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A MULTILEVEL MODEL OF SCIENCE ACHIEVEMENT OF IRISH STUDENTS PARTICIPATING IN PISA 2006

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A multilevel model of achievement in science using data from the OECD 2006 Programme for International Student Assessment (PISA) is presented. School- and student-level variables are analysed as conceptually-related blocks. A combined model explains almost half of the total variance in achievement (42% within schools and 79% between schools). Over and above student-level variables, school-level variables explain just 1% of the variance. Of the total explained variance, about 5% is accounted for by students' self-reported efficacy in science and enjoyment of science. The model confirms contributions of student and school socioeconomic status, home educational climate, take-up of science for the Junior Certificate, and general engagement in science. For students not taking science, boys have lower expected scores than girls.

A great many studies have been carried out over the past century in an attempt to unravel the complex relationships between a variety of scholastic achievements of students on one hand, and students' personal characteristics and their home, school and community characteristics on the other hand. Why another study? Two reasons may be advanced. First was the availability of detailed information on the scientific literacy (achievements) of Irish 15-year-olds and associated factors obtained in the Programme for International Student Assessment (PISA) in 2006, when science was the major focus of the assessment. The second factor prompting the present study was the availability of multilevel or hierarchical linear modelling techniques. Many studies of the correlates of student achievement in the past employed general linear models (e.g., ordinary least squares [OLS] regression). However, since these procedures involve disaggregating cluster-level (school- or class-level) data to the individual level, they may result in an over-estimation of the standard errors associated with cluster-level variables (Osborne, 2000). Multilevel models are explicitly designed to analyse clustered data structures and can incorporate individual-level

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predictors (e.g., student socioeconomic status), group-level predictors (e.g., school type), within-group interactions (e.g., an interaction term for gender and socioeconomic status) and individual-by-group-level interactions (e.g., between student gender and school type) (see Raudenbush & Bryk, 2002; Raudenbush, Bryk, Cheong, & Congdon, 2004; Snijders & Bosker, 1999).

Studies of the correlates of scientific literacy assessed in PISA 2000 (Shiel, Cosgrove, Sofroniou, & Kelly, 2001) and in PISA 2003 (Cosgrove, Shiel, Sofroniou, Zastrutzki, & Shortt, 2005), employing hierarchical linear modelling, yielded many similarities in the individual student variables that survived to the final models (e.g., student gender, family socioeconomic status, number of siblings, number of books in the home). The studies, however, were limited in two ways. First, in both cycles, science was a minor domain; hence, there was a lack of data collected in the questionnaires that related specifically to science and that might have been used for modelling science achievement. Second, although the reports include a commentary on the contribution of school-level variables over and above student-level ones, limited information on the separate contributions of structural, demographic, and/or socioeconomic variables, and other types of variable, was available.

An aim of the present study was to clarify the explained variance through a model-building process that partitions explanatory factors into conceptual blocks. A common approach in model-building is to compare models of socioeconomic and/or demographic variables with a subsequent model or models which include additional variables (see, e.g., OECD, 2004; OECD, 2007; Smyth, 1999). Raudenbush and Bryk (2002) recommend, particularly in exploratory models, dividing predictors into conceptually distinct subsets and running sub-models, then taking the best predictors from each set and combining the models. In the model-building procedure employed in the present study, a combination of both strategies is employed. PISA 2006 also offers an opportunity to expand and build on the findings associated with the PISA 2000 and PISA 2003 analyses by including variables that are specific to science from both international and national sources.

The three main questions addressed in the present study are: (i) How much variance in science achievement (total, within-school, between-school) is explained by the model? (ii) How much variance in science achievement is explained by school structural and socioeconomic characteristics, and how much by student demographic and socioeconomic characteristics? (iii) How much additional variance in achievement between and within schools is explained by variables other than structural, demographic, and socioeconomic characteristics?

The questions are addressed through a comparison of variances explained by different combinations or sub-sets of explanatory variables, i.e., variance explained by structural, demographic, and socioeconomic characteristics when considered on their own, then variance explained by other variables, once structural, demographic, and socioeconomic characteristics are taken into account.

METHOD

Participants

From the original PISA 2006 sample of 4,585 students in 165 schools in Ireland, a total of 3,873 students remained after deletion of cases missing one or more school/student variables (84.5% of the original student sample). The dataset in the present study is evenly balanced by gender (with 51.2% female).

Variables

A review of literature and exploratory analyses suggested a list of candidate variables which were selected on the basis of policy relevance and, where possible, their direct relevance to students' science achievements. Variables were organised into conceptually-related 'blocks' at student level (Table 1) and school level (Table 2).

Analyses

Variables with less than 5% missing data were preferred to ones with higher levels of missing data since the software package used, HLM 6.0, employs listwise deletion. Where a missing indicator for an explanatory variable would preserve over 2% of cases, and where that explanatory variable was felt to be important to include in the model, it was included as two variables: the original variable with missing values recoded to the mean (in the case of continuous variables) or to zero (in the case of binary indicator variables), along with a dummy indicator with values 0 = non-missing and 1 = missing. Missing indicators were included for three variables: scale of parental interaction, study of Junior Certificate science, and the existence of science clubs at school. Each variable was tested separately against the null model. Non-significant variables were removed and each block of remaining variables was then evaluated simultaneously. As an additional step, the combined effects of student blocks A and B were estimated and each subsequent student block was added to blocks A and B. The same procedure was then applied to the school-level blocks. Again, non-significant variables were removed in sequence. Finally, all blocks were entered simultaneously, and non-significant variables removed until all variables retained were significant at the .05 level.

Table 1
List of Student-Level Candidate Variables

Block	Block Name	Variable Name	Description
A	Demographic Variables	Gender	0=male (48.8%), 1=female (51.2%)
		Grade Level/Programme: Second Year Third Year (reference group) Fourth (Transition) Year Fifth Year (LCA) Fifth Year (LCG, LCVP)	Dummy indicator set for Year Level/Programme (Second Year: 2.2%; Third Year: 59.1%; Transition Year: 21.7%; LCA: 1.2%; LCG/LCVP: 15.8%)
		Number of Siblings None One Two (reference group) Three Four or more	Dummy indicator set for number of siblings (None: 4.1%; One: 25.1%; Two: 31.2%; Three: 22.1%; Four or more: 17.5%)
B	Socio-economic Variables	Parental SES (Occupation)	Mean = 0; sd = 1
		Parental education	Years of education: mean = 13.05; sd = 2.37
		Home language	0 = English/Irish (98.4%); 1 = other (1.6%)
C	Home Climate	Log (Books)	Log of books in the home. Original scale: 1 = 0-10; 2 = 11-25; 3 = 26-100; 4 = 101-200; 5 = 201-500; 6 = 500+
		Availability of place to study	0 = no (11.5%); 1 = yes (88.5%)
		Availability of computer	0 = no (11.0%); 1 = yes (89.0%)
		Availability of internet	0 = no (18.1%); 1 = yes (81.9%)
		Frequency of parental interaction* **	mean = 0; sd = 1
		Either parent in a science career	0 = no (82.1%); 1 = yes (17.9%)
D	Engagement in School & School Science	*Study of Junior Certificate Science* Does not study science* ** Studies Ordinary level science* ** Studies Higher level science (reference group)* **	Dummy indicator set for study of science (No: 7.4%; Ordinary: 25.4%; Higher: 67.2%)
		Time per week in science class	(Hours) mean = 2.47; sd = 1.68
		Time per week on science homework	(Hours) mean = 1.19; sd = 1.30
		Intent to complete the Leaving Certificate**	0 = no (9.1%); 1 = yes (90.9%)
E	General Engagement in Science	Watches science on TV	0 = no (38.2%); 1 = yes (61.8%)
		Looks at science websites	0 = no (63.6%); 1 = yes (36.4%)
		Reads science articles or magazines	0 = no (63.3%); 1 = yes (36.7%)
		Expects a science career at 30	0 = no (69.9%); 1 = yes (30.1%)
		Enjoyment of science	mean = 0; sd = 1
		Self-efficacy in science	mean = 0; sd = 1

*Variable has a missing indicator to reduce listwise deletion.
**Variable is not available in the international PISA database and was derived from national sources.

Table 2
List of School-Level Candidate Variables

Block	Block Name	Variable Name	Description
A	Structural Features	*Size of Community* Small (Rural <3,000) Medium (Town 3,000-100,000) (reference group) Large (City >100,000)	Dummy indicator set for size of community (Small: 27.5%; Medium: 47.0%; Large: 25.5%)
		School Enrolment Size Small (<40 students) Medium (40-80 students) Large (81+ students)	Dummy indicator for school size (Small: 6.5%; Medium: 27.5%; Large: 66.0%)
		School Type/Sector Community/Comprehensive** Vocational** Free Secondary (reference group) ** Fee-paying Secondary**	Dummy indicator set for school sector (Comm/Comp: 17.0%; Voc: 24.2%; Free Sec: 52.9%; Feepay Sec: 5.9%)
		School Sex Composition Mixed sex 51%+ male** Mixed sex 51%+ female** Single sex (reference group) **	Dummy indicator set for school sex composition (Mixed mostly boys: 35.3%; Mixed mostly girls: 25.5%; Single sex: 39.2%)
B	Social Composition	Average Junior Certificate fee waiver**	Mean = 0; sd = 1
		Language mix (standardized proportion of students with a first language other than English/Irish)	Mean = 0; sd = 1 (aggregate from student level)
C	Resources	Class size (English)	Mean = 23.4; sd = 4.1
		Shortage of science teachers	0 = no (90.2%); 1 = yes (9.8%)
		Shortage of lab technicians	0 = no (12.4%); 1 = yes (87.6%)
		Shortage of lab equipment	0 = no (52.9%); 1 = yes (47.1%)
D	Selectivity	*Academic Press* Low Medium (reference group) High	Dummy indicator set for parental academic press (Low: 10.5%; Medium: 49.0%; High: 40.5%)
		Academic selectivity	0 = no (17.0%); 1 = yes (83.0%)
E	Promotion of Science	Rate of JCE Higher level science take-up (standardized proportion)**	mean = 0; sd = 1
		Take-up of revised science syllabus**	0 = no (11.1%); 1 = yes (88.9%)
		Science clubs*	0 = no (77.1%); 1 = yes (22.9%)
		Science competitions	0 = no (48.4%); 1 = yes (51.6%)
		Provision of information for science-related careers	Mean = 0; sd = 1 (aggregate from student levell)

*Variable has a missing indicator to reduce listwise deletion.
**Variable is not available in the international PISA database and was derived from national sources.

Each student has five imputed estimates ('plausible values') for PISA science achievement (OECD, 2008), which HLM 6.0 can incorporate into parameter estimates and variance components. In the case of categorical variables with more than one level (e.g., school type/sector, which is fitted as three dummy variables), the significance test must be computed five times, once with each plausible value, following which the averages of the two sets of five deviance statistics (i.e., the set with and without the explanatory variable set of interest) are compared.

Each continuous variable was grand-centred around its mean and standardized to have a mean of 0 and standard deviation of 1. This facilitates interpretation since the intercept corresponds to the expected score of a student with an average score on each continuous variable, and the parameter estimate of each continuous variable corresponds to the expected score increase associated with a one standard deviation increase in the explanatory variable. Parental education is the exception: its parameter estimate corresponds to the expected score increase for each additional year of education. The number of books in the home was transformed to its natural log, since the response categories of the original form are not equal interval. No weights were used in the development of the model. Rather, the explicit sampling stratum (school enrolment size) and the two implicit sampling strata (school sector and gender composition) were included as school-level variables.[2]

Before finalising the model, the following tests (taking a p-value of $\leq .05$ as the criterion) were conducted: (i) tests for significant interactions between student gender and all other variables at the student level through the addition of each interaction term to the model and an evaluation of improvement of model fit via a deviance difference test (as described previously); (ii) tests for significance of cross-level interactions between school average social composition and each student-level variable; (iii) tests of significance of curvilinearity for each continuous variable through the addition of its squared term and evaluation of improvement of model fit via a deviance difference

[2] Aitkin, Francis and Hinde (2005) argue against the use of weights in model-building for two reasons. First, samples from larger sub-populations are given greater weight, despite the fact that observations are of individuals rather than aggregates. Second, evaluation of the model through examination of the change in deviance is affected by the application of weights. The non-application of weights is consistent with the multilevel models in the national reports for PISA 2000 and PISA 2003 (see, e.g., Shiel et al., 2001, p. 97).

test; (iv) tests for significance of random slopes for each student-level variable. The final computation of explained variances was on the basis of the model with fixed slopes.

To compute explained variance the residual variance of the final or comparison model was compared with the total variance of the unconditional (or null) model. Total variance, as well as between- and within-school components, were computed.

RESULTS

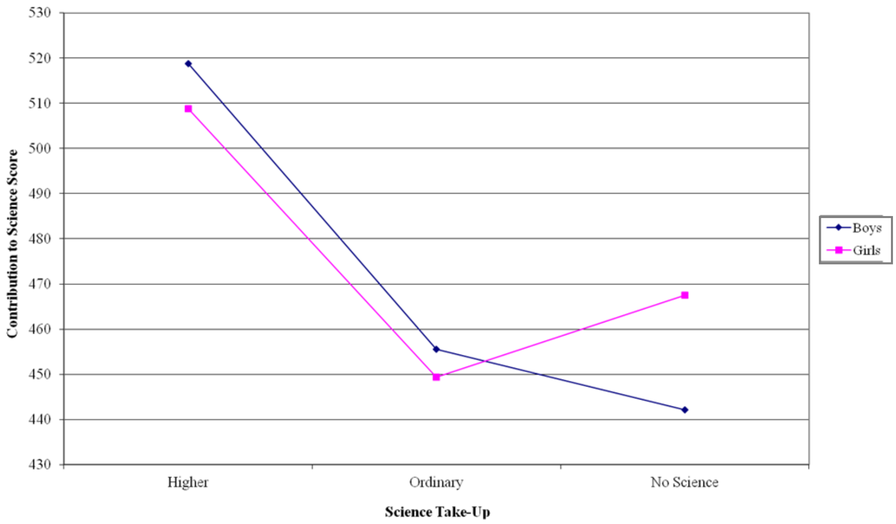
Table 3 presents the combined student and school model of science achievement. Variables associated with relatively strong effects are books in the home, enjoyment of science, science self-efficacy, study of Junior Certificate science, and grade level/programme. (The explained variance associated with various combinations of blocks, and with the combined models, is described below.) A back-transformation to the original underlying scale of the parameter estimate for books in the home indicates that the expected achievement score difference for students with the largest numbers of books (500+) compared with the lowest (0-10) is about 45.5 points. The relative gains in increasing numbers of books are more pronounced at the lower than the upper end of the scale. For example, the expected score difference for students with 0-10 books and those with 11-25 books is 12.4 points, while the expected score difference for students with 250-500 books and those with 500 books or more is just 5.1 points.

The slopes of three student-level variables were found to vary significantly across schools: expecting a science-related career (SD of slope = 13.82), reading science articles or magazines (SD = 14.13), and science self-efficacy (SD = 5.11). Taking 1.96 times the standard deviation and building confidence intervals around the parameter estimates for these three variables indicates the range of expected scores in 95% of schools. For students expecting a science-related career, the likely contribution to science scores ranges from -18.87 to 35.28; for reading science articles or magazines, the corresponding range is -20.82 to 34.58; and for science self-efficacy, the range is 7.22 to 27.26.

Table 3
Combined Model of PISA 2006 Science

Block	Block Name	Description	PE	SE	Test	Stat	df	p
Student								
		Intercept	518.787	5.832				
A	Demographic Variables	Gender	-10.002	3.328				
		Second Year	-56.084	14.770	Ddiff	207.138	4	<.001
		Fourth (Transition) Year	22.051	2.955				
		Fifth Year (LCA)	-11.763	11.458				
		Fifth Year (LCG, LCVP)	35.920	3.379				
		No siblings	6.252	5.791	Ddiff	15.205	4	.004
		One sibling	6.247	3.238				
		Three siblings	-2.626	3.095				
		Four or more siblings	-4.824	3.473				
B	Socioeconomic Variables	Parental SES (Occupation)	4.159	1.268	t	3.282	231	.002
		Home language	-30.758	10.685	t	-2.879	124	.005
C	Home Climate	Log of books in the home	9.671	1.047	t	9.237	111	<.001
D	Engagement in School & School Science	Does not study science	-76.598	8.298	Ddiff	472.495	6	<.001
		No science x Gender	35.340	9.480				
		Studies Ordinary level science	-63.257	4.007				
		Ordinary science x Gender	3.850	5.261				
		Missing indicator for study of science	-27.723	13.707				
		Intent to complete the Leaving Cert	8.014	4.011	t	1.998	156	.047
E	General Engagement in Science	Looks at science websites	-11.956	2.614	t	-4.573	149	<.001
		Reads science articles or magazines	6.880	2.890	t	2.380	209	.018
		Expects a science career at 30	8.205	2.696	t	3.043	1212	.003
		Enjoyment of science	13.414	1.485	t	9.032	1935	<.001
		Self-efficacy in science	17.241	1.459	t	11.816	282	<.001
School								
B	Social Composition	Socioeconomic Mix (Average)	-7.562	2.133	t	-3.546	150	<.001
E	Promotion of Science	Science competitions	7.489	3.460	t	2.165	150	.032

Figure 1
*Plot of Score Contributions for the Gender * Junior Certificate Science Take-Up Interaction*



Gender interacted significantly with take-up of Junior Certificate science (Figure 1). At Higher level, boys are expected to score 10 points higher than girls; at Ordinary level, the expected score difference is about 6 points, also in favour of boys. Male students not taking science, however, have an expected score that is about 25 points lower than that of girls. The model without the gender interaction (not shown here) indicates that although students not taking science for the Junior Certificate have an expected PISA science score that is about 10 points lower than students taking science at Ordinary level, this difference is not statistically significant given the size of the standard errors associated with the parameter estimates for these two groups.

Variance Explained by the Model

Table 4 shows the explained variance between schools, within schools, and in total, for each block tested separately, for combinations of the blocks, and for the final model. Overall, 14.5% of the variance in science achievement was between schools. The final model explains close to half of the total variance in achievement (47.3%), or 79.4% of between-school variance and 41.9% within-school variance.

Table 4

Percentage of Variance Explained in PISA 2006 Science for Various Combinations of Variable Blocks

Block(s)	% Between	% Within	% Total
Student			
A	14.02	6.29	7.42
B	31.88	4.10	8.13
C	43.71	11.38	16.07
D	58.07	26.11	30.75
E	38.50	23.81	25.94
A+B	38.60	9.73	13.91
A+B+C	57.76	17.92	23.69
A+B+D	65.63	30.78	35.83
A+B+E	58.00	30.86	34.79
Final student level model (A+B+C+D+E)	73.13	41.65	46.22
School			
B	46.81	0.02	6.81
E	10.67	0.01	1.56
B+E	50.62	0.02	7.36
Final school level model (B+E)	50.62	0.02	7.36
School and Student Combined			
(A+B student) + (B school)	57.94	9.81	16.79
Final Model	79.44	41.87	47.32
Final Model without student science self-efficacy and enjoyment of science	77.74	36.27	42.28

Note: At the student level, blocks are as follows: A = demographics; B = socioeconomic factors; C = home climate; D = engagement in school / school science; E = general engagement in science. At the school level, blocks are as follows: B = social composition; C = resources; D = selectivity; E = promotion of science. Blocks A, C and D are not included in the computation of variance components as none of the variables in these blocks is significant.

Variance explained by school and student demographic and socioeconomic characteristics. At the school level, none of the candidate variables relating to school structure, and only one of the socioeconomic indicators, remained in the final model. This indicator alone, the average percentage of students entitled to a Junior Certificate fee waiver, explained 46.8% of the variance in science scores between schools and less than 0.1% of the variance within schools. In contrast, all of the student-level demographic variables and all but one of the socioeconomic indicators remained in the final model. Student demographic factors alone explained 14.0% of between-school variance and 6.2% of within-school variance. The corresponding explained variances for student socioeconomic factors are 31.9 and 4.1 percent. When combined, student demographic and socioeconomic variables account for 38.6% of variance between schools and 9.7% of variance within schools. School and student demographic and socioeconomic variables explain 57.9% of the variance between schools and 9.8% of the variance within schools.

Covariation among demographic and socioeconomic characteristics. Student demographic characteristics account for 7.4% of the total variance, while student socioeconomic factors explain 8.1 percent. Taken together, they explain 13.9% of the total variance, indicating very little covariation with one another. Over and above these student variables, school socioeconomic composition explains an additional 2.9% of the total variance. There is considerable covariation between school socioeconomic and student variables: approximately 57.4% of the variance is shared[3].

Additional variance accounted for by variables other than demographic and socioeconomic ones. Just one variable other than school socioeconomic composition, school promotion of science, remained significant in the combined model. It adds about 3.8% to the variance explained between schools. This, however, equates to less than 1% of the total variance in science achievement. Over and above student socioeconomic and demographic variables, home climate explains an extra 19.2% of the variance between schools, 8.2% within schools, or 9.8% of total variance. General

[3] This is derived as follows: blocks A+B at the student level account for 13.9% of total variance, while block B at the school level accounts for 6.8 percent. The variance explained by entering all three blocks together is 16.8 percent. This additional 2.9% over student blocks A+B represents the unique variance of the school-level block B. This block shares (6.8-2.9)/6.8 = 57.4% of variance with student blocks A and B.

engagement in science explains an additional 19.4% of variance between schools, 21.2% of within-school variance, or 20.9% of total variance. Engagement in school and study of Junior Certificate science explains 27.0% of between-school variance, and 21.1% of within-school variance over and above demographic and socioeconomic variables, or 21.9% of the total variance. There is some, if not much, covariation among blocks C, D, and E: if no variance was shared, the total variance explained by student-level variables would be 66.5%, rather than 46.2 percent.[4] The amount of variance that the additional blocks share with blocks A and B is largest for block C (home climate: 39.1%), followed by block D (engagement in school and school science: 39.1%), then block E (general engagement in science: 19.4%).[5]

Additional variance explained by enjoyment of science and science self-efficacy. When the two student attitudinal/engagement variables are removed, the total explained variance between schools drops from 79.4 to 77.7 percent. The explained variance within schools drops from 41.9 to 36.1 percent. These two variables account for just 5% of the total variance in science achievement in PISA 2006 over and above the other variables in the model.

CONCLUSION

The final model for PISA 2006 science presented in this paper explained 47% of the total variance in achievement (or 79% of between-school variance and 42% of within-school variance). The partitioning of explained variance of the data into blocks that differentiate between structural, demographic, and socioeconomic, and other characteristics, and that examine covariation between different sets of characteristics, was intended to represent a development on the presentation and interpretation of previous models (Cosgrove et al., 2005; Shiel et al., 2001).

Only modest covariation was found between student demographic and socioeconomic factors. Results indicate that, over and above student demographic and socioeconomic factors, home educational climate explained

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[4] The 66.5% is derived from the sum of total variances explained by comparing 'A+B' with 'A+B+C', 'A+B+D', and 'A+B+E'. The variance explained by A+B = 13.9 percent. The additional explained variance for B is 9.8%, C is 21.9%, and D is 20.9 percent. If there were zero covariation between these blocks, then the explained variance would sum to (13.9+9.8+21.9+20.9) = 66.5 percent.

[5] These are computed in a manner analogous to that noted in Footnote 3.

substantial variance, reaffirming the importance of home educational climate that was found for both PISA 2000 and PISA 2003 data (books in the home showed substantial effects in both years). Also similar to earlier findings, the significance of parental SES (occupation, as opposed to educational level) was confirmed, and consistent with the previous two cycles, number of siblings remained in the final model. Unlike previous cycles, however, the final model for PISA 2006 included language spoken at home. Over and above SES and a range of other home background factors, students who spoke a language other than English or Irish at home (about 2% of the cohort) were expected to score 31 points lower than students who spoke English or Irish at home. Two points are of note with respect to this finding. First, in 2000 and 2003, there was not a sufficient number of other language speakers (just 0.9% in 2000 and 0.8% in 2003) to include this as a variable in the models. Second, with the comparatively large increase in immigration to Ireland over the past decade (OECD, 2012), the socioeconomic composition of immigrant students has changed such that immigrant students who speak another language have become less socioeconomically advantaged than previously (Perkins, Cosgrove, Moran, & Shiel, 2012).

The model for PISA 2006 included indicators specific to attitudes to/engagement in science that were not available in previous cycles. Intending to have a science career, reading science articles or magazines, engagement in science, and science self-efficacy all contributed significantly to science achievement in the final model. The additional explained variance attributable to enjoyment of science and science self-efficacy was 5 percent. The nature of the relationship between these two constructs and achievement is thought to be complex and potentially circular. Our figure is somewhat higher than the additional variance (2.4%) attributable to student learning strategies/self-concept indicators in the case of reading in PISA 2000 (Sofroniou, Shiel, & Cosgrove, 2002).

Our findings for student grade (year) level and programme of study differ somewhat from those obtained in PISA 2000 and PISA 2003. In both PISA 2000 and PISA 2003, models of science achievement indicated that students in fourth (transition) year and fifth year were expected to score 30 to 35 points higher than third year students. However, large achievement differences existed between the three Leaving Certificate programmes. In bivariate analyses, Eivers et al. (2008) reported that the mean science score of Leaving Certificate Applied students (425) was considerably lower than that of students in both the Leaving Certificate Established (530) and Leaving

Certificate Vocational (516) programmes. Following Eivers et al., we grouped fifth years into Applied, Established, and Vocational Leaving Certificate students. Our results indicate that there was a 48-point score difference between Leaving Certificate Applied and other Leaving Certificate students when account was taken of the other variables in the model. This implies that the large score differences between Leaving Certificate Applied and other Leaving Certificate students observed by Eivers et al. is partly explained by the other variables included in the model.

In both PISA 2000 and PISA 2003 data, study of Junior Certificate science (Higher and Ordinary levels combined, compared to not studying science) was associated with a score difference of around 40 points in favour of students who studied science (Cosgrove et al., 2005; Shiel et al., 2001). However, in analyses of PISA 2006, no difference was observed between the science achievement of students taking Junior Certificate science at Ordinary level and students not taking science for the Junior Certificate (Eivers, Shiel, & Cunningham, 2008). As in the Eivers et al. study, we distinguished between Higher and Ordinary levels by including two dummy variables (Ordinary, No, with Higher as the reference group), while analyses of the 2000 and the 2003 data did not. When the model for PISA 2006 without the gender interaction with Junior Certificate science was examined, it was found, consistent with Eivers et al., that the PISA science score of students taking Junior Certificate science at Ordinary level did not differ from that of students not taking Junior Certificate science. However, a gender interaction was found, whereby at Higher and Ordinary levels boys scored marginally higher than girls, while for students not taking science, girls scored 25 points higher than boys. This gender interaction was not found in analyses of science achievement using data from PISA 2000 or PISA 2003, when the level (Higher, Ordinary) at which students took science for the Junior Certificate was not distinguished. The reasons for the gender interaction found in our data were not explored. It may be that boys and girls that study science at Higher and Ordinary levels, as well as boys and girls who do not study science for the Junior Certificate, differ in terms of individual background characteristics such as socioeconomic status and home background and/or school characteristics.

At school level, one indicator, percent fee waiver for the Junior Certificate Examination, explained close to half (47%) of between-school variance. The only other school-level variable in the model was involvement in science competitions, which explained less than 4% of additional between-school variance. The lack of significant variables at the school level is similar to the findings of both PISA 2000 (where the only significant school variables were designated disadvantaged status and sector) and PISA 2003 (where significant school-level variables were percent fee waiver and disciplinary climate). Thus, there is consistent evidence for a modest social context effect, whereby, over and above individual student demographic factors and socioeconomic backgrounds, school socioeconomic composition is statistically significant. In the present study, fee waiver explained an additional 3% or so of the total variance in achievement. However, as one might expect, there is considerable covariation between student and school socioeconomic measures.

At the student level, the covariation between blocks measuring home background, engagement in school science, and general engagement in science on the one hand and demographic and socioeconomic factors on the other are notable in that, in all cases, shared variance is well under 50% (39%, 29%, and 19%, respectively). This suggests that these factors impact on achievement in a manner that is somewhat separate from demographic and socioeconomic ones, and therefore may be considered 'policy-sensitive' characteristics.

Four caveats/limitations should be kept in mind in interpreting the results of the present study. First, compared to other countries that participate in PISA, the between-school variance associated with achievement in Ireland is low. For example, based on *all* students that participated in PISA 2006, 17% of variance in science achievement in Ireland was between schools, compared to 33% on average across OECD countries. It would, therefore, be expected that school-level variables would have weaker explanatory power than student-level variables. The magnitude of between-school variance may be a function of both the sample design (where students are sampled at random by age cohort across year and class levels rather than on the basis of intact classes) and the nature of the measure (which is much broader than science as taught in schools). Secondly, as with all cross-sectional surveys, one cannot infer causality from the findings, even if they are presented in a framework that models several characteristics simultaneously. Thirdly, indicators derived from questionnaires may not be specific or precise enough to capture the underlying construct (especially if it is process-based) in an optimal manner. Finally, many attitudinal/engagement measures are prone to socially desirable responding, peer effects, and other student background effects, which are not well understood (e.g., Assor & Connell, 1992; Gnaldi, Schagen, Twist, & Morrison, 2005; OECD, 2008). For example, it has been hypothesized that self-efficacy plays a complex mediating role in its influence on achievement (Pintrich & deGroot, 1990; Schunk, 1985). The suggestion that the relationship between achievement and such factors as engagement and self-efficacy may be circular or mediating (Guthrie & Wigfield, 2000; McMahon & Portelli, 2004; Sofroniou, Shiel, & Cosgrove, 2002; Williams & Williams, 2010) points to the need to reconsider assumptions underpinning definitions of, and meanings associated with, such factors. It also underlines the need for caution in making causal inferences on the basis of the findings of surveys such as PISA.

REFERENCES

Aitkin, M., Francis, B., & Hinde, J. (2005). *Statistical modelling in GLIM 4.* Oxford: Clarendon Press.

Assor, A., & Connell, J.P. (1992). The validity of students' self-reports as measures of performance affecting self-appraisals. In D.H. Schunk & J.L. Meece (Eds.), *Student perceptions in the classroom* (pp. 25-47). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cosgrove, J., Shiel, G., Sofroniou, N., Zastrutzki, S., & Shortt, F. (2005). *Education for life: The achievements of 15-year-olds in Ireland in the second cycle of PISA.* Dublin: Educational Research Centre.

Eivers, E., Shiel, G., & Cunningham, R. (2008). *Ready for tomorrow's world? The competencies of Ireland's 15-year-olds in PISA 2006.* Dublin: Educational Research Centre.

Gnaldi, M., Schagen, I., Twist, L., & Morrison, J. (2005). Attitude items and low ability students: The need for a cautious approach to interpretation. *Educational Studies, 31,* 103-113.

Guthrie, J. T., & Wigfield, A. (2000). Engagement and motivation in reading. In M. L. Kamil, P.B. Mosenthal, P.D. Pearson, & R. Barr (Eds), *Handbook of reading research: Volume III* (pp. 403-422). Mahwah, NJ: Lawrence Erlbaum Associates.

McMahon, B., & Portelli, J.P. (2004). Engagement for what? Beyond popular discourses of student engagement. *Leadership and Policy in Schools, 3,* 59-76.

OECD (Organisation for Economic Co-operation and Development). (2004). *Learning for tomorrow's world: First results from PISA 2003.* Paris: Author.

OECD. (2007). *PISA 2006: Science competencies for tomorrow's world.* Paris: Author.

OECD. (2008). *PISA 2006 technical report.* Paris: Author.

OECD. (2012). *Untapped skills: Realising the potential of immigrant students.* Paris: Author.

Osborne, J.W. (2000). Advantages of hierarchical linear modeling. *Practical Assessment, Research & Evaluation*, *7(1)*. Retrieved June 2005 from *http://PAREonline.net/getvn.asp?v=7&n=1*

Perkins, R., Cosgrove, J., Moran, G., & Shiel, G. (2012). *PISA 2009: Results for Ireland and changes since 2000.* Dublin: Educational Research Centre.

Pintrich, P.R., & DeGroot, D.V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82,* 33-40.

Raudenbush, S.W., & Bryk, A.S (2002). *Hierarchical linear models: Applications and data analysis.* Newbury Park, CA: Sage.

Raudenbush, S.W., Bryk, A.S., Cheong, Y.F., & Congdon, R.T. (2004). *HLM 6: Hierarchical linear and nonlinear modeling.* Lincolnwood, IL: Scientific Software International.

Schunk, D. (1985). Self-efficacy and school learning. *Psychology in the Schools, 22,* 208-223.

Shiel, G., Cosgrove, J., Sofroniou, N., & Kelly, A. (2001). *Ready for life: The literacy achievements of Irish 15-year olds*. Dublin: Educational Research Centre.

Smyth, E. (1999). *Do schools differ? Academic and personal development among pupils in the second-level sector*. Dublin: ESRI/Oak Tree Press.

Snijders, A.B., & Bosker, R.J. (1999). *Multilevel analysis: An introduction to basic and advanced multilevel modelling.* London: Sage.

Sofroniou, N., Shiel, G., & Cosgrove, J. (2002). PISA reading literacy in Ireland: An expanded model exploring attributes of self-regulated learning. *Irish Journal of Education, 33,* 71-98.

Williams, T., & Williams, K. (2010). Self-efficacy and performance in mathematics: Reciprocal determinism in 33 nations. *Journal of Educational Psychology, 102*, 453-466.