

An Analysis of Factors Affecting Pupils' Science Achievement in Italy

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Abstract

Background indices in the TIMSS 2007 data are complex variables referring to educational contexts which are presumed to affect students' achievement in science subjects. The objective of this paper is to examine, for the Italian 4th grade data, the relationships between these indices both at school and at pupil level and the proficiency scores for overall achievement in science subjects. A multilevel analysis was conducted adopting a four-stage procedure and considering the home/student level nested under the school/teacher level. The results showed that pupils' performance in science subjects is significantly related to being a native student, to gender, to home educational resources, such as the number of books at home, to student self-confidence in learning science and to student perception of being safe at school.

Keywords: *science achievement, multilevel regression, TIMSS 2007, fourth grade, background indices.*

Introduction

Since in the present day technology and its scientific basis is present in every aspect of personal, social and professional life, there is a strong interest among policy makers, researchers and educators in acquiring a better understanding of what influences science achievement in school and consequently which aspects of science education could be improved in order to prepare pupils to better face the real world ahead of them. This is especially important at primary school where the bases of children's interest, motivation and success in learning science are established.

Several studies have drawn attention to the relevance of emotional and motivational factors as well as contextual variables in predicting academic performance in the field of mathematical and scientific subjects (e.g. Chang, Singh, & Mo, 2007; Lau & Roeser, 2002; Marsh, Trautwein,

Lüdtke, Köller, & Baumert, 2005; Pietsch, Walker, & Chapman, 2003; Shen, 2001; Zanobini & Usai, 2002) including data from the TIMSS studies (Eklöf, 2007a; Eklöf, 2007b; Shen & Pedulla, 2000). Nevertheless, most of these research studies concern lower and upper secondary level pupils, and there are few studies regarding primary school children.

The TIMSS study concerning 4th grade pupils offers a precious opportunity to investigate this issue. Furthermore, given the low numbers of students enrolled in scientific courses in Italian universities, the analysis of aspects related to academic success from the earliest years in school is particularly valuable in our national context, in order to discover the possible factors motivating young people to embark on scientific studies.

The aim of this study was to examine, for the Italian TIMSS 2007 data, the relationship between contextual factors at the school level and pupil level and the proficiency scores for science achievement. The theoretical framework of the study was consistent with the TIMSS 2007 assessment framework (Mullis et Al., 2005) which considers a multilevel and multidimensional structure of contexts and factors associated with students' learning in science. In particular, the TIMSS 2007 contextual framework underlines the importance of collecting, together with data on pupils' performance, also data regarding a series of pupil and school variables such as information about the school curriculum, teachers, pupils and their family backgrounds.

The pupils are asked to rate their agreement with items regarding various aspects of their home backgrounds (e.g. number of books at home and other educational resources) and their attitudes and motivation towards learning science. In particular, there are several questions about domain-specific self-concept, self-confidence and positive feelings towards science; these constructs have been shown to be related to motivation for studying and to achievement (Wigfield & Eccles, 2002).

The TIMSS assessment framework does not elucidate the theoretical assumptions behind the inclusion of these constructs and we therefore decided to use an empirical process to identify the significant variables. Thus this selection was based upon the reliability coefficients of the indices and other variables included in the TIMSS assessment framework.

The results of the present paper are especially relevant to the Italian context, in the light of various recent initiatives intended to enhance science learning in primary schools. Furthermore, in Italy at the moment a reform of the education system is being implemented; since this reform also affects primary schools it is vital to monitor pupils' performance in various subjects taught at school, especially those more likely to have less human resources and less school time devoted to them in future.

Methodology

Sample

Data is based on the answers of 4,470 pupils in Grade 4 (48.7% girls and 51.3% boys), as well as those of the teachers and principals of the 170 schools which took part in the TIMSS 2007 study in Italy.

Variables

Measurements were taken at home/student level and at school/teacher level. The dependent variable of the analysis was the proficiency score for overall science achievement drawn from the five plausible values obtained through the IRT methodology (Olson, Martin, & Mullis, 2008).

The independent variables were the international background indices (Olson et al., 2008) based on questionnaires for students, teachers, schools and parents.

The variable “parents born in country”, recoded as a dummy variable (1 = at least one parent born in country; 0 = no parents born in country), was added as likely to be relevant in the Italian context.

The variable “number of books at home” was used both at the individual level and aggregated at the school level as a possible indicator of the school cultural context.

The indices and derived variables considered were:

- ***School and teacher level***

- Index of teacher reports on teaching science classes with few or no limitations (SCFL)
- Index of teachers’ emphasis on science homework (ESH)
- Index of teachers’ perception of school climate (TPSC)
- Index of science teachers’ adequate working conditions (S-TAWC)
- Index of teachers’ perception of safety at school (TPSS)
- Number of books at home – aggregated (BOOK_2)

- ***Student level***

- Gender (SEX)
- Number of books at home (BOOK)
- Parents born in country (NATIVE)

- Index of time spent on science homework (TSH)
- Index of students' positive affect toward science (PATS)
- Index of students' self-confidence in learning science (SCS)
- Index of students' perception of being safe in school (SPBSS)

Analysis

The data were analyzed according to the following scheme:

1. selection of the indices on the basis of their reliability;
2. handling of missing data;
3. multilevel analysis.

Selection of the indices on the basis of their reliability. First we looked at the reliability of indices in the Italian sample as reported in Olson et al. (2008): indices with a very low Cronbach's alpha value (less than .60) were not considered for further analysis.

Handling of missing data. Missing data were imputed using the estimates derived from EM algorithm (Dempster, Laird, & Rubin, 1977; Lin, 2010).

Multilevel analysis. To develop and test a multilevel model (Hox, 2002), we used the strategy of randomly splitting the data file into two sub-sets in order to perform a validation of the model: The first random sample was used to develop a satisfying model and the second sample was used to check the validity of the model itself. Finally we applied the model to the whole sample weighted at both levels of analysis.

The multilevel analysis was conducted using two levels, the home/pupil level and the school/teacher level. Home and student variables were modeled on the home/student level only, except for the variable regarding home educational resources (number of books at home), which were aggregated at the school level and assessed also at the second level as a possible indicator of the school cultural context.

The process of analysis was carried out in four stages:

1. We analyzed a model with no explanatory variables (intercept-only model) to estimate the school intra-class correlation.
2. We analyzed a model with all the pupil level explanatory variables fixed in order to assess the contribution of each individual explanatory variable. We tested the improvement of the final model (the one with only variables significant at the 1% level) compared to intercept-only model.

3. At step 3 we included all the school/teacher level variables and consequently removed from the model those that were not significant at the 1% level.
4. We validated the final model developed at step 3 using the second random sample of the data file.
5. Finally we performed again the first three stages on the whole sample. Table 1, Table 2 and Figure 1 report the results at each stage of analysis.

[Take in Table 1 about here]

[Take in Table 2 about here]

[Take in Figure 1 about here]

Finding and Discussion

The school intra-class correlation was 0.34, meaning that roughly 34% of the variance is attributable to school traits.

Results showed that students perform significantly better in science subjects ($p < 0.01$) if their home educational resources are higher, self-confidence in learning science and the student perception of being safe at school are higher. Students also tend to perform better if they are male and native.

When school/teacher level predictors are added to the model, it appears that none of the indices taken into consideration are significant at the 1% level.

Conclusion and Implications

This study seems to show that in Italy 34% of the total variance accounted for is between-schools and that the school and teacher factors analyzed do not significantly affect students' performance in science. Future in-depth studies and analyses will hopefully search for school level variables that can explain these important differences between schools. In fact it is widely recognized that the issue of school choice needs special attention and careful management by policy makers, especially in order to avoid increasing differences in the social composition of different schools and this is particularly the case at such an early stage of schooling (e.g. Dupriez & Dumay, 2006; Field, Kuczera, & Pont, 2007; Wößmann & Schütz, 2006).

Our finding that in the Italian context being a non-native student and having less cultural resources negatively and substantially affects science performance is consistent with several studies pointing out the advantages deriving from home and parental features (Cooper, Jackson, Nye, & Lindsay, 2001; Hoover-Dempsey at al., 2001; Hoover-Dempsey at al., 2005).

This is an issue that requires particular attention, especially considering the equity related issues of the country's educational system: not only the average level of achievement is important, but also its distribution across the population (Levin, 2003). It would seem that at present the Italian school system is not only unable to balance out the existing gap between students from various backgrounds, but that it even replicates and emphasizes these differences, with a cumulative effect from one level of schooling to the next (Alivernini, Losito, & Palmerio, 2010; INVALSI, 2008).

In conclusion one should also note that, in the present study, students' self-confidence in learning science proved to be the most important predictor of their performance.

Due to the content of the items included in this particular index, it is possible to assimilate it to the construct of self-efficacy (Bandura, 1997), which concerns the extent to which individuals are confident in performing tasks or attaining various goals. In fact a number of studies indicate that higher levels of self-efficacy are positively correlated to achievement at school and to education in general (Pajares, 1996; Schraw, Crippen and Hartley, 2006). The results of the present study are consistent with these studies as well as with other longitudinal studies (e.g. Caprara et al., 2008) giving further evidence that self-confidence plays an important role in accounting for academic achievement. From a teacher's or a school's point of view this is an encouraging outcome, since self-efficacy and self-confidence are features that can be enhanced by specific intervention; in fact research into educational psychology (e.g. Fencl & Scheel, 2005) shows that teachers can improve students' self-confidence and self-efficacy by means of specific teaching methods such as engaging students in a creative manner and using collaborative learning or inquiry-based activities.

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Table 1. Parameter estimation – Model step 2 (Level-1 predictors)

	<i>Coefficient</i>	<i>Standard Error</i>	<i>P-value</i>
Intercept	540.52	5.82	0.000
BOOK	6.90	1.55	0.000
TSH	7.62	3.01	0.012
PATS	-2.85	3.21	0.383
SCS	-26.79	3.25	0.000
SPBSS	-11.80	2.21	0.000
NATIVE	20.67	7.06	0.005
SEX	14.65	2.77	0.000
VARIANCE COMPONENTS			
	<i>Standard Deviation</i>	<i>Variance</i>	<i>P-value</i>
U_{0j}	47.07	2215.85	0.000
r_{ij}	63.19	3992.59	--

Table 2. Parameter estimation – Model step 3 (Level-1 and Level-2 predictors)

	<i>Level-1 Predictors</i>		
	<i>Coefficient</i>	<i>Standard Error</i>	<i>P-value</i>
Intercept	538.28	4.70	0.000
SCFL	-13.63	8.76	0.122
ESH	12.28	10.66	0.230
TPSC	-13.28	11.34	0.244
S-TAWC	-9.65	10.26	0.349
TPSS	1.47	18.13	0.936
BOOK_2	9.78	13.13	0.458
<i>Level-1 Predictors</i>			
BOOK	7.03	1.50	0.000
SCS	-28.45	2.40	0.000
SPBSS	-11.66	2.19	0.000
NATIVE	24.16	6.45	0.000
SEX	14.60	2.68	0.000
VARIANCE COMPONENTS			
	<i>Standard Deviation</i>	<i>Variance</i>	<i>P-value</i>
U_{0j}	45.45	2065.94	0.000
r_{ij}	63.76	4065.85	--

$\text{Science Perf.} = 539.1 + 7.2*\text{BOOK} - 28.4*\text{SCS} - 11.7*\text{SPBSS} + 24*\text{NATIVE} + 14.6*\text{SEX} + u_0 + r$

Fig. 1. Equation for the final model