is the middle-achieving group. The overall significance of a variable (or variable set, in the case of categorical variables with more than one indicator) may be evaluated through a change in the χ^2 statistic with degrees of freedom equal to the number of parameters corresponding to the variable or dummy indicator set multiplied by 2 to allow for the fact that two equations are estimated in this case, low versus medium and high versus medium.

More formally, the sampling model at level 1 may be expressed as (Goldstein, 1995; Raudenbush & Bryk, 2002; Raudenbush, Bryk, Cheong, & Congdon, 2004):

$$\text{Prob}\ (R_{ij} = m) = \varphi_{ij} \qquad (1)$$

where the probability that person i in group j will be in category m is φ_{ij}, for categories m = 1, ..., M, in which there are M possible categories. According to the multinomial distribution, the expected value and variance of $Y_{mij,}$ given φ_{mij} are:

$$E\ (Y_{mij} \mid \varphi_{mij}) = \varphi_{mij},\ \text{Var}(Y_{mij} \mid \varphi_{mij}) = \varphi_{mij}(1 - \varphi_{mij}); \qquad (2)$$

and the covariance between the outcomes Y_{mi} and $Y_{m'ij}$ is:

$$\text{Cov}\ (Y_{mij}\ ,\ Y_{m'ij}\ ) = \varphi_{mij,}\varphi_{m'ij}. \qquad (3)$$

The level 1 link function for a multinomial regression model is the multinomial logit link. Let η_{mij} be the log-odds of falling into category *m* relative to category *M.* For each category *m* = 1, …, *M* – 1, this is expressed as:

$$\eta_{mij} = \log(\varphi_{mij} / \varphi_{Mij}) = \log[\text{Prob}(R_{ij} = m) / \text{Prob}(R_{ij} = M)]. \quad (4)$$

The structural (null) model for the present analysis, where there are three groups and two comparisons, is expressed as:

$$\eta = \gamma_{00(1)} + \gamma_{00(2)} + u_{0(1)} + u_{0(2)}. \quad (5)$$

Adding specific variables, student gender and school type (with secondary as the reference group) to the model, yields the following equation:

$$\eta = \gamma_{00(1)} + \gamma_{01(1)}\text{*COMMUNITY} + \gamma_{02(1)}\text{*VOCATIONAL} \quad (6)$$

$$+ \gamma_{10(1)}\text{*GENDER} + \gamma_{00(2)} + \gamma_{01(2)}\text{*COMMUNITY}$$

$$+ \gamma_{02(2)}\text{*VOCATIONAL} + \gamma_{10(2)}\text{*GENDER} + u_{0(1)} + u_{0(2)}.$$

In order to make the odds ratios more meaningful in the case of continuous variables, the change in log-odds associated with a one-unit change in the explanatory variable was multiplied by the number of units by which the 25th and 75th percentile values of the variable differ. This gives the odds of a student at the 75th percentile on the explanatory variable being in the low (or high) achievement category versus the middle achievement category compared to a student at the 25th percentile.

Initial tests were done using the first plausible value only, and the model was finalised using all five plausible values. Student- and school-level variable models were first tested separately. All school- and student-level variables that were statistically significant individually were tested simultaneously. Standard errors were corrected to incorporate for between- and within-imputation variance (see OECD, 2005, pp.101-102). Confidence intervals (CIs) corresponding to the odds ratios were computed using the corrected standard error.

Tests for significant curvilinear effects were conducted for each continuous variable. Interactions between gender and each other student-level variable and cross-level interactions were also examined. The appropriateness of fixing the effect of each student-level variable across schools was tested. No sampling weights were used (Aitkin, Francis, & Hinde, 2005). Rather, the explicit sampling stratum (school enrolment) and the two implicit sampling strata (sector and gender composition) were included as school-level variables.

RESULTS

This section initially describes descriptive (bivariate) results and then considers multivariate (multinomial) results. Significance tests are carried out in the context of the multilevel models and thus, bivariate results are for descriptive purposes only.

Descriptive (Bivariate) Analyses of High and Low Achievement

Table 2 shows for each categorical background variable the percentages of students in each category by mathematics achievement group. Table 3 reveals that the patterns for science are highly consistent with those for mathematics. The exception is with respect to gender. In mathematics, there are about 1.5 times as many high-achieving males as females and little difference in the percentages of males and females at Level 1 or below. In science, there is little difference in the percentages of males and females in either the highest (male: 10.4%, female: 8.5%) or lowest (male: 16.6%, female: 14.5%) groups. In both mathematics and science, substantial differences in the distribution of students across the three achievement groups are associated with home language, intention to leave school early, parental education, cultural capital, grade in school, and school sector. More modest differences are associated with native status, school sex composition, and school location.

[INSERT Tables 2 and 3 about here]

Table 4 shows the means and standard errors for continuous background variables by achievement group. Students in the high-achieving group in both domains have about three times as many books in their homes as low-achieving students. They also have higher socioeconomic status, higher school average socioeconomic status, and a higher level of home educational resources than students at or below Level 1. Differences between the low- and high-achieving groups on these continuous variables range from about 0.6 to 1.0 standard deviations in mathematics and science.

[INSERT Table 4 about here]

Multinomial Models of High and Low Achievement

Tables 5 and 6 present the parameter estimates and hypothesis tests for the variables in the final models of mathematics and science, respectively. They also show the odds ratios for mathematics and science, respectively, for example values of each of the explanatory variables, together with 90% CIs. The 90% level was used as the aim of this exploratory modelling to identify factors whose measurement might be refined or whose effects might become significant at the 95% level in the future. CIs in bold indicate odds ratios significant at the 90% level. There is no significant slope variation, no significant curvilinear effects, and just one significant gender interaction (with early school-leaving intent for science). Variables dropped from the final models were indicated in the footnotes in Table 1.

[INSERT Tables 5 and 6 about here]

There are marked similarities across the two models, with school average SES being the only school-level variable to remain in either model. There are, however, some notable differences between the models. In the case of mathematics, females were significantly more likely to be in the low-achieving group than males and significantly less likely to be in the high-achieving group. The odds ratios for gender in the case of science must be interpreted with respect to early school-leaving intent and the significant interaction term. The odds ratios are computed based on the parameter estimates on the logit scale for two comparisons, low versus medium and high versus medium. For males, this corresponds to 1.171 (parameter estimate associated with low achievers who intend to leave school early) and -1.859 (parameter estimate for high achievers who intend to leave school early); for females, the parameter estimate of the interaction term is added to the parameter estimate for students who intend to leave school early, that is, (1.171 – 0.615) = 0.556 (low-achieving females) and (-1.859 + 1.086) = -0.773 (high-achieving females). The exponential of these are the odds ratios. A computation of the odds ratios for the four comparisons in question (low versus medium and high versus medium for males intending to leave school, and low versus medium and high versus medium for females intending to leave school), indicates that early school-leaving intent was more strongly predictive of the achievement level of males than females. Males intending to leave school early were 3.23 times more likely to be in the low compared to the medium group. The corresponding odds ratio for females is considerably lower, at 1.74. Conversely, females intending to leave school were 0.46 times as likely to be in the high versus the middle group. The corresponding figure for males is 0.16.

Students who speak languages other than English or Irish at home were about three times more likely to be in the low achievement group than the medium group in both mathematics and science. The CIs for home language are wide since few students (1.6%) speak a language other than English or Irish. Home language was not significantly associated with high achievement in either mathematics or science.

Intending to leave school prior to completing grade 12 was significantly associated with both high and low achievement in mathematics (and interacted with gender in the case of science, as noted previously). Students who intend to leave school early were more than twice as likely to be low mathematics achievers as medium achievers and were also less likely to be high achievers than medium achievers.

Student SES was significantly associated with membership of both the high- and low-achieving groups, and the odds ratios are similar for both domains. Odds ratios associated with the difference between students at or above the 75^{th} percentile in SES compared to those at the 25^{th} percentile are about 0.70 for low versus medium achievement, and they range from about 1.4 to 1.6 for high versus medium achievement.

Grade level was strongly predictive of both high and low achievement. Comparing the low and medium groups, the odds ratio for grade level was largest for science where students below Grade 9 were about 4.5 times more likely to be low achievers as opposed to medium-level achievers compared to students in Grade 9. Few students (2.3%) are below Grade 9, so CIs are wide. Students in grades above the modal grade were about half as less likely to be low achievers compared to medium achievers and are over 1.5 times more likely to be high achievers than medium achievers in both mathematics and science. Grade level is indicative of students' educational career, such as grade repetition and school starting age, which was not directly measured.

The number of books at home was also associated with both high and low achievement. In both domains, students with between 201 and 500 books (75^{th} percentile) were about half as likely as students with between 11 and 25 books (25^{th} percentile) to be low achievers compared to medium achievers, while students with 201-500 books were over 3.5 times more likely to be high achievers than medium achievers.

The impact of cultural capital varied across the models for mathematics and science. Cultural capital was significantly associated with low but not high achievement in mathematics while in science it was significantly associated with both low and high achievement.

Students attending schools with average socioeconomic composition at or above the 75^{th} percentile were about 0.6 times as likely to score at or below Level 1 compared to students attending schools where average SES is at or below the 25^{th} percentile, and about 1.3

times more likely to be in the high-achieving group in the case of mathematics. School average SES did not significantly predict high achievement in the case of science.

CONCLUSION

The study described in this article sought to establish the extent to which the same student and school characteristics are associated with low and high achievement in mathematics and science and whether or not these are different in the two domains. Low achievers were those at or below PISA proficiency Level 1. High achievers were those at proficiency Levels 5 or 6. The reference was the middle group of students at proficiency Levels 2, 3, or 4.

The first research question investigated the characteristics associated with achievement in mathematics and science and considered whether the same aspects predict achievement at both extremes of the distribution and in both domains. Results showed that, of the student-level variables, gender, home language, intention to leave school early, socioeconomic status, grade level, cultural capital, and books in the home remained significant in the final models for both domains. School average SES was the only variable to be statistically significant at the school level in the final models. The background variables included in the models were found to be more strongly associated with low, rather than high, achievement. Results for science and mathematics were broadly similar. The most salient difference between the models related to the effects of gender, which are discussed below.

The second research question relates to gender differences between the domains and the extent to which gender differences are independent of other variables examined. Females were more likely to be low achievers and males were more likely to be high achievers (both relative to middle achievers) in mathematics. The gender differences in mathematics are relatively independent of the other variables examined, as coefficients for the two groups do not vary appreciably from the initial testing of gender individually to the final model, which includes all significant variables. Gender is not independent of the other variables considered in the case of science where an interaction was found between gender and having the intention to leave school prior to the end of Grade 12. Males intending to leave school early were more likely to be in the low-achieving science group than females intending to leave school early.

The finding that females are more likely to be low achievers in mathematics and less likely to be high achievers can be contrasted with the results of a multinomial model of reading based on PISA 2006 data that indicated that females are less than half as likely as males to be low achievers and over 1.5 times more likely to be high achievers (both compared with medium achievers) than males (Cosgrove & Gilleece, 2009). Thus, any initiatives aimed at improving gender equity must take into account differences between the different domains as well as the nature of the achievement measure used. As noted in the introduction, gender differences on national tests of mathematics and science are not consistent with gender differences found on PISA.

The finding that school-level SES is the only variable at school level to remain in the final models of mathematics and science has implications for initiatives designed to promote educational equity. This relates to the third research question considered in the present study. The current initiative in Ireland in this area is a school-based approach (Department of Education and Science, 2005) that identifies schools at post-primary level based on both socioeconomic indicators (rates of medical card possession) and educational outcomes (school performance on the Junior Certificate and retention rates).

Results, however, show that a number of student-level variables remained significant. This suggests that allocation of resources at the school level may not be sufficient. Over and above socioeconomic characteristics, home language, home educational climate, and cultural capital are important individual-level characteristics associated with achievement. These indicators, combined with the socioeconomic indicators, have the potential to be used to identify students for further within-school interventions targeted at individual students. Home-School-Community Liaison Officers, who provide a crucial link between students' school and home/community environments, are in a position to gain insights into individual students' home circumstances (e.g. Conaty, 2002) and might assist in this regard by noting these aspects of a student's home environment. They could also raise awareness in families about education and capitalising on program opportunity.

PISA offers an opportunity to extend the present analyses in five ways. There would be merit in examining characteristics associated with high and low achievement across countries. The strength of the association between socioeconomic/cultural characteristics and achievement varies across countries (e.g., OECD, 2007), and there may be country differences that could be interpreted with respect to differences in education systems, policies, and practises. Second, changes across PISA administrations in the variables associated with high and low achievement could be examined. Any evidence of change in the 2009–2015 phase of PISA relative to the current analyses could have important policy implications. This is, for example, of relevance to Irish policy aimed at addressing the needs of foreign national students. The literature review noted the substantial increase of immigrant students in Ireland since 2000 (Commission of the European Communities, 2008). Third, additional domain-specific information is collected during each administration that corresponds to the major domain. There would be merit in extending the type of analysis presented here to include variables specific to individual achievement domains (e.g., attitudes toward mathematics). Fourth, more information might be gleaned on the nature of the gender differences observed in the present study through the analysis of alternative achievement measures in a multivariate context. Finally, PISA samples students by age, not class/grade, so it does not allow an in-depth examination of variables associated with teachers or classroom climate. Therefore, future analyses based on datasets that use intact class sampling would be worthwhile.

In conclusion, this paper has attempted to demonstrate that treating achievement outcomes as discrete has considerable potential. However, as with any single study, PISA cannot provide exhaustive information on the complex contexts of students and schools; therefore, policy development should not be based on one study alone.

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Table 1

Description of Background Variables Included in Analyses

Variable	Description
	Student Level
Gender	Male = 0; Female = 1
Grade: Less than 9, Grade 9, Greater than 9	Dummy variables (Yes = 1, No = 0). Reference group is Grade 9
Home Language	English or Irish = 0; Other = 1
Native[a,b]	Native = 0; Non-native = 1. Defined as native if either of the student's parents is native, else the student is non-native
Intend to leave school early	Yes = 1, No = 0. 'Yes' if intending to leave prior to grade 12
Parental SES (occupation)	Higher of the two parents' international socioeconomic index of occupational status (HISEI). *M* = 0, *SD* = 1
Books	Number of books in the home, recoded to the midpoint of each response category (e.g., 0-10 recoded to 5). Original scale: 1 = 0-10; 2 = 11-25; 3 = 26-100; 4 = 101-200, 5 = 201-500; 6 = 500+. *M* = 154.5, *SD* = 164.43
Ln(Books)	Natural log of the categorical value of books in the home
Parental education[a,b]: Lower secondary or less, Upper secondary, Post secondary	Higher of the two parents' levels of education converted into years and entered as dummy variables (Yes = 1, No = 0). Reference category is upper secondary
Home educational resources[a,b]	Availability of items pertaining to education (e.g., study desk, computer, dictionary). *M* = 0, *SD* = 1
Index of cultural capital: Low, Medium, High	Availability of (e.g., classic literature, poetry books, works of art). Entered as dummy variables (Yes = 1, No = 0). Low = lowest 25% of scores on this index; reference category = medium; high = highest 25% of scores on this index
	School Level
School location[a,b]: Rural, town, city	Dummy variables (Yes = 1, No = 0). Rural = population less than 3,000; town = reference category; city = population greater than 100,000
School average SES	Z score for school average socioeconomic status. *M* = 0, *SD* = 1
School sector[a,b]: Community or comprehensive, Secondary, Vocational	Dummy variable (Yes = 1, No = 0). Reference category = secondary
School size[a,b]: Small, Medium, Large	Dummy variables (Yes = 1, No = 0). Small = 40 or fewer PISA students enrolled; medium = reference category; large = 81 or more PISA students enrolled
Gender composition[a,b]	Single sex = 1; Mixed sex = 0

Note. [a]Variable dropped from final model of mathematics; [b]Variable dropped from final model of science.

Table 2

Distribution of Students across each Categorical Background Variable by Mathematics Achievement Group

			Achievement Group					
			Level 1 or below		Levels 2 to 4		Level 5 or 6	
		N	%	*SE*	%	*SE*	%	*SE*
Overall		4585	16.42	1.219	73.34	1.315	10.24	0.785
Gender	Male	2264	15.45	1.677	72.29	1.666	12.27	1.061
	Female	2321	17.36	1.320	74.37	1.563	8.27	1.023
Home language	English or Irish	4396	15.44	1.122	74.10	1.234	10.46	0.800
	Other	83	39.92	9.518	51.68	9.589	8.40	3.842
Native	Native	4200	15.31	1.097	74.25	1.156	10.44	0.774
	Non-native	242	24.97	5.378	64.92	5.851	10.11	2.531
Intend to leave school early	Do not intend	4046	13.43	1.027	75.17	1.197	11.40	0.845
	Intend	445	38.43	3.599	59.77	3.595	1.81	0.724
Parental education	Lower secondary	497	28.61	2.963	67.99	2.911	3.402	1.110
	Upper secondary	1897	17.31	1.329	75.65	1.393	7.037	0.879
	Post secondary	2068	11.03	1.127	73.57	1.531	15.41	1.244
Cultural capital	Lowest quartile	1031	22.02	2.017	71.27	2.094	6.714	0.966
	Interquartile range	2338	17.77	1.314	73.41	1.467	8.818	0.790
	Highest quartile	1104	6.233	1.155	76.22	1.956	17.55	1.578
Grade	Below Grade 9	120	57.25	5.957	41.82	5.705	0.93	1.435
	Grade 9	2722	19.06	1.346	73.02	1.316	7.92	0.706
	Above Grade 9	1743	9.48	1.171	76.09	1.856	14.43	1.409
School sector	Community/ comprehensive	767	18.65	2.694	71.73	3.066	9.62	2.124
	Secondary	2803	11.99	1.078	75.96	1.237	12.05	0.975
	Vocational	1015	25.99	3.535	67.88	3.229	6.14	1.222
School gender composition	Mixed	2565	19.30	1.769	71.83	1.948	8.87	1.021
	Single sex	2020	12.42	1.482	75.44	1.339	12.15	1.160
School location	Rural/small town	1178	17.25	2.033	74.35	2.028	8.40	1.459
	Town/small city	2129	16.24	1.610	74.05	1.778	9.71	1.123
	City	1278	15.91	2.506	71.17	1.951	12.92	1.714

Table 3

Distribution of Students across each Categorical Background Variable by Science Achievement Group

			Achievement Group					
			Level 1 or below		Levels 2 to 4		Level 5 or 6	
		N	%	*SE*	%	*SE*	%	*SE*
Overall		4585	15.51	1.080	75.08	0.978	9.41	0.707
Gender	Male	2264	16.55	1.537	73.11	1.460	10.35	1.000
	Female	2321	14.50	1.088	77.00	1.143	8.50	0.796
Home language	English or Irish	4396	14.61	0.980	75.77	0.885	9.62	0.720
	Other	83	40.52	8.387	51.25	7.722	8.23	3.694
Native	Native	4200	14.61	0.964	75.94	0.903	9.45	0.699
	Non-native	242	21.78	4.076	66.22	3.911	1200	2.785
Intend to leave school early	Do not intend	4046	12.28	0.830	77.23	0.855	10.50	0.777
	Intend	445	40.93	3.976	57.76	3.911	1.31	0.550
Parental education	Lower secondary	497	27.17	2.975	69.49	2.878	3.34	0.933
	Upper secondary	1897	16.06	1.262	77.64	1.262	6.30	0.676
	Post secondary	2068	10.61	1.034	75.14	1.212	14.25	1.194
Cultural capital	Lowest quartile	1031	22.28	2.378	72.63	2.310	5.08	0.852
	Interquartile range	2338	16.44	1.127	75.86	1.127	7.70	0.670
	Highest quartile	1104	5.34	0.911	76.54	1.880	18.12	1.731
Grade	Below Grade 9	120	58.01	5.576	39.89	5.480	2.09	1.554
	Grade 9	2722	17.51	1.303	74.77	1.254	7.72	0.710
	Above Grade 9	1743	9.43	1.033	78.07	1.193	12.49	1.071
School sector	Community/ comprehensive	767	16.90	2.464	73.56	2.622	9.54	1.855
	Secondary	2803	11.57	1.051	77.38	1.056	11.05	0.955
	Vocational	1015	24.45	3.075	70.36	2.835	5.19	0.959
School gender composition	Mixed	2565	18.36	1.529	73.41	1.462	8.22	0.881
	Single sex	2020	11.56	1.525	77.38	1.364	11.06	1.114
School location	Rural/small town	1178	16.22	1.899	76.21	1.776	7.57	1.282
	Town/small city	2129	15.38	1.481	75.40	1.404	9.22	0.890
	City	1278	15.04	2.645	73.44	2.343	11.52	1.641

Table 4

Means of Continuous Background Variables by Achievement Group

	Achievement Group					
	Level 1 or Below		Level 2 to 4		Level 5 or 6	
	M	*SE*	*M*	*SE*	*M*	*SE*
Mathematics						
Books in the home	84.20	5.969	154.67	4.296	261.10	10.998
Socioeconomic status	-0.44	0.045	0.01	0.030	0.53	0.069
Home educational resources	-0.38	0.056	0.05	0.023	0.21	0.051
School average SES	-0.50	0.083	0.04	0.067	0.50	0.148
Science						
Books in the home	83.69	5.968	154.62	4.249	265.76	11.805
Socioeconomic status	-0.45	0.040	0.02	0.033	0.49	0.075
Home educational resources	-0.41	0.061	0.06	0.022	0.22	0.045
School average SES	-0.50	0.076	0.05	0.070	0.46	0.130

Table 5

Multinomial Model of Mathematics: Final Model with Hypothesis Tests and Odds Ratios for Example Values of Explanatory Variables

	L1 or below vs. L2 to L4					L5 or L6 vs. L2 to L4					Test Statistic		
	Parameter	*SE*	Odds Ratio	90% CI Lower	90% CI Upper	Parameter	*SE*	Odds Ratio	90% CI Lower	90% CI Upper	Chi-sq	*df*	*p*-value
School average SES	-0.412	0.099	0.607	**0.498**	**0.739**	0.184	0.098	1.250	**1.028**	**1.520**	29.452	2	<.001
Gender: Female-Male	0.387	0.146	1.472	**1.158**	**1.872**	-0.576	0.152	0.562	**0.438**	**0.722**	31.032	2	<.001
Home language: Other language-English or Irish	1.168	0.469	3.214	**1.487**	**6.948**	-0.018	0.604	0.982	0.363	2.654	15.075	2	<.001
Intend to leave school early: Yes-No	0.767	0.163	2.153	**1.647**	**2.816**	-1.425	0.457	0.240	**0.113**	**0.509**	50.640	2	<.001
Socioeconomic status	-0.202	0.071	0.682	**0.547**	**0.850**	0.248	0.068	1.600	**1.293**	**1.980**	34.110	2	<.001
Grade:													
Below grade 9-Grade9	1.304	0.240	3.683	**2.483**	**5.463**	-1.007	0.910	0.365	0.082	1.632	122.305	4	<.001
Above grade 9-Grade 9	-0.765	0.131	0.466	**0.375**	**0.578**	0.640	0.129	1.897	**1.534**	**2.347**			
Cultural capital:													
Low-medium	-0.145	0.158	0.865	0.667	1.121	0.142	0.217	1.152	0.807	1.646	23.113	4	<.001
High-medium	-0.719	0.208	0.487	**0.346**	**0.686**	0.138	0.125	1.148	0.935	1.409			
Log books index	-0.779	0.130	0.490	**0.403**	**0.595**	1.413	0.286	3.650	**2.372**	**5.617**	125.770	2	<.001

Note. CI = Confidence intervals; CI in bold indicate odds ratios significant at the 90% level.

Table 6

Multinomial Model of Science: Final Model with Hypothesis Tests and Odds Ratios for Example Values of Explanatory Variables

	L1 or below vs. L2 to L4					L5 or L6 vs. L2 to L4					Test Statistic		
	Parameter	*SE*	Odds Ratio	90% CI Lower	90% CI Upper	Parameter	*SE*	Odds Ratio	90% CI Lower	90% CI Upper	Chi-sq	*df*	*p*-value
School average SES	-0.398	0.107	0.617	**0.498**	**0.764**	0.107	0.073	1.139	0.985	1.316	25.806	2	<.001
Gender: Female-Male	0.183	0.144	1.201	a	a	-0.440	0.139	0.644	a	a	15.361	2	.001
Home language: Other language-English or Irish	1.242	0.328	3.462	**2.018**	**5.942**	0.291	0.544	1.338	0.547	3.273	16.068	2	<.001
Intend to leave school early: Yes-No	1.171	0.176	3.224	a	a	-1.859	0.889	0.156	a	a	60.409	2	<.001
Socioeconomic status	-0.188	0.078	0.701	**0.551**	**0.892**	0.179	0.077	1.404	**1.104**	**1.786**	19.985	2	<.001
Grade:													
Below grade 9-Grade9	1.492	0.268	4.447	**2.860**	**6.916**	-0.760	0.920	0.468	0.103	2.124	104.590	4	<.001
Above grade 9-Grade 9	-0.654	0.145	0.520	**0.410**	**0.660**	0.430	0.119	1.536	**1.263**	**1.869**			
Cultural capital													
Low-medium	-0.068	0.151	0.934	0.729	1.197	-0.097	0.173	0.908	0.683	1.207	30.852	4	<.001
High-medium	-0.702	0.227	0.496	**0.341**	**0.719**	0.355	0.151	1.427	**1.112**	**1.830**			
Log books index	-0.864	0.132	0.421	**0.339**	**0.523**	1.423	0.207	4.151	**2.951**	**5.839**	123.304	2	<.001
Gender x Intention to leave school early	-0.615	0.349	0.541	**0.304**	**0.960**	1.086	1.150	2.963	0.447	19.648	6.723	2	.035

Note. CI = Confidence intervals; CI in bold indicate odds ratios significant at the 90% level; [a]CI are only directly available for the interaction between gender and intention to leave school early.