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USING PISA VARIABLES TO EXPLAIN PERFORMANCE ON JUNIOR CERTIFICATE EXAMINATIONS IN MATHEMATICS AND SCIENCE

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Multilevel models of achievement on the Junior Certificate Examination (JCE) taken at the end of junior cycle in second-level schools are presented for mathematics and for science. The response variables are derived from JCE grades in mathematics and science of students who participated in the OECD Programme for International Student Assessment (PISA) in 2000. Explanatory variables consist of answers that students and their principal teachers gave on questionnaires administered as part of the PISA survey, as well as school-level variables taken from the database of the Irish Department of Education and Science. The model developed for JCE mathematics contained 10 student-level variables that included indicators of socioeconomic status and parental education, the number of books in the home, absenteeism, completion of homework on time, and intent to leave school prior to completion of the senior cycle (grades 10-12), as well as an interaction between student gender and completion of homework on time. At the school level, the model developed for mathematics contained two variables: school sector (whether vocational, secondary, or community/comprehensive) and designated disadvantaged status. The model for JCE science was similar to that for mathematics, also including socioeconomic status and parental education, books in the home, absenteeism, completion of homework on time, and intent to leave school at the student level. An interaction between books in the home and student gender was observed. The model also included at the school level school sector and designated disadvantaged status as well as school disciplinary climate. These models were compared with those of achievement on the PISA mathematics and science scales. A considerable degree of similarity between the two sets of models was found, confirming the association of a number of student-level and school-level variables with performance on both the JCE and PISA.

The international report on PISA 2000, which provides an overview of the results of the assessment, includes the between-school and within-school variance components in achievement on the three literacy scales for each country (OECD, 2001). The variance component that lies between schools gives an indication of how much schools differ from each other with respect to achievement, since it corresponds to the variance that can be attributed to schools. Expressed as a proportion, the between-school variance component, sometimes misleadingly called the intra-class correlation, is referred to as the intra-cluster correlation (ICC) in this paper. It is also commonly expressed as a percentage, and is presented in this form throughout the paper. The lower the between-school variance, or ICC, the more homogenous schools are with respect to achievement (see Postlethwaite, 1995).

Across OECD countries, 14.0% of the total variation lies between countries, 28.0% is between schools, and the majority (58.0%) lies within schools. The corresponding figures for scientific literacy are 8.8%, 28.4%, and 62.8%. Although the percentage of variation in achievement that lies between countries is higher for mathematical literacy than for scientific literacy, it should be noted that the between-country variance components are small, are based on a small sample of countries, and are not as stable as the components at the other two levels (D. Willms, personal communication, 12 July, 2002). The between-school variance components within Ireland are substantially lower than the OECD average (11.4% for mathematical literacy and 14.1% for scientific literacy), suggesting that Irish schools are comparatively homogenous with respect to achievement.

The between-school variance components associated with the Irish PISA data are lower than previous international studies of achievement might have led one to expect (Kellaghan, Madaus & Rakow, 1979; Smyth, 1999). For example, in an analysis of data for Irish students in eighth grade (second year of secondary school) in the Third International Mathematics and Science Study (TIMSS) carried out at the Educational Research Centre using maximum likelihood estimation of variance components and all five plausible values associated with the achievement estimates, ICCs of 44% and 33% for mathematics and science respectively, were obtained[1]. When performance on JCE mathematics and science for the same group of students was analysed, ICCs of 61% and 52%, respectively, were obtained. However, these estimates are likely to have been inflated since the TIMSS sample design entailed sampling of an intact mathematics class, while PISA entailed a random sample of 15-year olds across classes and grade (year) levels. This implies that the between-school variance components (ICCs) associated with the TIMSS data also include all the between-class variance, for mathematics, and some of the between-class variance, for science. The sample design of TIMSS inflates the between-school variance components for the JCE results of that sample in a similar fashion to

1 These estimates are somewhat lower than those reported in Martin, Mullis, Gregory, Hoyle, & Shen, (2000) (.50 for mathematics and .38 for science).

their scores on the original scales (Sofroniou & Kellaghan, in press). This also appears to be a plausible explanation of the variance components found in a recent study of students' overall performance on the JCE carried out by Smyth (1999), who reported an ICC of 22 percent. Note, however, that Smyth selected students with reference to their base classes, so they would not have been together for most subjects. This makes the calculation of variance components for academic subjects problematic.

The PISA international report includes three hierarchical linear models of achievement on the three literacy scales. Each model has three levels: one for country, one for school, and one for student, i.e., two nested random effects plus the random component for the residual variation. Fitting a hierarchical linear model across countries in this manner makes the assumption that individual countries are exchangeable, given the terms included in the model, and that the variation of countries from the country average follows a Normal distribution. The three-level model for mathematical literacy explains 32.2% of between-country variation, 67.8% of variation between schools, and 11.2% of variation between students. The three-level model for scientific literacy is broadly similar, accounting for 15.6% of between-country variation, 69.0% of variation between schools, and 10.7% of variation within schools. The approach taken in the present paper, which is most appropriate for a detailed study of the Irish population, involves fitting a two-level hierarchical linear model to a single country's data, and analysing the between-school and within-school variance components, as well as the fixed effects, specific to the country.

Since only one model for each domain was developed across all countries, the international models run the risk of omitting a number of variables that may be relevant to explaining achievement in individual countries. The international models did not include any domain-specific explanatory variables (e.g., use of a calculator during the assessment, or time spent doing science homework). Furthermore, the fitting of a Normally-distributed random effects model at the country level raises theoretical issues concerning inferences about the population from which the relatively small number of countries is deemed to be a random sample (within the context of a frequentist statistical framework), or about the exchangeability of one country for another (in a Bayesian statistical framework) (see Raudenbush, Cheong, & Fotiu, 1994).

Following a decision to develop hierarchical linear models of achievement on the PISA literacy assessments, subsets of the larger set of explanatory variables were identified as candidates for inclusion, taking into account collinearity of variables in the full set and policy issues identified by the PISA National Committee. The Irish models of mathematical and scientific literacy were found to explain about three-quarters of between-school variance, and about one-third of the variance within schools (Shiel, Cosgrove, Sofroniou, & Kelly, 2001).

The Irish model for mathematical literacy included just two school-level variables (school type, i.e., sector and designated disadvantaged status) and several student-level variables: gender, socioeconomic status, number of siblings, index of books in the home, dropout risk, frequency of completion of homework on time, grade (year) level, parental education, lone-parent status, and an interaction term (gender x lone-parent status). The model for scientific literacy included the same two school-level variables, and several student-level variables: gender, socioeconomic status, number of siblings, index of books in the home, dropout risk, frequency of completion of homework on time, grade (year) level, student absenteeism, whether the student studies science in school, parental engagement, and an interaction term (gender x index of books in the home).

In the Irish national report on PISA 2000, some comparisons were drawn between the performance of students on PISA, and their performance on the JC English, mathematics and science examinations (Shiel et al., 2001). To make these comparisons possible, the JCE grades of PISA students who had taken the examination in 1999 (33.1%) or 2000 (60.9%) were matched with the PISA database. Students' JCE grades were placed on a JCE Performance Scale that ranges from 1 to 12 (in the case of English and mathematics) or 4 to 12 (in the case of science) to accommodate the level of the examination taken (Higher, Ordinary, Foundation) (Table 1).

Table 1
Junior Certificate Performance Scale

Higher Level	Ordinary Level	Foundation Level	Junior Certificate Performance Scale Score
A			12
B			11
C			10
D	A		9
E	B		8
F	C		7
	D	A	6
	E	B	5
	F	C	4
		D	3
		E	2
		F	1

Foundation level science is not offered.

The scale has been used in a number of studies to summarize overall performance on the JCE rather than on individual subjects (Kellaghan & Dwan, 1995; Martin & Hickey, 1993). Exploratory comparisons between the 12-point scale and alternative 8-, 10- and 14-point scales using ordinary least-squares (OLS) regressions found that the 12-point scales (9-point in the case of science) generally worked better than the alternatives (see Shiel et al., 2001, p. 224). However, because the scale is bounded at its upper and lower points, care is needed in predicting from the extremes of explanatory variables with linear models.

Shiel et al. (2001) note that the PISA framework for mathematical literacy is rooted in the Realistic Mathematics Education (RME) approach (see, e.g., van den Heuvel-Panhuizen, 1998), which differs from the more abstract, context-free mathematics approach in the Junior Certificate mathematics syllabus and examination. While questions in the Junior Certificate mathematics examination papers are presented in a mathematical and abstract context with little or no redundant information, in PISA, students were presented with questions that were commonly embedded in rich authentic contexts, often accompanied by text and diagrams. Discrimination between necessary and redundant information and formulation of the problem (‘mathematization’) were commonly required.

The general aims and objectives of the Junior Certificate science syllabus (Department of Education, 1990) appear to be broadly congruent with those identified in the PISA framework for scientific literacy (Shiel et al., 2001). Further, neither assessment in its current form accords a high degree of emphasis to physics or chemistry. However, there are some notable differences. PISA includes questions in areas of applied science such as genetics and the greenhouse effect, neither of which appears on the Junior Certificate science syllabus in its current form. PISA also emphasizes earth science to a greater extent than the Junior Certificate science syllabus, which includes it as an optional rather than a core component.

Apart from some differences in science content areas, there are differences between the two science assessments with respect to the emphasis placed on an understanding of science processes and the scientific method. The Junior Certificate science syllabus emphasizes the understanding of scientific concepts, but accords a much lower emphasis to the understanding of the scientific process and method (such as identifying and formulating hypotheses, evaluating and communicating conclusions, or the design of a valid experiment). In contrast, PISA gives precedence to the understanding of the scientific method and scientific processes.

Despite differences between the two assessments, correlations between students' scores for PISA mathematical and scientific literacy and their Junior Certificate Performance Scale scores in the respective subjects are substantial and significant($p<.001$)[2] ; for both mathematical literacy/JCE mathematics and scientific literacy/JCE science, it is .73. The strength of the correlations is perhaps surprisingly high, and suggests that explanatory models of achievement on the two sets of assessments might be broadly similar.

The purpose of the study reported in this paper was to develop multilevel models[3] of performance on Junior Certificate Examinations (JCE) in mathematics and science, and to compare these with models of performance based on tests of mathematical and scientific literacy administered as part of the OECD Programme for International Student Assessment (PISA). Response variables are the outcomes of students who participated in PISA on the 1999 and 2000 Junior Certificate mathematics and science examinations. A subset of the variables collected in the PISA questionnaires and from the Irish Department of Education and Science schools database comprise the explanatory variables used in the models.

METHOD

Participants

Participants in the current study were 15-year olds (i.e., born in 1984) attending Irish second-level schools who had participated in PISA in 2000, who had taken the Junior Certificate Examination in either 1999 or 2000, and for whom data on all the PISA student-level candidate variables were available (Table 2; Table A1). A total of 1,896 students had complete data on the relevant variables in the Junior Certificate mathematics examination dataset, and 1,629 in the Junior Certificate science examination dataset. The proportion of females in the mathematics dataset is .53, and in the science dataset .49. The mean JCE Performance Scale score for mathematics is 8.20 (SD=2.05), and the mean JCE Performance Scale score for science is 9.36 (SD=1.77).

2 The test statistics and the method used to establish the significance of correlation coefficients are reported on p. 206 of Shiel et al. (2001).

3 A multilevel model is a statistical model which explains variation in an outcome (in this case student academic achievement) through the addition of explanatory variables at two or more levels, e.g., the school (cluster level) and student (within-cluster level). The clustering of students into schools is taken into account through the addition of one or more random effects.

Variables

Candidate variables considered for inclusion in the models for JCE mathematics and science were ones that had been used to model PISA mathematical and scientific literacy, with two exceptions. While the PISA models included a variable reflecting the grade the student was in, this was replaced in the JCE models by the year in which the student had taken the Junior Certificate (1999 or 2000). Furthermore, while the model for achievement in PISA scientific literacy included a variable indicating whether or not the student had studied science at junior cycle level, this variable was not needed in the JCE model since all students in that dataset had studied science (Table 2; Appendix 1).

Eleven student-level variables and six school-level variables were considered for inclusion in analyses. The student-level variables were

(i) *socioeconomic status,* as indicated by the higher of the parents' occupation (where applicable) coded according to the International Standard Classification of Occupations (ISCO) (see Ganzeboom & Treiman, 1996)
(ii) *parental engagement*, a composite variable constructed from responses to items on the student questionnaire, scaled to have a mean of 0 and standard deviation of 1
(iii) *number of siblings*, which ranged from 0 to 11
(iv) *student gender*
(v) *parental education*, which is the higher of the parents' completed level of education (where applicable, ranging from primary to third-level)
(vi) *lone parent status* (whether one or both parents reside in the student's household)
(vii) *dropout risk* (intent to leave school prior to completion of the senior cycle, which spans grades 10-12)
(viii) *number of absences from school* in the two weeks prior to the PISA survey, ranging from none to three or more
(ix) *completion of homework on time* ranging from never to always
(x) *year in which the JCE was taken (1999 or 2000)*
(xi) *index of the number of books in the home* ranging from none to more than 500 (the log of the scale was used).

The school-level variables were:

(i) *disciplinary climate*, a composite variable constructed from responses to items on the student questionnaire and aggregated to the school level
(ii) *student-teacher ratio*, the total student enrolment divided by the total number of teachers (where full-time students were given a weight of 1 and part-time teachers a weight of 0.5)

(iii) *school stratum*, which is an indicator of school enrolment size (large, medium, or small) used in the sampling of schools and evaluated to minimize any bias that might be induced by the stratified sample design
(iv) *school sector* (vocational, secondary, or community/comprehensive)
(v) *school gender composition* (all male, all female, or mixed sex)
(vi) *school designated disadvantaged status* (whether the school was included in the Irish Department of Education and Science Disadvantaged Areas Scheme, which allocates additional teaching posts, funding to launch book rental schemes, extra capitation grants, and a home-school liaison grant to develop links with parents).

Table 2
School and Student Variables for Hierarchical Linear Models of Performance on the Junior Certificate Mathematics and Science Examinations

School Variables (Level 2)	Student Variables (Level 1)
Structure	Background
School Size/Stratum*	Gender
School Type/Sector**	Socioeconomic Status
Disadvantaged Status**	Parental Education
Gender Composition**	Lone-parent Status*
Climate/Policy	Number of Siblings
Negative Disciplinary Climate*	Home Educational Climate
Resources	Parent Engagement
Student-Teacher Ratio	Index of Number of Books at Home
	Student as Learner
	Dropout Risk*
	Absence from School
	Complete Homework on Time
	Junior Cert. Year*

*Variables collected or derived locally from the questionnaires (i.e., not in the PISA international database).
**Variable derived from the Schools Database of the Department of Education and Science.

Implementation of Modelling Procedures

Separate models for the Junior Certificate mathematics and science examinations were developed using hierarchical linear modelling. These types of models incorporate a random effect at the level of the cluster (i.e., schools) that allows for the variation across clusters to be taken into account. They also permit the inclusion of one or more random coefficients to allow variation in one or more of the explanatory variables across clusters to be taken into account. A random effect at the cluster level consisting only of a random intercept indicates that the slopes of the fitted parameters are constant across clusters, but that they vary in a parallel manner from school to school. Making a coefficient random rather than fixed indicates that the slope for that explanatory variable varies significantly from one school to another, i.e., across the clusters.

In the models presented in this paper, full maximum likelihood estimation was used. This method enables deviance tests of both fixed and random effects to be carried out. The HLM 5 software package was used for estimation, together with macros written in GLIM 4. Consistent with Aitkin, Francis, and Hinde (in press), sampling weights were not applied in developing the models; rather, the sample design strata were evaluated in the model itself. Uncentred continuous explanatory variables were used. This results in the model intercept having the conventional interpretation of the intercept in OLS regression (i.e., the value of the linear predictor when all explanatory variables have a value of zero). The development of each model involved the procedures which follow.

Candidate variables at the student level were initially evaluated separately as fixed effects added to a random intercept-only model of achievement (in either the Junior Certificate mathematics or science examination models), and then evaluated simultaneously. Non-significant variables, with the exception of gender which was retained to enable subsequent evaluation of gender interactions (a matter of policy interest), were omitted from the model using a manual backwards elimination strategy. Any borderline significant variables (i.e., p=.05 to .10) were retained at this point. Categorical variables with more than two levels (such as frequency of absence from school) were evaluated using omnibus tests of deviance changes by fitting the model with, and without, the corresponding set of dummy variables. Following this, interactions between student gender and the other student-level variables were tested separately by addition to the model, and significant interactions were added to form a new model.

School-level variables were then evaluated both separately and simultaneously in the same manner as those at the student level. One school-level variable, student-teacher ratio, was missing for one school. To avoid the loss of data, a missing value indicator method was applied, in which student-teacher ratio was nested within a binary variable (where a value of 1 indicated non-missing) (see Lindsey & Lindsey, 2001).

The explicit stratifying variable, school size (the number of 15-year olds enrolled), which had been used in the sample design, was included as a variable at this level, as were the two variables used as implicit stratifying variables (school type and school gender composition). The evaluation of these three variables served to ensure that the unweighted analysis was not distorted by over-sampling of any particular sub-group. The school-level variables were then added to the random intercept model containing the student-level variables and any variables for which parameter estimates were not significant were removed sequentially. Any remaining explanatory variables were then tested using a stricter criterion ($p < .05$).

Estimates and tests of quadratic terms for all continuous variables at both levels were tested separately (or jointly in cases where there were interactions between those variables and gender). Significant quadratic terms (and their interactions with gender if applicable) were added to the model and evaluated sequentially. Finally, random coefficients for student-level variables were tested through changes in deviance referred to a chi-squared distribution, with the change in the number of terms in the model as the number of degrees of freedom.

RESULTS

Junior Certificate Mathematics Examination

Model of Performance. Prior to testing each student-level variable by addition to a random intercept-only model, exploratory analyses of the curvilinearity of their relationships with performance on the Junior Certificate mathematics examination indicated that index of books in the home would be well represented by its logarithmic form. Table 3 shows the parameter estimates

Table 3
Performance Scores on the Junior Certificate Mathematics Examination: All Level 1 Variables Tested as Separate Models by Addition to the Random Intercept-Only Model

	Parameter	SE	Test Statistic	*df*	*p*
Gender: Male – Female	-0.106	0.112	t = -0.945	1894	.345
Socioeconomic Status	0.034	0.003	t = 11.685	1894	<.001
Parental Education			χ^2=95.342	3	<.001
None/Primary–Upper Sec	-0.750	0.157			
Lower Sec–Upper Sec	-0.613	0.123			
Third Level–Upper Sec	0.418	0.108			
Lone-parent: Yes– No	-0.683	0.136	t =-5.025	1894	<.001
Number of Siblings	-0.105	0.032	t = -3.262	1894	.001
Parent Engagement	0.342	0.046	t = 7.378	1894	<.001
Log Index of Books in the Home	1.733	0.132	t = 13.162	1894	<.001
Dropout Risk: Yes– No	-1.795	0.131	t = -13.751	1894	<.001
Absence			χ^2 =74.336	2	<.001
No days–1 or 2 days	0.659	0.098			
3 days or more–1 or 2 days	-0.460	0.178			
Homework on Time			χ^2= 108.493	3	<.001
Never–Mostly	-0.959	0.216			
Sometimes–Mostly	-0.654	0.111			
Always–Mostly	0.596	0.110			
Junior Cert. Year (2000-1999)	-0.455	0.093	t = -4.883	1894	<.001

χ^2 tests are based on deviance differences.

and tests of significance of the student-level variables that were tested separately. All are significant with the exception of gender. When all variables were entered simultaneously, all remain significant, except for gender, which becomes borderline significant (p=.055), and the direction of its parameter estimate changes from positive to negative.

After testing for interactions with each variable separately, it was found that gender interacted significantly with single parent status, homework on time, and log of books in the home. However, when tested simultaneously through addition to the student-level model, only one interaction remains significant: gender x homework on time.

The next stage involved testing each school-level variable separately when added to an intercept-only model (Table 4)[4]. All school-level variables tested separately are significant with the exception of school size, the explicit stratifying variable.

Table 4
Achievement Scores on the Junior Certificate Mathematics Examination: All Level 2 Variables Tested as Separate Models by Addition to the Intercept-Only Model

	Parameter	SE	Test Statistic	*df*	*p*
Negative Disciplinary Climate	-0.556	0.214	t = -2.600	137	.010
School Type			χ^2= 32.995	2	<.001
Secondary–Community/Comp	0.251	0.216			
Vocational–Community/Comp	-0.844	0.250			
Not Designated Disadv–Disadvantaged	0.821	0.175	t = 4.680	137	<.001
School Gender Composition			χ^2= 12.145	2	.002
All Males–Mixed	0.716	0.219			
All Females–Mixed	0.411	0.186			
School Size (Number of 15–Year Olds)			χ^2 = 4.114	2	.128
Large–Medium	-0.139	0.389			
Small–Medium	0.340	0.194			
Student–Teacher Ratio	0.115	0.042	t = 2.727	136	.007

χ^2 tests are based on deviance difference.

4 Student-teacher ratio was tested as a fixed effect nested within its non-missing binary indicator in models for achievement in both the Junior Certificate mathematics and science examinations.

When all school-level variables were added to the existing student-level model, school size remains non-significant. Student-teacher ratio loses its significance in the presence of the other variables, and negative disciplinary climate becomes borderline significant (p=.082). Following the removal of school size and student-teacher ratio, as negative disciplinary climate is no longer significant (p=.106), it too was removed from the model. As school gender composition is also non-significant at this point (p=.095), as is the non-missing indicator for student-teacher ratio (p=.075) and the number of siblings (p=.077), they too were removed from the model.

Tests for curvilinearity of the two continuous student-level variables that remained in the model (socioeconomic status and parental engagement) revealed no significant curvilinear relationships with performance on the Junior Certificate mathematics examination. Finally, random coefficients for the remaining student-level variables were tested by adding each one separately to the model, yielding a final model (Table 5), which includes one statistically significant random coefficient at the student level (lone-parent status).

The variance components associated with the intercept-only model correspond to the intra-cluster correlation of the response variable (.156). This suggests that 15.6% of the variance in achievement is attributable to the school level, the remainder coming from the student/class level, though information on the class groupings of students was not gathered in PISA. To estimate the proportions of variance explained by the model, the variance components associated with the model prior to the addition of the random coefficients for lone-parent status were used. The mean number of 15-year olds enrolled in the population (86.88) was used as the typical cluster size in the calculations (see Snijders & Bosker, 1999). The model explains 29.5% of variance within schools, and 64.3% of variance between schools.

A comparison with the analysis of the PISA 2000 model of mathematical literacy (Shiel et al., 2001, Chapter 5) indicates that the percentage of variance that lies between schools is somewhat higher for the Junior Certificate mathematics examination than for PISA mathematical literacy (15.6% versus 11.4%). The percentage of within-school variance explained by the two models is comparable (29.5% versus 31.9%), while the percentage of explained between-school variance is slightly lower for the Junior Certificate mathematics examination than for PISA mathematical literacy (64.3% versus 78.8%). The addition of the school-level variables to the model of achievement on the Junior Certificate mathematics examination results in an increase of 10.2% of explained variance at the school level and 1.7% at the student level.

Table 5
Final Model of Performance on the Junior Certificate Mathematics Examination

	Parameter	SE	Test Statistic	*df*	*p*
Intercept	6.100	0.303			
Student-Level Variables					
Gender: Male–Female	0.219	0.120			
Socioeconomic Status	0.017	0.003	t = 5.742	1874	<.001
Parental Education			χ^2 =13.405	3	.004
None/Primary–Upper Sec	-0.300	0.144			
Lower Sec–Upper Sec	-0.342	0.111			
Third Level–Upper Sec	0.016	0.101			
Lone-Parent Status: Yes–No	0.453	0.125	t = -3.616	138	.001
Log Index of Books in the Home	0.928	0.131	t = 7.101	1874	<.001
Parental Engagement	0.103	0.043	t = 2.393	1874	.017
Dropout Risk: Yes– No	-1.249	0.127	t = -9.811	1874	<.001
Junior Certificate Year (2000-1999)	-0.432	0.083	t = -5.202	1874	<.001
Absence			χ^2= 25.256	2	<.001
No days–1 or 2 days	0.366	0.085			
3 days or more–1 or 2 days	-0.202	0.157			
Homework on Time					
Never–Mostly	-0.822	0.314			
Sometimes–Mostly	-0.454	0.139			
Always–Mostly	0.616	0.135			
Gender x Homework on Time			χ^2= 9.072	3	.028
Gender x Never–Mostly	0.652	0.401			
Gender x Sometimes–Mostly	0.236	0.197			
Gender x Always–Mostly	-0.339	0.198			
School-Level Variables					
School Type			χ^2= 14.241	2	.001
Secondary–Community/Comp	-0.016	0.164			
Vocational–Community/Comp	-0.538	0.186			
Not Designated Disadv–Disadvantaged	0.334	0.132	t = 2.541	135	.011
Variance Components					
Level 2 Random Component					
Intercept Variance	0.269				
Single Parent RC			χ^2= 6.613	2	.037
Single Parent Variance	0.235				
Intercept-Single Parent Covariance	-0.236				
Level 1 Variance	2.742				
Variables Dropped from Model (in sequence)					
School Size	School Gender Composition				
Student-Teacher Ratio	Number of Siblings				
Negative Disciplinary Climate	Non-missing Indicator for Student-Teacher Ratio				

χ^2 tests are based on deviance differences.

Fitted Values of the Model. The model is additive in the sense that every variable contributes to the linear predictor. Contributions can be used to compare the effects of explanatory variables. While the contributions of categorical variables are directly apparent from the final model (Table 5), those corresponding to continuous variables and any interactions are not. Therefore, some example values are provided.

As evident from the parameter estimates in Table 5, a student in a vocational school has a predicted Junior Certificate mathematics examination grade that is 0.54 grades (around one-quarter of a standard deviation) below that of the predicted score of a student in a community/comprehensive school; and a student at risk of dropping out of school before the end of the senior cycle has a predicted grade that is 1.25 grades (three-fifths of a standard deviation) below the predicted score of a student who is not at risk. For a variable with a random slope (dropout risk in the case of the final model of performance on the Junior Certificate mathematics examination), the range of values that the random slope takes for 95% of the population may be estimated by taking the square root of the variance associated with the slope (i.e., the standard deviation), and adding +/- 1.96 times this value to the parameter estimate. For dropout risk, the values range from -2.20 to -0.30 grades.

Continuous variables were categorized into high, medium, and low categories, using the values closest to the 33rd and 67th percentiles on their scales as cut-points, and these values were used in estimating effects of being at the mean of each of these groups, using the parameter values from the model in Table 5. Table 6 gives the contributions for students scoring at the means of the high, medium, and low categories for the two continuous variables in the final model of achievement on the Junior Certificate mathematics examination.

Table 6

Contributions to Grades in the Junior Certificate Mathematics Examination Attributable to Socioeconomic Status and Parental Engagement

Variable	Estimated Contributions to Scores
Socioeconomic Status	
Low	0.520
Medium	0.800
High	1.082
Parental Engagement	
Low	-0.127
Medium	-0.013
High	0.084

The difference in the predicted scores of students at the mean of the low and high socioeconomic backgrounds is 0.56 of a grade (just over one-quarter of a standard deviation), while the difference between the predicted scores of students indicating they are at the mean of low and high parental engagement is just 0.21 of a grade (around one-tenth of a standard deviation).

Table 7 presents data on the contributions to achievement associated with the index of books in the home (which is in its logarithmic form in the model). The estimates suggest that the effect of different numbers of books in the home tapers off at the upper end, and that the difference in the predicted scores of students with no books at home and those with more than 500 books is 1.81 grades (nine-tenths of a standard deviation).

Table 7
Contributions to Grades in the Junior Certificate Mathematics Examination Attributable to Number of Books in the Home

Index of Books in the Home	Estimated Contributions to Scores
No Books (1)	0.000
1-10 books (2)	0.643
11-50 books (3)	1.019
51-100 books (4)	1.286
101-250 books (5)	1.493
251-500 books (6)	1.662
501+ books (7)	1.805

Table 8 shows the contributions of frequency of completion of homework on time, which had a significant interaction with gender. The estimates suggest that female students who never complete their homework on time are predicted to score 0.87 grades lower than males in the same category, and that there is little difference in the expected scores (just 0.12 grades) of male and female students who always complete their homework on time. The difference between the lowest and highest categories is higher for females than for males (1.44 grades compared to 0.45 grades), suggesting that the effect for this explanatory variable is substantially stronger for females.

Table 8
Contributions to Grades in the Junior Certificate Mathematics Examination Attributable to Frequency of Completion of Homework on Time, for Male and Female Students

Completion of	Estimated Contributions to Scores	
Homework on Time	Males	Females
Never	0.049	-0.822
Sometimes	0.001	-0.454
Mostly	0.219	0.000
Always	0.496	0.615

Junior Certificate Science Examination

Model of Performance. Table 9 shows the parameter estimates and tests of significance for the student-level variables that were initially tested separately in modelling performance on the Junior Certificate science examinations. All candidate variables are significant. When all variables were entered simultaneously, single parent status and parental engagement are no longer significant at the initial criterion ($p \leq .10$) and were removed from the model at this point. Junior Certificate year is borderline significant after removal, but was retained until tests for the significance of interactions between gender and the other explanatory variables were carried out.

Table 9

Performance Scores on the Junior Certificate Science Examination: All Level 1 Variables Tested as Separate Models by Addition to the Random Intercept-Only Model

	Parameter	SE	Test Statistic	*df*	*p*
Gender: Male – Female	-0.476	0.103	t = -4.616	1627	<.001
Socioeconomic Status	0.029	0.003	t = 10.664	1627	<.001
Parental Education			χ^2 = 77.211	3	<.001
None/Primary–Upper Sec	-0.582	0.151			
Lower Sec–Upper Sec	-0.346	0.116			
Third Level–Upper Sec	0.484	0.099			
Lone-parent: Yes– No	-0.379	0.134	t = -2.830	1627	.005
Number of Siblings	-0.140	0.030	t = -4.662	1627	<.001
Parent Engagement	0.276	0.044	t = 6.257	1627	<.001
Log Index of Books in the Home	1.584	0.124	t = 12.736	1627	<.001
Dropout Risk: Yes– No	-1.797	0.126	t = -14.280	1627	<.001
Absence			χ^2 = 59.741	2	<.001
No days–1 or 2 days	0.577	0.089			
3 days or more–1 or 2 days	-0.299	0.163			
Homework on Time			χ^2= 87.000	3	<.001
Never–Mostly	-0.997	0.204			
Sometimes–Mostly	-0.555	0.104			
Always–Mostly	0.452	0.104			
Junior Cert. Year (2000-1999)	-0.214	0.089	t = -2.410	1627	.016

χ^2 tests are based on deviance differences.

After testing the significance of interactions between gender and the other explanatory variables separately, just one significant interaction emerged: gender x index of books in the home. This term was then added to the model and variables that were borderline significant were removed. All variables retain significance except for Junior Certificate year (p=.100) which was removed.

Each school-level variable was then examined separately by addition to an intercept-only model (Table 10). All school-level variables tested separately are significant. When the school-level variables were added simultaneously to the existing student-level model, school gender composition, student-teacher ratio and its non-missing indicator, and school size (stratum) are not significant and were removed in sequence.

Table 10

Performance Scores on the Junior Certificate Science Examination: All Level 2 Variables Tested as Separate Models by Addition to the Intercept-Only Model

	Parameter	SE	Test Statistic	*df*	*p*
Negative Disciplinary Climate	-0.577	0.192	t = -3.010	135	.003
School Type			χ^2 = 37.417	2	<.001
Secondary–Community/Comp	0.508	0.190			
Vocational–Community/Comp	-0.553	0.227			
Not Designated Disadv–Disadvantaged	0.778	0.161	t = 4.829	135	<.001
School Gender Composition			χ^2 = 19.741	2	<.001
All Males–Mixed	0.276	0.187			
All Females–Mixed	0.762	0.166			
School Size (Number of 15–Year Olds)			χ^2= 7.096	2	.029
Large–Medium	-0.499	0.346			
Small–Medium	0.270	0.178			
Student–Teacher Ratio	0.111	0.039	t = 2.855	134	.005

χ^2 tests are based on deviance differences.

Tests for curvilinearity of the three remaining continuous student-level variables revealed no significant relationships. Finally, random coefficients for the remaining student-level variables were tested by adding each one separately to the model. Although the deviance test statistic for the slope associated with the socioeconomic status coefficient was just statistically significant (Ddiff = 6.286; *df*=2; *p*=.043), the random coefficient for this explanatory variable was not added to the model because of low reliability (.082).[5] In addition, the estimated

5 A random effect is considered reliable if it has a reliability of .10 (Raudenbush, Bryk, Cheong, & Congdon, 2000).

random coefficient was far less than 1.96 times its standard error (random coefficient = 0.00008, with standard error = 0.0378). Thus, the final model (Table 11) does not involve quadratic terms or random coefficients, and contains one interaction term.

Table 11
Final Model of Achievement Scores on the Junior Certificate Science Examination

	Parameter	SE	Test Statistic	*df*	*p*
Intercept	6.720	0.351			
Student-Level Variables					
Gender: Male–Female	0.731	0.367			
Socioeconomic Status	0.013	0.003	t = 4.825	1610	<. 001
Parental Education			χ^2 = 8.067	3	.045
Primary-Upper Second	-0.275	0.137			
Lower Second-Upper Second	-0.121	0.104			
Third Level-Upper Second	0.104	0.092			
Log Index of Books in the Home	1.261	0.177			
Dropout Risk: Yes– No	-1.293	0.121	t = -10.663	1610	<. 001
Absence			χ^2 = 33.865	2	<. 001
No days–1 or 2 days	0.396	0.080			
3 days or more–1 or 2 days	-0.186	0.145			
Homework on Time			χ^2 = 34.820	3	<. 001
Never–Mostly	-0.538	0.185			
Sometimes–Mostly	-0.233	0.095			
Always–Mostly	0.342	0.093			
Number of Siblings	-0.091	0.027	t = -3.386	1610	.001
Log (Index of Books) x Gender	-0.601	0.227	t = -2.648	1610	.008
School-Level Variables					
School Type			χ^2 = 11.038	2	.004
Secondary–Community/Comp	0.170	0.144			
Vocational–Community/Comp	-0.278	0.170			
Not Designated Disadv–Disadvantaged	0.238	0.121	t = 1.974	132	.048
Negative Disciplinary Climate	-0.286	0.132	t = -2.169	132	.030
Variance Components					
Level 2 Variance	0.133		χ^2 = 251.803	132	<.001
Level 1 Variance	2.062				
Variables Dropped from Model (in sequence)					
Lone-Parent Status	Student-Teacher Ratio				
Parental Engagement	Non-Missing Indicator for Student-Teacher Ratio				
Junior Certificate Year	School Size (stratum)				
School Gender Composition					

χ^2 tests of fixed effects are based on deviance differences.

The variance components associated with the intercept-only model of achievement on the Junior Certificate science examination are given by the intra-cluster correlation (.162), which indicates that 16.2% of the variance in achievement is attributable to the school level, the remainder coming from the student/class level. The model explains 31.1% of variance within schools, and 71.3% of variance between schools.

A comparison with the PISA model of scientific literacy suggests that the percentage of variance that lies between schools for the two science assessments is close (16.2% for the Junior Certificate examination and 14.1% for PISA). The proportion of within-school variance explained by the two models is also similar (31.1% for the Junior Certificate science examination versus 34.1% for PISA scientific literacy), as is the percentage of explained between-school variance (71.3% for the Junior Certificate science examination and 74.5% for PISA scientific literacy). The addition of the school-level variables to the model of achievement on the Junior Certificate science examination results in an increase of 10.7% of explained variance at the school level and 1.9% at the student level.

Fitted Values of the Model. As examples of the contribution of categorical variables, a student in a school that is designated disadvantaged is predicted to score 0.29 grades (around one-sixth of a standard deviation) below that of the score predicted for a student in a school that is not designated disadvantaged; and a student at risk of dropping out of school before the end of the senior cycle has a predicted grade that is 1.29 grades (almost three-quarters of a standard deviation) below the predicted score of a student who is not at risk.

Table 12 gives the contributions for students scoring at the means of the high, medium, and low groupings for the two continuous variables in the final model of achievement on the Junior Certificate science examination.

Table 12
Contributions to Grades in the Junior Certificate Science Examination Attributable to Socioeconomic Status and Negative Disciplinary Climate

Variable	Estimated Contributions to Scores
Socioeconomic Status	
Low	0.391
Medium	0.615
High	0.834
Negative Disciplinary Climate	
Low	0.145
Medium	0.018
High	-0.099

The difference in the predicted scores of students of low and high socioeconomic backgrounds is 0.44 of a grade (one-quarter of a standard deviation), and the difference between the predicted scores of students in schools with high and low negative disciplinary climates is 0.24 grades (around one-seventh of a standard deviation).

Table 13
Contributions to Grades in the Junior Certificate Science Examination Attributable to Number of Books in the Home, by Gender

Index of Books in the Home	Estimated Contributions to Scores: Males	Females
No Books (1)	0.731	0.000
1-10 books (2)	1.189	0.874
11-50 books (3)	1.457	1.386
51-100 books (4)	1.647	1.749
101-250 books (5)	1.794	2.030
251-500 books (6)	1.915	2.260
501+ books (7)	2.016	2.454

Table 13 shows the contributions to achievement associated with the index of books in the home (which is in its logarithmic form in the model, and interacts significantly with gender). At the lower end of the scale, the predicted contribution is higher for males, while at the upper end, the contribution to the achievement of females is higher. The gradient for males is shallower, tapering off slightly at the upper categories, while that for females is steeper and tapers off more noticeably. When one compares the difference between the uppermost and lowermost categories, for females, it amounts to 2.45 grades (1.4 standard deviations), while for males, it is 1.29 grades (under three-quarters of a standard deviation).

CONCLUSION

An examination of variance components associated with the models of achievement on PISA mathematical and scientific literacy indicates that those for Ireland are well below the corresponding OECD averages (11.4% compared to 31.4% in the case of mathematical literacy, and 14.1% compared to 30.6% in the case of scientific literacy). This suggests that Irish schools are comparatively homogenous with respect to achievement in both mathematical and scientific literacy, though there is considerable variation within schools on these measures. Irish schools are also comparatively more homogenous with respect to achievement in reading literacy (Shiel et al., 2001).

The between-school variance components associated with the models of achievement in the Junior Certificate mathematics and science examinations are also quite low (15.6% and 16.2%, respectively), although the value for Junior Certificate mathematics is somewhat higher than for achievement in PISA mathematical literacy (11.4%). These components for both PISA Junior Certificate mathematics and science achievement are lower than the results of previous international studies for Ireland would suggest (Beaton et al., 1996a; Beaton et al., 1996b). However, the use of intact-class sampling in previous studies had the effect of combining between-school and between-class variance into a single component.

The final model of achievement on the Junior Certificate mathematics examination described in this paper explains 64.3% of variance between schools and 29.5% within schools. The model of achievement in PISA mathematical literacy explained 78.8% of the variance between schools, and 31.9% of within-school variance (Shiel et al., 2001). Although the value for explained between-school variance is somewhat higher for the PISA model of mathematical literacy, it should be borne in mind that the variance components associated with the two measures of achievement in mathematics differ somewhat. (For PISA mathematics the percentage of the total variance that lies between schools was 11.4, while for Junior Certificate mathematics, it was 15.6).

The final models of achievement in mathematics are broadly similar. At the school level, just two of the six candidate variables were retained in both of the final models: school type and designated disadvantaged status.

At the student level, an index reflecting the number of books in the home (a proxy for home educational resources) is highly significant in both models: differences in the expected scores of students with the highest and lowest numbers of books amount to just over one standard deviation in the case of achievement on PISA mathematical literacy, and just under one standard deviation for the Junior Certificate mathematics examination. Although socioeconomic status is significant in both models of achievement in mathematics, its effect (around one-quarter of a standard deviation in achievement between low and high groups in both models) cannot be regarded as large compared with other related explanatory variables such as books in the home.

Another explanatory variable that is highly significant in both models of mathematical achievement (PISA and the Junior Certificate examination) is dropout risk. Its expected contribution to achievement in both measures is just over three-fifths of a standard deviation. However, it is of interest that the effect of dropout risk varies across schools in the model of the Junior Certificate mathematics examination, but is constant in the case of PISA mathematical literacy. It should be borne in mind that students taking PISA included those who took the Junior Certificate examinations about ten months prior to taking the PISA assessment (in 1999) and those who took it two months after taking the PISA assessment (in 2000). Students' intention to leave school early may change somewhat after they sit the Junior Certificate examination.

Lone-parent status also survived in both models, although effects of living in a household headed by one parent in the case of PISA mathematical literacy should be interpreted in light of an interaction with the student's gender. It should be noted that, when tested separately, the interaction between gender and lone-parent status in the model of achievement on Junior Certificate mathematics is significant, and that it is rendered non-significant in the presence of a term reflecting an interaction between frequency of completing homework on time and gender, which may merit more in-depth exploration.

The effects associated with frequency of absence from school are moderate (the difference between the expected scores of students who are least and most frequently absent is 0.57 of a grade or three-tenths of a standard deviation) and suggest that missing school is detrimental to performance on the Junior Certificate mathematics examination. This variable is not significant in the case of PISA mathematical literacy when the remaining variables in the corresponding final model are present. The effects associated with parental engagement are small (around one-tenth of a standard deviation), and, although statistically significant, are unlikely to be of substantive importance.

The PISA model of mathematical literacy included two variables (apart from grade level) that are not in the final model for the Junior Certificate mathematics examination: number of siblings and parental education. The fact that parental education is significant for achievement in PISA mathematical literacy but not Junior Certificate mathematics, coupled with the fact that absence from school is significant in the model for Junior Certificate mathematics only, suggests that exposure to the curriculum is more relevant to school-based mathematical literacy, but that parents may have a role to play in the more general mathematical literacy achievements of their children.

The final models of achievement in PISA scientific literacy (Shiel et al., 2001) and Junior Certificate science, described in this paper, are very similar. The final model of achievement on Junior Certificate science explains 71.3% of variance between schools and 31.1% within schools. The model of achievement in PISA scientific literacy explained 74.5% of the variance between schools, and 34.1% of within-school variance.

In terms of the variables included in both models, at the school level, school type and designated disadvantaged status were included, as was the case with the two models of achievement in mathematical literacy. However, the model for achievement in Junior Certificate science also included a variable reflecting negative disciplinary climate at the school level. The contribution of negative disciplinary climate (about one-seventh of a standard deviation difference between the expected scores of students in schools with high and low negative climates) is comparable to the contribution of attending a school that is designated disadvantaged. It may be the case that effective instruction in preparation for the Junior Certificate science examination is more vulnerable to a poor disciplinary climate. This is plausible when one considers that in science classes where students are participating in practical work in small groups, effective discipline may be more crucial to students' learning than in classes in other subjects, where students sit and work mostly as a whole class (e.g., Beaton et al., 1996a; Beaton et al., 1996b).

At the student level, dropout risk is highly significant in both models. The difference between the expected scores of students who intended to drop out and those who did not was almost two-thirds of a standard deviation in PISA, and almost three-quarters of a standard deviation in the case of Junior Certificate science. The number of books in the home was also related to achievement, and in both models, there was a significant interaction with gender: the effects of books in the home was stronger for females; females with fewer books at home did less well than males, and females with more books did better than males. A gender x books in the home interaction was also observed in the final model of achievement in PISA reading literacy (Shiel et al., 2001) and Junior Certificate English (Sofroniou, Shiel, & Cosgrove, 2000) and merits further exploration.

A comparison of the six models of achievement described in this paper and elsewhere (Shiel et al., 2001; Sofroniou et al., 2000) indicates that two school-level characteristics are consistently related to achievement in multiple domains: school type and designated disadvantaged status. These two variables explain an additional 10 to 11% of variance between schools, over and above several important student characteristics.

All six models include a variable reflecting student socioeconomic status. However, the effects are rather small compared to other variables. Indeed, variables relating to students' learning habits emerge as significant after accounting for socioeconomic status and related variables, including frequency of absenteeism and frequency of completion of homework on time. This is important because student learning behaviours may be more amenable to change than socioeconomic status.

A variable reflecting students' intent to drop out of school prior to completion of senior cycle is also included in all six models. The differences between the expected achievement scores of students who did and did not intend to drop out were substantial, ranging from around three-fifths to three-quarters of a standard deviation. Intent to drop out is not uncommon; Shiel et al. (2001) reported that 14.0% of the PISA sample intended to drop out prior to completing the senior cycle. Moreover, the effects of dropout risk were found to vary across schools in the case of the models of Junior Certificate mathematics, Junior Certificate English, and PISA reading literacy. These findings point to the need to examine dropout risk more closely as a research and policy issue.

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APPENDIX 1

Description of Candidate Variables

Level/Variable	
Level 2 (School)	
School Size/Stratum*	Categorical (3): Large (81+ 15-year olds enrolled); Medium (41-80); Small (40 or less); reference category: Medium
School Type/Sector**	Categorical (3): Secondary, Community/Comprehensive; Vocational ; reference category: Community/Comprehensive
Disadvantaged Status**	Binary (Designated Disadvantaged/Not Designated Disadvantaged); reference Category: Yes
Gender Composition**	Categorical (3): All Boys, All Girls, Mixed Sex; reference category: Mixed Sex
Negative Disciplinary Climate*	Continuous: Composite based on student responses to statements about behaviour in class; OECD M=0.0; SD=1.00
Student-Teacher Ratio	Continuous: Total enrolment divided by the total number of teachers (each full-time teacher=1; each part-time=0.5); M=15.1; SD=1.82
Level 1 (Student)	
Gender	Binary (Male, Female); reference category: female
Socioeconomic Status	Continuous: Higher of parent(s') occupation; Range=16-88, Irish M=48.4; SD=15.65***
Parental Education	Categorical (4): Primary, Lower Second-level, Upper Second-Level; Third Level; reference category: Upper Second-level
Lone-parent Status*	Binary (Yes, No); reference category: Yes
No. of Siblings	Continuous: Range=0-11; Mode=2
Parent Engagement	Continuous: Composite based on student responses to statements about interactions with parent(s); OECD M=0.0; SD=1.00
Log Index of Books at Home	Categorical (7); Range on untransformed scale=0-10 books-250 books
Dropout Risk*	Binary (High, Low): Based on student's intent to drop out of school before the end of Senior Cycle; reference category: Low
Absence from School	Categorical (3): 0 absences (no absences in two weeks prior to PISA); 1-2 absences; 3 absences; reference category: 1-2 absences
Complete Homework on Time	Categorical (4): No Homework (never done on time); Sometimes; Mostly, Always; reference category: Mostly
Junior Cert. Year*	Binary (1999, 2000); reference category: 1999

*Variables collected or derived locally from the questionnaires (i.e., not in the PISA international database).

**Variables derived from the Schools Database of the Department of Education and Science.

***Based on the International Standard Classification of Occupations (ISCO) system (see Ganzeboom & Treiman, 1996).