An Examination of Science Achievement and School Compositional Effects in Ireland Using TIMSS Data

Sonja Nonte[*] iD
Osnabrueck University, GERMANY

Aidan Clerkin
Educational Research Centre, IRELAND

Rachel Perkins
Educational Research Centre, IRELAND

Abstract: Recent educational policy initiatives in Ireland have focused on improving outcomes in reading and mathematics among students, particularly those experiencing educational disadvantage. However, science achievement in Irish primary schools has received much less research attention, especially in the context of educational disadvantage. This article examines science achievement and its relationship to school compositional effects in primary schools at the national level, including school-average indicators of the school context, as well as examining factors associated with science achievement in three distinct categories of schools (those with high, moderate, or minor levels of educational disadvantage). The data are drawn from the Fourth grade Trends in International Mathematics and Science Study (TIMSS) 2015 database for Ireland. Multilevel analyses were implemented in a stepwise manner. Findings suggest the relevance of school contexts with regard to science achievement. Before including school-level contextual variables, students from 'minor disadvantaged' schools achieved significantly higher science scores than students from schools with 'moderate' or 'high' levels of disadvantaged. However, this difference disappears after controlling for predictors at the school level. The findings highlight the importance of the home environment, including early numeracy activities and skills before children start school. Results are discussed with regard to educational policy and educational practice in Ireland.

Keywords: *Early learning, educational disadvantage, home learning environment, Ireland, school composition, science achievement.*

Introduction

Fourth grade students in Ireland achieved science scores that were significantly above the international average in the *Trends in International Mathematics and Science Study* (TIMSS) in 2011 (Eivers & Clerkin, 2012), TIMSS 2015 (Clerkin et al., 2016), and TIMSS 2019 (Perkins & Clerkin, 2020). Two further points are worth noting. First, the relative performance of students in Ireland compared to other participating countries indicates that Irish Fourth graders tend to perform very well in assessments of reading (Eivers & Clerkin, 2012; Eivers et al., 2017), moderately well in mathematics (Clerkin et al., 2016; Eivers & Clerkin, 2012; Perkins & Clerkin, 2020), and more modestly again in science (Clerkin et al., 2016; Eivers & Clerkin, 2012; Perkins & Clerkin, 2020). Although direct comparisons across domains cannot be made, a broad view of the results of recent large-scale assessments suggests that science is a subject for which students in Ireland are relatively less well equipped by comparison to the other tested domains.

Several detailed models of reading and mathematics achievement focusing on primary-level students have been generated from a range of sources in recent years, including Ireland's national assessments (Gilleece et al., 2012; Kavanagh et al., 2015) and Irish participation in both the *Progress in International Reading Literacy Study* (PIRLS) and TIMSS in 2011 (Cosgrove & Creaven, 2013; Eivers & Clerkin, 2013; Gilleece, 2015). However, corresponding studies of science achievement involving nationally-representative samples have been less frequent, particularly at primary level.

Cosgrove and Creaven (2013) have provided the only multilevel analysis of science achievement among primary school students in Ireland that the authors are aware of (see also Gilleece & Clerkin, 2020, for a review). Overall, the model accounted for about one-quarter (27%) of the observed variance in science achievement. One finding of note from this analysis was that "over and above pupil characteristics, school socioeconomic characteristics are not significantly associated with achievement in Ireland" (Cosgrove & Creaven, 2013, p.217) which is contrary to previous studies of achievement in Ireland (Perkins et al., 2013; Sofroniou et al., 2004). It should be noted, however, that this study did not use student-level aggregates of measures of school socioeconomic status (SES) but instead relied on an indicator of a

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[*] **Corresponding author:**
Sonja Nonte, Osnabrueck University, Institute of Education, Osnabrueck; Germany. ✉ sonja.nonte@uni-osnabrueck.de

school's eligibility to receive additional supports as part of the School Support System (SSP) under the *Delivering Equality of Opportunity in Schools* (DEIS) program. DEIS is the most recent initiative aimed at addressing educational disadvantage in Ireland. Under this program, schools with the highest concentrations of students at risk of educational disadvantage were identified based on a number of indicators of economic disadvantage (Weir, 2016). These indicators were based on data originally collected in 2005. About 20 percent of primary-level students in Ireland attend DEIS schools that receive additional supports including access to literacy and numeracy programs, reduced class sizes and additional staffing (Weir et al., 2011).

The Current Policy Context

Initiatives aimed at addressing educational inequality in Ireland, including DEIS, have primarily focused on enhancing literacy and numeracy levels among students at risk of educational disadvantage, which have been found to be lower on average than among more advantaged students (Weir et al., 2011). Recent evidence suggests that these efforts have contributed to a reduction in inequality in educational outcomes for reading and mathematics among primary-level students (Karakolidis et al., 2021). In 2017, however, three policy documents were published which acknowledge the need to address the achievement gap between students in DEIS and non-DEIS schools in *science, technology, engineering, and mathematics* (STEM) disciplines more broadly (Department of Education and Skills, 2017a, 2017b, 2017c). These policy documents recognize the need to provide a high-quality STEM education to all learners, including those at risk of educational disadvantage, and intend that doing so will reduce the achievement gap in STEM disciplines. In particular, the DEIS Plan 2017 (Department of Education and Skills, 2017c) includes a number of targets for improving achievement outcomes among students in DEIS schools. However, the specific targets relating to STEM focus primarily on outcomes in mathematics.

Literature Review

Recent research examining outcomes among students in DEIS schools from the 2018 cycle of the *Programme for International Student Assessment* (PISA) indicate that students in these schools not only have significantly lower achievement outcomes in reading and mathematics, but also in science, when compared to their peers in non-DEIS schools (Gilleece et al., 2020). Gilleece et al. (2020) note that the DEIS action plan would benefit from the inclusion of targets specifically relating to outcomes in science achievement, as well as for mathematics and reading.

Research examining the effects of school social mix in Ireland has found evidence of a threshold effect such that concentration of disadvantage beyond a certain level is associated with lower levels of achievement, when school, teacher and student factors are accounted for. This threshold effect appears to differ somewhat for reading and mathematics, with significantly lower levels of reading achievement observed among students in urban schools with moderate and high concentrations of disadvantage, while lower levels of mathematics achievement are only observed amongst students in urban schools with the highest concentrations of disadvantage (McCoy et al., 2014). The extent to which a threshold effect among schools in Ireland may also exist for science is unknown and warrants further research.

Cosgrove and Creaven's (2013) analysis used data gathered for TIMSS 2011 to identify a number of variables that were significantly associated with students' science achievement, including aspects of the home environment (e.g., parental educational attainment), school-level factors (e.g., principals' perceptions of parental support for learning across the school), and student characteristics (e.g., expressing liking for science lessons, experiences of bullying behavior). They found that a greater number of books, higher level of maternal education and the number of full-time jobs held by students' parents were positively associated with science achievement, while the frequency of being bullied was negatively associated with achievement. They also noted a significant interaction between gender and books in the home. Previous research has also identified that the extent of children's engagement in early learning play, or early learning activities, is not only associated with achievement but also with SES and the presence of other resources for learning at home (Clerkin & Gilligan, 2018; Clerkin et al., 2020). A further factor which may be relevant in the Irish context is teachers' level of experience. Teachers in urban DEIS schools tend to be younger and less experienced than teachers in rural DEIS schools or in non-DEIS schools (Clerkin, 2013; McCoy et al., 2014).

From a theoretical perspective, it can be argued that students experiencing social marginalization are more likely to underachieve in school. Following Goffman (1952), students experiencing marginalization may go through a so-called "cooling out process", where individual and institutional characteristics interact such that schools with a higher amount of resources and social and financial capabilities also have more capacity to compensate for disadvantages that students may be experiencing.

Recent studies highlight the relevance of socioeconomic segregation as a "robust and potent predictor of student achievement, learning, and dropout" (Palardy, 2008, p.22). Based on data from the National Education Longitudinal Study of 1988, the author reported that school factors matter most in schools with a low social class composition, finding that school resources accounted for 34 percent of the between-school variance in this group but only for 8 percent in the middle group and for 11 percent in the high social class group. Many other studies, observing different aspects of segregated schools, have reported similar findings. These have included findings of lower achievement rates for students (Hanushek et al., 2009; Palardy, 2008; Reardon, 2016) and a lower supply of highly qualified and/or less experienced

teachers (Allen & McInerney, 2019; Goldhaber et al., 2019; Organisation for Economic Co-operation and Development [OECD], 2018; Palardy, 2008).

Research aim

TIMSS is an international large-scale assessment of mathematics and science. In TIMSS 2015, more than 580,000 students within 57 countries participated. This paper presents a multilevel analysis of science achievement using data gathered for TIMSS in 2015. The analysis extends previous work (Cosgrove & Creaven, 2013) by considering variation in outcomes across a range of school contexts. Our primary focus in undertaking this analysis is on the issue of educational disadvantage. Science achievement is preferred as the outcome variable in an effort to address the relative lack of information available in the current literature on factors associated with science achievement at primary level, particularly in the context of varying degrees of educational disadvantage, and in response to ongoing policy efforts to promote a stronger focus on science education (STEM Education Review Group, 2016).

Although the DEIS program is the main policy lever used to address educational disadvantage in Ireland, the analysis reported below adopts a more exploratory approach to identifying thresholds for disadvantaged educational contexts than would be possible using the existing DEIS categorizations.

There are two main reasons for taking this approach. First, an indicator of DEIS status is not included in the TIMSS 2015 public use database (https://timssandpirls.bc.edu/timss2015/international-database). However, TIMSS does collect information from school principals on the percentage of students in their school from economically disadvantaged backgrounds. Second, as the selection of schools for the DEIS initiative was based on data originally collected in 2005 for the schools participating in TIMSS 2015, the TIMSS measure of school-level disadvantage offers a more up-to-date indicator of the school context. For these reasons, the TIMSS data are used as the measure of school-level disadvantage in the current study.

Methodology

Research design

The study aims to examine school compositional effects at primary level in an exploratory context in two ways. First, by analyzing the data in a multilevel framework at an overall (national) level with the inclusion of school-level aggregate indicators of educational disadvantage. Second, by identifying three discrete groups of schools – characterized as those reporting 'minor', 'moderate', or 'high' levels of educational disadvantage – and examining factors associated with science achievement in each of the three school contexts. The aim of these analyses is to examine, firstly, how the selected student-level and class/school-level predictor variables are associated with students' achievement in science at the national level and secondly, which predictors are most strongly associated with achievement in each of the three categories of school context (educational disadvantage).

Sample

The data are drawn from the Fourth grade sample for Ireland in TIMSS 2015. The average age at time of testing was 10.4 years. The sample, which is representative of the national population of Fourth grade students, consists of 4,242 students within 206 classes (47.4% female, 52.6% male).

In line with the modelling approach used by Cosgrove and Creaven (2013) and Gilleece (2015), we used student-level data at Level 1 in the multilevel models reported below and class/school-level data at Level 2. Although, in principle, the class- and school-levels could be considered separate levels, the portion of variance accounted for in the Irish context tends to be very similar whether classes and schools are modelled separately or together (Cosgrove & Creaven, 2013; Gilleece, 2015), suggesting that a combined class/school Level 2 is more parsimonious. The inclusion of 'class' alongside 'school' at Level 2 is important as it allows teacher characteristics to be included in the model.

Based on information provided by school principals in the school questionnaire, this sample is split into three subgroups of schools for the analyses addressing the second and third research questions. Principals were asked about the percentage of students in their schools who come from economically disadvantaged homes. Schools reporting 0–10% of students from economically disadvantaged homes are labelled having 'minor levels of disadvantage' (n = 1,298 students within 71 classes in 49 schools); schools reporting 11–49% are referred to as having 'moderate levels of disadvantage' (n = 1,622 students within 91 classes in 61 schools), and schools with more than 50% of students coming from economically disadvantaged backgrounds are categorized as having 'high levels of disadvantage' (n = 543 students within 44 classes in 31 schools).

Instruments

Data were gathered using standardized questionnaires answered by participating students, their parents, their class teachers, and their school principals (Mullis & Martin, 2013).

The outcome variable is students' science achievement. This was measured by utilizing plausible values, which provide unbiased estimates of population characteristics. Five plausible values were calculated for each student, with the overall scale score set to an international centrepoint of 500 and a standard deviation of 100 (Foy & Yin, 2016).

Predictors were measured on individual-, class- and school-levels. At the individual level, data from students' and parents' questionnaires are available. This includes students' socioeconomic background, process variables (such as parental support before their child began school), and motivational aspects (including students' valuing of science and students feeling confident in science). At the class-level, information about teaching practices and resources is available from the teacher questionnaires. At the school-level, the school's location in rural or urban areas was gathered from school principals' questionnaires. Martin, Mullis, Hooper et al. (2016) provide further information about the construction and validation of the scales derived from these questionnaire variables, which are described briefly next.

Demographic Characteristics

Students were asked about the number of 'Books at Home' (ASBG04, 1 = 0 to 10 books, 2 = 11 to 25 books, 3 = 26 to 100 books, 4 = 101 to 200 books, 5 = more than 200 books). Parents answered questions about their 'Highest Level of Education' (ASDHEDUP, 1 = some primary, lower secondary or no school, 2 = finished lower secondary, 3 = finished upper secondary, 4 = finished post-secondary but not university, 5 = finished university or higher), and about their employment situation, the 'Parents' Highest Occupation Level' (ASDHOCC, 1 = never worked for pay, 2 = general laborer, 3= skilled worker, 4 = clerical, 5 = small business owner, 6 = professional). Information about students' 'Sex' was gathered from their teachers (ITSEX, 0 = female, 1 = male).

Experience of Bullying: Students answered questions about how often they felt they were bullied at school ('Student Bullying' scale, ASBGSB). Based on eight bullying behaviors (example: 'made fun of me or called me names'), a scale was created such that a score of at least 9.6 corresponds to students' being bullied almost never, a score not higher than 8.0 means that students reported bullying behavior about weekly, and a score between 8.1 and 9.5 meaning that students reported being bullied about monthly. Cronbach's alpha for the scale is .85.

Early Childhood Learning: The 'Early Numeracy Activities' scale (ASBHENA) was used to control for this in the context of the current study. Parents responded to questions about what they did with their child before they started school (example: 'count different things'). Based on seven items (ASBH02J, ASBH02K, ASBH02L, ASBH02M, ASBH02N, ASBH02O, ASBH02P), a scale was constructed such that a scale point not higher than 6.5 describes students never or almost never engaged in these activities, a scale point of 10.4 or higher describes students often engaged in early numeracy activities, and a scale point between 6.6 and 10.3 describes students who sometimes engaged in early numeracy activities. Cronbach's alpha for the early numeracy activities scale is .81.

Parents also provided information about how well their child could do 'Early Numeracy Tasks' when they began primary school (ASBHENT, 5 items, example: 'count by him-self/herself'). Students who could do numeracy tasks very well had a score of at least 11.5 on this scale, students not doing well had a score not higher than 8.7, and students doing numeracy tasks moderately well at the beginning of primary school had a score between 8.8 and 11.4. Cronbach's alpha for this scale is .81.

Student Motivation and Attitudes: Students were asked how much they agree or disagree (1 = agree a lot, 2 = agree a little, 3 = disagree a little, 4 = disagree a lot) with nine statements such as 'I wish I did not have to study science', which were combined to create the 'Students Like Learning Science' (SLS; ASBGSLS) scale. Students with a score not higher than 7.6 do not like learning science, students scoring 9.6 or higher like learning science very much, and students with a score between 7.7 and 9.5 like learning science. Cronbach's alpha is .91.

Students were also asked how much they agree with seven statements such as 'I usually do well in science' (1 = agree a lot, 2 = agree a little, 3 = disagree a little, 4 = disagree a lot) in order to construct a 'Students Confident in Science' (SCS; ASBGSCS) scale. Students scoring not higher than 8.2 on this scale are not confident in science, students with a score of 10.2 or higher are very confident in science, and students with a score between 8.3 and 10.1 are confident in science. Cronbach's alpha is .82.

Teacher and Classroom Characteristics: Teacher were asked about the total 'Number of Students in the Class' (ATBG12A), their 'Level of Formal Education' (ATBG04, 1 = did not complete upper secondary, 2 = upper secondary, 3 = post-secondary, non-tertiary, 4 = short-cycle tertiary, 5 = bachelor's or equivalent, 6 = master's or equivalent, 7 = doctor or equivalent), the 'Number of Years They Have Been Teaching' (ATBG01) and about the degree to which 'Students Lacking Prerequisite Knowledge or Skills' limits teaching in the classroom (ATBG15A, summarized as categories: 0 = not at all, 1 = to some degree or a lot).

Parental Involvement: Teachers were asked to characterize five aspects of parental commitment and support within the school (example: 'parental involvement in school activities') on a four-point Likert scale (1 = very low, 2 = low, 3 = medium, 4 = high, 5 = very high). Based on this information, a scale was constructed (average of ATBG06F, ATBG06G, ATBG06H, ATBG06I and ATBG06J). Cronbach's alpha is .88.

School Location: Finally, school principals provided information about the immediate area in which the school is located (ACBG05B). Based on this, a binary measure was constructed with 0 indicating a rural area and 1 indicating all other areas (urban; suburban; medium size city or large town; small town or village). Following McCoy et al. (2014), this indicator is intended to facilitate distinctions between any contextual effects observed in urban or rural schools.

Analysis Framework

Driven by previous research (e.g., Reardon & Owens, 2014), individual as well as contextual variables, derived from the state of research, were selected and implemented in a multilevel modelling framework in a stepwise manner.

The IEA IDB-Analyzer (International Association for the Evaluation of Educational Achievement [IEA], 2022) was used for merging data files and descriptive analysis. The multilevel analysis was implemented with Mplus 7.11 (Muthén & Muthén, 1998–2011). Missing data ranged from 0% (students' sex) to 14.7% (parents' occupational status). It is handled by using full information maximum likelihood (FIML), which is also implemented in Mplus. Plausible values for science achievement were pooled based on the option "type = imputation".

In a first step, we calculated a set of overall models to investigate the relationship of predictors on student- and class/school-levels in a stepwise manner. In a second step, we applied a multigroup framework to analyze within- and between-group differences for schools classified as experiencing minor, moderate or high levels of economic disadvantage with regard to science achievement. Multilevel analyses are calculated simultaneously for all three subgroups of schools. The framework is therefore able to account for "any group specific differences such as, for example, different variability within groups" (Asparouhov & Muthén, 2012, p.2). MLR was used as the estimator. Student weights (TOTWGT) and science teacher weights (SCIWGT) are applied to report descriptives of predictors at L1 and L2. There is no common position on how best to use weights in multilevel analysis with complex survey designs (Grilli et al., 2016), but it is argued that ignoring sampling weights in multilevel approaches leads to biased estimates (Rabe-Hesketh & Skrondal, 2006). Following Rutkowski et al. (2010), we recalculated the sampling weights for student- and class-level separately (L1wgt = wgtfac3 * wgtadj3 on student-level; L2wgt = wgtfac2 * wgtadj2 * wgtfac1 * wgtadj1). Accordingly, L1wgt is utilized on student-level and L2wgt is used on class/school-level.

First of all, we conducted an overall intercept-only-model (M1.0) to split the variance of science achievement into within- and between-components. The intraclass correlation coefficient (ICC) reveals information about how much of the overall variation in science achievement is explained by clustering (class/school affiliation). In a second step, an overall random-intercept-model with fixed effects (M1.1) is conducted to account for differences in science achievement on individual level. For this purpose, all variables apart from sex have been standardized (M = 0, SD = 1) and group-mean centered. In a third step, within and between variables predicting students' science achievement are implemented in an overall random-intercept-model (M1.2). Finally, we examined compositional effects of SES on student- and class-level with regard to science achievement (M1.3). Aggregated variables were calculated using a latent variable approach "which takes the unreliability of the group mean into account when estimating the contextual effect" (Lüdtke et al., 2008, p.204).

For the second part of the analysis, we repeated the previous modeling (M1.0 to M1.2) with the additional step of running the models for the three groups of schools (those with minor, moderate and high levels of economic disadvantage) as follows: intercept-only-model (M2.0), random-intercept-model with predictors on student-level (M2.1) and random-intercept-model with predictors on student- and class-level (M2.2).

Model fit was evaluated using the deviance (-2*LL) of the model, the AIC and sample size adjusted BIC. The model with the smallest values was selected to draw final conclusions.

Results

There were significant differences in science achievement by students' school context (Figure 1). Students attending schools with minor levels of disadvantage outperformed students from schools with high levels of disadvantage schools by more than 40 points on average, which is equivalent to more than a one-year difference in schooling (Wendt et al., 2017). Students in schools with moderate levels of disadvantage (11-49% of students from disadvantaged backgrounds) scored 18 points lower than their peers in schools with minor levels of disadvantage (≤10%) and 24 points higher than those from schools with high levels of disadvantage (≥ 50%). These differences are statistically significant and correspond to theoretical assumptions.

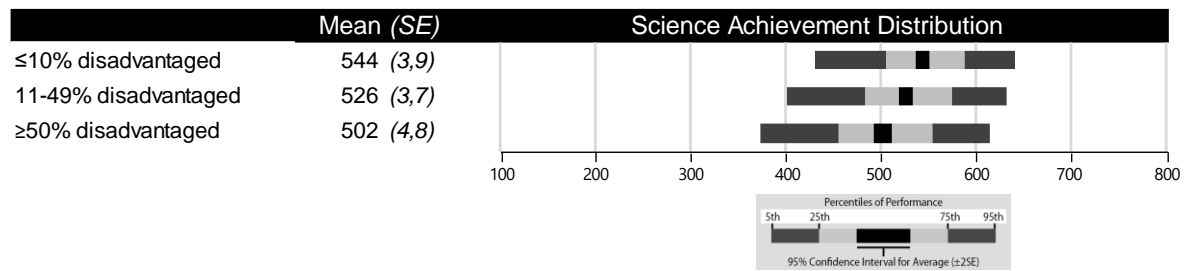|	Mean *(SE)*	Science Achievement Distribution
≤10% disadvantaged	544 *(3,9)*	
11-49% disadvantaged	526 *(3,7)*	
≥50% disadvantaged	502 *(4,8)*	

Figure 1. Fourth Grade Students' Science Achievement in Schools with Minor, Moderate or High Levels of Disadvantage in Ireland (Format for figure adapted from Martin, Mullis, Foy et al.; 2016).

Bivariate differences between schools with minor, moderate and high levels of economic disadvantage were also evident for student-level predictors (Table 1). Compared to students attending schools with minor or moderate levels of disadvantage, parents whose children attend schools with high levels of economic disadvantage reported lower values of 'Parents' Highest Occupation Level' ($F = 36.25$, df = 2, $p \leq .001$) and lower values of 'Parents' Highest Level of Education' ($F = 38.90$, df = 2, $p \leq .001$). The number of 'Books at Home' was lower for students in schools with high levels of disadvantage than in schools with moderate or minor levels ($F = 29.87$, df = 2, $p \leq .001$). All these differences are significant at $p < .001$. Finally, students attending schools with high levels of economic disadvantage were reported to have lower early numeracy task skills when they began primary school than students in schools with minor or moderate levels of disadvantage ($F = 3.15$, df = 2, $p \leq .05$). There were no significant differences between the three categories of schools for 'Student Bullying', 'Early Numeracy Activities' before school, 'Students Like Learning Science', 'Students Confident in Science', or students' sex.

Table 1. Means and Standard Errors for Predictors on Student-Level Split by Group (Schools with Minor, Moderate and High Levels of Economic Disadvantage)

	Minor (n = 1473)		Moderate (n = 2011)		High (n = 758)		Missing data		
	M	SE	M	SE	M	SE	%	$F_{(df=2)}$	$p \leq$
Parents' Highest Level of Education	4.31	.04	4.03	.04	3.63	0.07	7.8	38.90	.001
Parents' Highest Occupation Level	5.18	.05	4.91	.05	4.37	0.08	14.7	36.25	.001
Books at Home	3.38	.06	3.12	.05	2.63	0.06	1.3	29.87	.001
Sex (male)	0.53	.03	0.54	.03	0.49	0.07	0.0	0.35	n.s.
Student Bullying	10.75	.09	10.92	.07	10.67	0.10	1.2	2.18	n.s.
Early Numeracy Activities	10.91	.08	10.97	.05	10.74	0.10	7.0	2.08	n.s.
Early Numeracy Tasks	11.02	.06	10.87	.06	10.75	0.09	7.5	3.15	.05
Students Like Learning Science	10.12	.10	10.14	.09	10.18	0.17	1.1	0.05	n.s.
Students Confident in Science	9.76	.07	9.82	.06	9.80	0.13	1.6	1.19	n.s.

Results from One-Way-ANOVAs. Weight by TOTWGT.

Several significant bivariate differences were also found at the class/school-level (Table 2). The 'Number of Students in Class' was lower in schools with high levels of disadvantage than in schools than in schools with moderate or minor levels of disadvantage ($F = 8.90$, df = 2, $p \leq .001$). 'Parental Involvement' was reported by teachers to be lower in schools with high levels of disadvantage than in schools with moderate or minor levels of disadvantage schools ($F = 22.24$, df = 2, $p \leq .001$). Teachers in schools with high levels of disadvantage reported a greater proportion of 'Students Lacking Prerequisite Knowledge' compared to schools with moderate or minor levels of disadvantage ($F = 4.67$, df = 2, $p \leq .05$). Finally, schools with high levels of disadvantage were more likely to be situated in an urban region than schools with minor levels of disadvantage. Nearly 90% of students in schools with high levels of disadvantage attended school in an urban area, compared to 66% of students in schools with minor levels of disadvantage. In addition, the class average of parent's education, occupation and books at home differ significantly between these type of schools (Table 2).

Table 2. Means and Standard Errors for Predictors on Class/School-Level Split by Group (Schools with Minor, Moderate and High Levels of Disadvantage)

	Minor (n = 71 classes)		Moderate (n = 91 classes)		High (n = 44 classes)		Missing data		
	M	**SE**	**M**	**SE**	**M**	**SE**	**%**	$F_{(df=2)}$	**p ≤**
Number of Students in the Class	26.37	0.52	26.44	0.57	22.92	0.65	0.8	8.90	.001
Teachers Level of Formal Education	5.12	0.04	5.05	0.05	5.06	0.09	2.9	0.49	n.s.
Years been Teaching	14.04	1.25	13.85	1.51	10.88	1.36	3.4	1.10	n.s.
Parental Involvement	3.90	0.08	3.69	0.09	2.92	0.12	0.0	22.24	.001
Students Lacking Prerequisite Knowledge or Skills (yes)	0.62	0.07	0.80	0.05	0.89	0.05	0.7	4.67	.01
Area in Which School is Located (urban)	0.66	0.07	0.88	0.05	0.90	0.03	0.0	5.23	.01
Parents' Highest Level of Education (class-average)	4.31	0.04	4.02	0.04	3.63	0.07	0.0	42.19	.001
Parents' Highest Occupational Level (class average)	5.18	0.06	4.89	0.05	4.33	0.08	0.0	49.30	.001
Books at Home (class average)	3.38	0.06	3.12	0.05	2.62	0.06	0.0	35.36	.001

Results from One-Way-ANOVAs. Weight by SCIWGT.

Multilevel Analysis: Overall (National) Sample

We conducted multilevel models for the overall sample in a stepwise manner (Table 3). In a first step, we implemented an overall intercept-only model (M0) for partitioning the variance in science achievement in within-class and between-class variance components. The ICC for science achievement in the overall sample of TIMSS 2015 Fourth grade students in Ireland is 0.16. The raw average science achievement score is 529.33 (SE = 2.71; see Table 3, Model 1.0).

Taking the average cluster size and ICC into account, the design effect (*deff*) indicates how much the standard errors are underestimated in a complex sample compared to a simple random sample (Kish, 1989; Maas & Hox, 2005). It can be calculated using the formula provided by Maas and Hox (2005, p.87): "in cluster samples, the design effect is approximately equal to 1 + (average cluster size – 1) x ICC". The average cluster size here is 20.3, therefore *deff* = 1 + (20.3 – 1)*0.16; therefore *deff* = 4.15. There is evidence that a design effect greater than two may lead to biased (inflated) estimates of standard errors in clustered samples (Lai & Kwok, 2015; Maas & Hox, 2005). Using a multilevel approach therefore not only disentangles the effects of individual and contextual predictors with regard to science achievement, but also is necessary to control for biased estimates that may occur due to sampling processes.

Model 1.1 adds predictors at the student-level (Table 3). All variables, except sex, have been standardized and group-mean centered. These predictors explain 23% of the within-school variance of science achievement. The number of Books at Home is the strongest predictor for science achievement for Fourth grade students in Ireland (b = 14.27, SE = 1.22; p ≤ .01). It is followed by Early Numeracy Tasks before attending school (b = 8.76; SE = 1.34; p ≤ .001) and Parents' Highest Level of Education (b = 7.27; SE = 1.44; p ≤ .001). Therefore, we can see that socioeconomic indicators have a strong association with students' science achievement in Fourth grade.

These patterns remain broadly stable after adding additional predictors on the class/school-level (Model 1.2). Books at Home (b = 14.37; SE = 1.29; p ≤ .001) persists as the strongest predictor, followed by Early Numeracy Tasks (b = 8.79; SE = 1.46; p ≤ .001). In model M1.2, Sex is another strong predictor for science achievement (b = 8.29; SE = 2.85; p ≤ .01) as well as Parents' Highest Level of Education (b = 7.05; SE = 1.44; p ≤ .001) and Students Confident in Science (b = 7.10; SE = 1.90; p ≤ .001). At the class-level, teachers' perception of Students' Lacking Prerequisite Knowledge and Skills is a significant predictor of students' science achievement (b = -14.83; SE = 5.32; p ≤ .01). That is, students achieve significantly lower science scores when their teacher reports difficulties teaching due to students' lacking prerequisite knowledge or skills. Moreover, teachers' perception of Parental Involvement was associated with science achievement (b = 6.97; SE = 2.60; p ≤ .01). All predictors on student- and class/school-levels account for 23% of variance at L1 and 30% of the variance at L2.

Finally, with the overall national sample, we added compositional effects of students' and class/school-average SES on science achievement (M1.3). After accounting for class-average SES (using class-average Parents' Highest Occupational Level, class-average Parents' Highest Level of Education, and class-average Books at Home), teachers' perception of Students' Lacking Prerequisite Knowledge and Skills and teachers' perception of Parental Involvement were no longer significant predictors for students' science achievement. In model M1.3, the number of years a teacher has been teaching (b = 3.90; SE = 1.83; p ≤ .05) and the class-average Parents' Highest Occupational Level (b =77.60; SE = 29.50; p ≤ .01) are significant predictors at the class-level. The compositional effect regarding Parents' Highest Occupational Level indicates that students who attend classes where a high number of students whose parents have a high occupational status achieve significantly higher science scores than students in classes with a high number of students whose parents report lower

occupational levels. This effect appears independently from students' own background. At the student-level, all predictors remain significant in model M1.3. The explained variance for the model M1.3 is 24 percent at the student- and 51 percent at the class/school-level.

However, the deviance, AIC and adjusted BIC values indicate that M1.2 provides a more parsimonious representation of the data, and so can be considered the final model for the overall national sample.

Table 3. Multilevel Analysis Based on the Overall Sample of Ireland (Fixed Effects, Unstandardized Betas, n = 4,344 Students, Significant Effects in Italic)

	M1.0		M1.1		M1.2		M1.3	
	b	**SE**	**b**	**SE**	**b**	**SE**	**b**	**SE**
Intercept	*529.33*	2.71	*532.50*	3.10	*550.83*	6.47	*549.42*	7.54
within (student)								
Parents' Highest Level of Education			*7.27*	1.44	*7.05*	1.44	*7.87*	1.55
Parents' Highest Occupation Level			*4.34*	1.46	*4.84*	1.51	*5.52*	1.63
Books at Home			*14.27*	1.22	*14.37*	1.29	*15.40*	1.40
Sex (male)			*6.96*	2.84	*8.29*	2.85	*8.03*	2.82
Student Bullying			*4.51*	1.42	*4.14*	1.46	*4.12*	1.46
Early Numeracy Activities			*5.85*	1.12	*5.63*	1.16	*5.63*	1.16
Early Numeracy Tasks			*8.76*	1.34	*8.79*	1.46	*8.80*	1.47
Students Like Learning Science			*5.42*	1.74	*5.36*	1.88	*5.37*	1.88
Students Confident in Science			*6.80*	1.77	*7.10*	1.90	*7.13*	1.89
between (classes)								
Number of Students in the Class					3.38	2.00	*0.56*	2.15
Teachers Level of Formal Education					-3.07	2.00	-2.13	1.96
Years been Teaching					1.38	2.02	*3.90*	1.83
Parental Involvement					*6.97*	2.60	1.44	2.91
Students Lacking Prerequisite Knowledge or Skills (yes)					*-14.83*	5.32	-6.68	4.74
Area in Which School is Located (urban)					-11.25	5.84	-16.37	8.61
Parents' Highest Occupational Level (class average)							*77.60*	29.5
Parents' Highest Level of Education (class-average)							-31.25	38.14
Books at Home (class-average)							-8.36	33.86
ICC	0.16							
R² (within)			*0.23*		*0.23*		*0.24*	
R² (between)					*0.30*		*0.51*	
Deviance	48772.39		38507.10		35964.99		61527.24	
AIC	48778.40		38531.10		36001.00		61569.24	
aBIC	48787.99		38567.02		36053.68		61630.70	

Weight on student-level: L1wgt; weight on class-level: L2wgt.

School Context: Incorporating School-Level Disadvantage

For the second part of the analysis, we split the overall sample into three subgroups based on data from the school principal questionnaires as described above. Accordingly, schools with a high proportion of students from economically-disadvantaged homes (50–100% of students) were labelled as having 'high' levels of economic disadvantage. Schools with a lower number of students coming from economically-disadvantaged homes (11-49%) were labelled as having 'moderate' levels of disadvantage, and schools with few students (not more than 10%) from economically-disadvantaged homes were described as having 'minor' levels of disadvantage.

First, we conducted an intercept-only model (M2.0) to display within- and between- variance components (Table 4). The ICC was found to differ very slightly between the three contexts. The highest ICC can be found for the group of students attending schools with minor levels of disadvantage (ICC = 0.15), with the lowest amount of clustering among the group of students attending schools with moderate levels of disadvantage (ICC = 0.12). The group of students attending schools with high levels of disadvantage have an ICC of 0.13. The design effect for the three subgroups of students attending a school with minor, moderate or high level of disadvantage is 4.00, 3.35 and 3.06, respectively.

Based on the intercept-only model (M2.0), we found differences in raw science achievement in the expected direction. Students attending schools with minor levels of disadvantage had higher science achievement scores (M = 542.96, SE = 4.34) than students attending schools with moderate levels (M = 526.06, SE = 3.77) or high levels of disadvantage (M = 504.46, SE = 6.25). These differences are statistically significant (F = 13.30, df = 2, p ≤ .001).

In a second step, we integrated predictors on individual-level (within) by using a random-intercept model with fixed effects (M2.1). Again, all variables, except sex, have been standardized and group-mean centered. Average science achievement scores for students in schools with minor, moderate and high levels of disadvantage still differ significantly (minor: M = 545.60, SE = 5.20; moderate: M = 529.21, SE = 4.16; high: M = 507.32, SE = 6.99; F = 9.60, df = 2, p ≤ .001).

As in the previous (overall) model (Table 3), all incorporated predictors at the student-level were significant for at least one subgroup (M2.1). Regarding the socioeconomic background, the number of Books at Home showed a significant association with science achievement for all Fourth grade students, with the strongest relationship for students attending classes in schools with moderate and high levels of disadvantage (b_{high} = 14.13, SE = 3.41, p ≤ .001, $b_{moderate}$ = 15.26, SE = 1.70, p ≤ .001; b_{minor} = 13.16, SE = 2.25, p ≤ .001). In schools with high levels of disadvantage, Books at Home was less important than students' Sex (b_{high} = 17.05, SE = 8.17, p ≤ .05). Male students in highly-disadvantaged contexts attained significantly higher science achievement scores than girls after accounting for the other predictors. Sex was not a significant predictor in the other school contexts. Regarding SES, Parents' Highest Level of Education was significant for students attending classes in schools with minor and moderate levels of disadvantage (b_{minor} = 6.49, SE = 2.35, p ≤ .01; $b_{moderate}$ = 7.44, SE = 2.40, p ≤ .01), whereas Parents' Highest Occupation Level was significant in schools with moderate and high levels of disadvantage ($b_{moderate}$ = 4.87, SE = 2.12, p ≤ .05; b_{high} = 10.29, SE = 3.19, p ≤ .01).

The process variables relating to parental support for learning (Early Numeracy Activities before starting school and Early Numeracy Tasks) were significantly related to science achievement in all three subgroups (Early Numeracy Activities: b_{minor} = 5.50, SE = 1.75, p ≤ .01; $b_{moderate}$ = 5.58, SE = 2.13, p ≤ .01; b_{high} = 6.46, SE = 2.68, p ≤ .05; Early Numeracy Tasks: b_{minor} = 7.92, SE = 2.53, p ≤ .01; $b_{moderate}$ = 8.81, SE = 1.94, p ≤ .001; b_{high} = 10.57, SE = 3.35, p ≤ .01). Student Bullying was a significant predictor for students attending schools with minor levels of disadvantage (b_{minor} = 6.32, SE = 1.89, p ≤ .001), but not for students attending schools with moderate or high levels of disadvantage.

Regarding motivational orientations, students attending schools with moderate and high levels of economic disadvantage who reported liking science had higher science achievement scores ($b_{moderate}$ = 5.64, SE = 2.74, p ≤ .05; b_{high} = 12.79, SE = 3.85, p ≤ .001;). This relationship is stronger for students in classes within schools with high levels of disadvantage than it is for students in schools with moderate levels of disadvantage. However, feeling confident in science was significantly associated with achievement only for students attending schools with minor levels of disadvantage (b_{minor} = 10.48, SE = 2.21, p ≤ .001).

The explained variance of science achievement at the student-level for schools with minor levels of economic disadvantage schools is R^2_{within} = .21, for schools with moderate levels of disadvantage R^2_{within} = .24, and for schools with high levels of disadvantage R^2_{within} = .28.

In a third step we included predictors on both student- and class-level (M2.2). Nearly all relations from the previous model (M2.1) remained stable, except for Sex and Students Like Learning Science. After adding Level 2 predictors, Sex was no longer a significant predictor for students attending schools with high levels of disadvantage but became significant in schools with moderate levels of disadvantage ($b_{moderate}$ = 7.84, SE = 3.83, p ≤ .05). Students Like Learning Science was no longer significant for students attending schools with moderate levels of disadvantage, but remained significantly associated with achievement in schools with high levels of disadvantage (b_{high} = 12.65, SE = 4.16, p ≤ .01).

At the class-level, none of the predictors in schools with moderate levels of disadvantage were significantly associated with achievement. For students attending schools with minor levels of disadvantage, teachers' perception of Students Lacking Prerequisite Knowledge and Skills was a significant predictor of students' science achievement, such that students achieved higher science scores in classes where the science teacher did not perceive a lack of students' prerequisite knowledge. However, in schools with high levels of economic disadvantage, a number of predictors at the class-level were associated with science achievement: the Number of Students in the Class (b_{high} = 10.77, SE = 4.67, p ≤ .05), Teachers Level of Formal Education (b_{high} = -9.51, SE = 3.72, p ≤ .05), Years Teaching (b_{high} = -8.49, SE = 3.59, p ≤ .05) and, again, teachers' perception of Students Lacking Prerequisite Knowledge and Skills (b_{high} = -37.79, SE = 10.29, p ≤ .001).

Notably, after controlling for these predictors at the class-level, the average predicted science achievement scores for students from schools with minor, moderate and high levels of disadvantage did not differ significantly (F = 0.039, df = 2, n.s.).

At the class-level, 21–81% of the variance of science achievement was explained by these models. The highest amount of explained variance was found for schools with high levels of disadvantage ($R^2_{between}$ = .81; p ≤ .001) and the lowest amount for schools with moderate levels of disadvantage ($R^2_{between}$ = .21; p ≤.001). For schools with minor levels of disadvantage, 25% of the variance between classes was explained ($R^2_{between}$ = .25; n.s.). The explained variance of science achievement at the student-level for schools with minor levels of economic disadvantage schools in this last model is R^2_{within} = .21, for schools with moderate levels of disadvantage R^2_{within} = .24, and for schools with high levels of disadvantage R^2_{within} = .29.

Table 4. Multilevel Analysis Split by Group (Schools with Minor, Moderate and High Levels of Economic Disadvantage; Fixed Effects, Unstandardized Estimates; Significant Effects in Italic)

	M2.0						M2.1						M2.2					
	minor		moderate		high		minor		moderate		high		minor		moderate		high	
	b	SE	b	SE	b	SE	b	SE	b	SE	b	SE	b	SE	b	SE	b	SE
Intercept	*542.96*	4.34	*526.06*	3.77	*504.46*	6.25	*545.60*	5.20	*529.21*	4.16	*507.32*	6.99	*547.28*	7.72	*550.08*	11.77	*552.48*	13.67
within (student)																		
Parents' Highest Level of Education							*6.49*	2.35	*7.44*	2.40	3.72	3.34	*6.68*	2.34	*7.33*	2.46	4.37	3.40
Parents' Highest Occupation Level							1.54	2.56	*4.87*	2.12	*10.29*	3.19	1.60	2.66	*4.84*	2.14	*10.80*	3.25
Books at Home							*13.16*	2.25	*15.26*	1.70	*14.13*	3.41	*13.25*	2.45	*15.41*	1.74	*15.10*	3.34
Sex (male)							4.15	4.19	7.11	3.88	*17.05*	8.17	6.10	4.50	*7.84*	3.83	12.20	8.34
Student Bullying							*6.66*	1.81	3.48	2.31	2.30	3.43	*6.32*	1.89	3.30	2.40	1.38	3.07
Early Numeracy Activities							*5.11*	1.66	*6.20*	2.12	*6.50*	2.67	*5.50*	1.75	*5.58*	2.13	*6.46*	2.68
Early Numeracy Tasks							*7.64*	2.26	*8.78*	1.85	*11.36*	3.48	*7.92*	2.53	*8.81*	1.94	*10.57*	3.35
Students Like Learning Science							1.07	2.10	*5.64*	2.74	*12.79*	3.85	1.02	2.24	5.43	3.00	*12.65*	4.16
Students Confident in Science							*10.48*	2.21	5.12	2.76	2.47	4.76	*10.33*	2.28	5.66	3.02	2.32	4.90
between (classes)																		
Number of Students in the Class													-4.29	2.68	3.05	2.94	*10.77*	4.67
Teachers Level of Formal Education													1.04	3.35	-3.43	3.16	*-9.51*	3.72
Years been Teaching													4.39	3.67	0.60	2.97	*-8.49*	3.59
Parental Involvement													2.12	4.53	4.48	4.16	0.50	5.52
Students Lacking Prerequisite Knowledge or Skills (yes)													*-15.09*	7.72	-12.06	10.30	*-37.79*	10.29
Area in Which School is Located (urban)													6.61	8.43	-12.51	8.74	-14.60	14.80
ICC	0.15		0.12		0.13													
R² (within)							*0.21*		*0.24*		*0.28*		*0.21*		*0.24*		*0.29*	
R² (between)													0.25		*0.21*		*0.81*	
Deviance			47549.00						37467.60						35203.08			
AIC			47567.01						37539.62						35401.09			
aBIC			47595.59						37646.50						35558.29			

Weight on student-level: L1wgt; weight on class-level: L2w

Discussion

The purpose of this article was to analyze the associations between selected predictors and science achievement and to examine school compositional effects related to the number of students coming from economically-disadvantaged homes. The analysis revealed several findings of relevance for schools serving varying proportions of students from disadvantaged backgrounds. For all prior models, we found statistically significant and large group differences for average science achievement between schools in different contexts. However, notably, average differences in science achievement scores between the three groups of school contexts were found to be small and no longer statistically significant after controlling for relevant predictors at the school level and for schools' level of economic disadvantage.

The most robust finding is that, aside from the number of books at home, only two variables were found to be significantly associated with science achievement in all three school contexts in the final model: parents' reports of the extent to which they had engaged in early numeracy activities at home before their child started school, and parents' estimates of their child's ability to demonstrate various numeracy-related skills or complete numeracy tasks before beginning school (M2.2, Table 4). Similarly, in the models of science achievement at the overall national level, the most parsimonious model (M1.2, Table 3) indicated that the only class/school-level factors that were significantly associated with science achievement were teachers' reports of students lacking prerequisite knowledge or skills, and the extent of parental involvement – both variables that are closely related to parents' reports of early learning activities and skills.

The consistency of the association between Fourth grade achievement and students' early learning activities and skills, across varying socioeconomic contexts, indicates that a strong policy focus on learning and development in early childhood is warranted. For example, Clerkin and Gilligan (2018) found that parents in homes with fewer resources for learning (a measure incorporating parental education, parental occupation, and the number of books in the home) reported substantially less engagement in various early numeracy activities (e.g., counting objects, or playing with building blocks or shape toys) with their children than parents of children who had access to some or many learning resources. The frequency of engagement in early numeracy play was associated with higher confidence in mathematics and (for boys only) stronger liking of mathematics in Fourth grade, after controlling for mathematics achievement, gender, home learning resources, and engagement in other early (literacy-related) activities. In general, children who begin school with stronger early numeracy and literacy skills, and more positive attitudes to learning, will tend to be better equipped to engage with the intended curriculum in a formal classroom setting and to maintain progress through their educational careers. These findings strongly support the value of the Home School Community Liaison component of the DEIS program, which is specifically targeted at maintaining strong links between the school and the home and assisting families with children in need of educational support.

The importance of making a strong start at school is further indirectly suggested by teachers' reports of the extent to which they felt their ability to teach was limited by students who did not have the expected prerequisite knowledge or skills for Fourth grade. The models reported here shows that student achievement was significantly lower in classes where teachers reported that a lack of prerequisite skills hampered their teaching. This pattern is evident in both the most and least disadvantaged contexts, although the relationship with achievement is particularly marked among student in the most disadvantaged contexts. This can be interpreted as indicating that, even where individual students are well-prepared to learn, achievement may be lower in classes where teachers have to dedicate substantial time and attention to 'catching up' students who are unable to engage effectively with the expected material.

Elsewhere, some different associations with science achievement were found for the three groups of schools. In schools with a high proportion of economically disadvantaged students, parents' highest occupational level was a significant predictor for science achievement, where-as parents' highest level of education was not. The opposite effect was found for students attending schools with minor levels of disadvantage, where parents' educational background was strongly associated with students' science achievement but occupational status was not. In schools with moderate levels of disadvantage, science achievement was associated with both parental occupation and education. This may point to threshold effects, as noted by McCoy et al. (2014). That is, in schools with high or minor levels of disadvantage, concentration of disadvantage or privilege beyond a certain point may contribute to lower or higher achievement scores, rather than presenting as a linear effect of social composition.

McCoy et al. (2014) point to previous inconsistent findings of contextual effects on student achievement, which vary in international research by the student cohort studied and the measure of social context used. They also highlight the interaction between residential patterns, parental choice and school admission policies, which often seem to result in different student profiles at schools (see also Byrne & Smyth, 2011). In addition, noteworthy differences have been found between schools in urban areas compared to those in rural settings. Using standardized test data on reading and mathematics, McCoy et al. (2014) found that there was no difference in average performance between rural disadvantaged and non-disadvantaged schools once students' social background was considered, but they did find a significant difference in achievement despite controlling for individual-level social background in urban schools. In contrast, the results of the current study show no differences in science achievement between urban and rural schools; most of the significant effects can be found at the individual (student) level.

Students' self-reported attitudes towards science emerged as being significantly associated with achievement at the national level and in some school contexts, but not all. In particular, students in schools with high levels of disadvantage who reported a stronger liking for science (an affective indicator; e.g., "I enjoy learning science") achieved significant higher scores on the TIMSS assessment than peers who reported less positive attitudes. Students in schools with minor levels of disadvantage who reported higher confidence in science (a cognitive indicator: e.g., "I usually do well in science") achieved higher scores than students who were less confident. It should be noted that no causal inferences are possible with these cross-sectional data. There is some evidence that high achievement may lead to more positive attitudes more clearly than vice-versa (Gorard et al., 2012), although the true relationship is likely to be bidirectional and mediated through particular pathways, such as cognitive and behavioral engagement at school (Pekrun & Linnenbrink-Garcia, 2012; Wang & Degol, 2014).

Compared to the overall sample model for science achievement in Ireland (Table 3), student's sex was not a significant factor, except for students in schools with moderate levels of disadvantage (Table 4). Based on student data from 30 countries from PISA 2000, Marks (2008) found little or no gender difference in the effects of socioeconomic background on educational performance (reading and mathematics) in almost all countries examined. Connolly (2006) analyzed the effect of social class and ethnicity on gender differences with regard to General Certificate of Secondary Education in England and Wales and found that ethnicity and social class showed a far greater influence on performance than gender. The results of this study show boys outperforming girls in science achievement in the overall model after controlling for individual predictors as well as school-level predictors. However, examined in the varying contexts of minor, moderate or high levels of disadvantage, gender differences in science achievement appear to be marginal.

Some of the results need to be interpreted in the context of educational policy and practice in Ireland. For example, the finding of a positive relationship between class size and science achievement is likely to be an indirect result of the smaller class sizes introduced as part of the DEIS program. In TIMSS 2015, primary schools in Ireland with the highest concentrations of economically disadvantaged children were much more likely to have smaller class sizes (i.e., fewer than 20 students; Clerkin et al., 2017). Thus, larger class sizes are likely to be, in part, reflective of schools with lower levels of economic disadvantage. The finding that a similar pattern holds even within the subset of highly-disadvantaged schools may suggest organizational practices within those schools, with staff and resources deployed flexibly to provide additional support where possible to the students in greatest need.

Similarly, the finding that teachers' level of experience is negatively associated with science achievement in schools with high levels of disadvantage may be related to educational practices at the school level. As noted earlier, previous research has shown that teachers in more disadvantaged urban schools tend to be younger and less experienced (Allen & McInerney, 2019; Clerkin, 2013; McCoy et al., 2014). Similarly, an unpublished report prepared by the Economic and Social Research Institute as part of the ESF (EUROCORES) ADDITION study found that, in Ireland, Fourth grade teachers in schools experiencing greater levels of economic disadvantage were more likely to be recently qualified than those in other primary schools (ESRI, n.d.). While these patterns might suggest that, in general, a positive relationship between teaching experience and achievement would be expected, the current analysis goes one step further by indicating that, within the subset of more highly-disadvantaged schools, teacher experience is negatively associated with achievement. It is possible that these findings indicate a selective effect within schools with high levels of disadvantage such that teachers with the most experience are preferentially assigned to teach the most challenging classes. In the same way, teachers with higher levels of formal qualifications may be prioritized when selecting teachers for classes with high concentrations of lower achieving students.

Conclusion

This secondary analysis of TIMSS data on science achievement offers several advantages. Through the use of a high-quality and nationally-representative dataset drawing on multiple information sources, and by using sample weights and plausible values to get unbiased estimates for students' science achievement, the results of these models can be reliably generalized to the national population of Fourth grade students in Ireland. Further, as noted in the introduction, science education has received comparatively little attention compared to reading or mathematics outcomes in Ireland, especially in the absence of a national assessment of science achievement at primary level, despite increasing policy emphasis on STEM education in recent years. This means that the TIMSS science assessment can provide uniquely valuable and timely insights into the teaching and learning of science in primary schools in Ireland.

Due to the relative scarcity of representative data on science achievement at primary level, it is of particular importance to pay attention to the context of the learning environment when examining student achievement. The finding presented here that significant differences are found in the performance of students in schools with a high level of disadvantage compared to those in schools with a lower level of disadvantage, but that these differences are significantly reduced when controlling for other school-level characteristics like class size, teacher training and teaching experience, provides important new information on science education and educational disadvantage in primary schools in the Irish context.

The use of TIMSS data to examine differences related to school compositional effects can inform ongoing policy discussions on providing adequate supports to schools and students experiencing educational disadvantage. For example, the finding that teachers' perception of students lacking prerequisite knowledge and skills was a significant

predictor of students' science achievement, particularly in schools with high concentrations of economic disadvantage, suggests that students in such schools could benefit from extra resources targeted at teaching and learning in science, similar to the types of literacy and numeracy resources that have been offered in such schools as part of the DEIS program.

Furthermore, the robust finding that early learning is associated with science achievement in Fourth grade supports the value of the Home School Community Liaison aspect of the DEIS program, which aims to strengthen links between the school and families at risk of educational disadvantage and to support parents and children from more disadvantaged backgrounds. However, the consistency of the findings related to engagement in early numeracy activities across all school contexts also highlights the importance of the home learning environment, in particular in the early years, for all students regardless of whether they attend a school with high concentrations of economic disadvantage.

Recommendations

The current study examined factors associated with science achievement in schools with differing levels of economic disadvantage, as reported by school principals. It is recommended that the analyses presented here should be supplemented and replicated with further evidence drawn from independent datasets (e.g., TIMSS 2019) and triangulated using other markers of school-level disadvantage (e.g., up-to-date DEIS status or other indicators of school-level disadvantage).

Limitations

These analyses are limited by the fact that the data used here offer a cross-sectional perspective. As a result, many process variables related to science education (such as teachers' pedagogic methods or school-based efforts to support students) remain unconsidered. The data provide a snapshot at one moment in time during students' Fourth grade education, but cannot disentangle effects accumulated over previous years and months from any additional effects specific to the students' circumstances within Fourth grade. In addition, the indicator of school-level disadvantage is drawn from a single perspective – principals' reports of the proportion of students coming from economically-disadvantaged homes – which may not capture all of the facets of school-level disadvantage that one may wish to consider.

Authorship Contribution Statement

Nonte: Conceptualization, design, analysis, writing, interpretation. Clerkin: Conceptualization, design, writing, interpretation, editing. Perkins: Conceptualization, design, writing, interpretation, editing.

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