

THE EFFECTS OF STUDENT, CLASS AND SCHOOL CHARACTERISTICS ON MATHEMATICS ACHIEVEMENT: EXPLAINING THE VARIANCE IN FLEMISH TIMSS-R DATA

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Abstract

In Flanders, the TIMSS-R sample design differed from the general design: instead of taking one class in each of the selected schools, two classes per school were selected. Because of this design, a multilevel model with an intermediate level could be implemented. Whereas in other countries only a division between one higher level (the school level, which coincides with the teacher and the class level) and a lower level (student level) can be made, in Flanders the higher level can be subdivided into a school and a class level. The Flemish dataset contains valid data of more than 4000 students in about 260 classes and about 130 schools. In an 'empty' model, the variance of the scores on the mathematics test can be divided: about 58% of the variance is situated at the student level, 28% at the class level and 14% at the school level. Other national options in Flanders were the extension of the student's, teacher's and principal's questionnaires with additional questions, an intelligence test for the students and a parents' questionnaire. To explain the variance on the distinguished levels, different variables (derived from the extended questionnaires) were added to the model. The results of the multilevel analyses with the explanatory variables at the different levels will be presented. The 'numerical and spatial intelligence score of the student', as the only explanatory variable, can explain more than a third of the variance. The considered student, class, and school characteristics together can explain almost half of the total variance.

INTRODUCTION

Flanders (the Dutch speaking part of Belgium) was one of the 38 countries that participated in TIMSS-R. The general data collection of TIMSS-R was comprehensive: the students of one class in 150 schools per country completed a mathematics and science test and filled in a questionnaire. Information on teacher practices, classroom and school characteristics was gathered through questionnaires for the

principals and the mathematics and science teachers of the students. In Flanders, the data collection of TIMSS was considerably extended. Instead of taking one class per school, two classes in each of the schools were selected at random. Furthermore, several questions were added to all the questionnaires, a parents' questionnaire was administered and a numerical and spatial intelligence test for the students was included as well.

There were three main reasons for the extension of the data collection. The first reason was to determine the distribution of the total variance of the achievement scores across the distinguished levels. In the international design with one class per school, only two levels can be distinguished (the student level and a higher level); no distinction between the class level and the school level can be made. This means that 'school' effects are actually effects of the combination of the class, the teacher and the school (Van den Broeck, Opdenakker, Hermans & Van Damme, 2003; Opdenakker & Van Damme, 2000). The Flemish sample design with two classes per school makes it possible to distinguish between the class and the school level and consequently to implement a three-level model.

Second, since background characteristics appear to have a significant effect on mathematics achievement, it is important to control for their effect, particularly if classes and schools are composed in a rather homogeneous way. The effects of classes and schools can be overestimated if the control for background characteristics is inadequate. The student background characteristics considered in this study are 'numerical and spatial intelligence', 'educational level of the parents', 'language at home', and 'possessions at home'.

The final reason was to reduce the variance at the different levels by means of the introduction of some explanatory variables in the multilevel models. The explanatory variables were derived from (the extensions of) the questionnaires.

In this study, the distribution of the total variance across the three levels will be reported and multilevel models with the background characteristics and with the other student, class and school characteristics will be presented. Based on the results of the analyses, it can be determined whether the extensions were worthwhile and whether suggestions can be made to improve the data collection of TIMSS.

LITERATURE

Student characteristics

In the research literature, a number of variables are mentioned as predictors of achievement levels. Several studies reveal that the educational level of the parents is important for the prediction of the achievement level of their children (Dekkers, Bosker & Driessen, 2000; Beaton, Mullis, Martin, Gonzalez, Kelly & Smith, 1996; Robitaille & Garden, 1989). The socioeconomic status of the family has also been found to be an important background characteristic (Coleman et al., 1966; Marjoribanks, 2002). Previous studies show that ability is another factor that can explain variance in academic achievement (e.g., Grisay, 1996; Hill, Rowe, & Holmes-Smith, 1995; Opdenakker, Van Damme, De Fraine, Van Landeghem & Onghena, P.,

2002). A recent study reveals mathematics achievement is influenced by the language used in the test, i.e., is it the students' main language (Howie, 2002).

In addition to these background characteristics, there are other student features that can predict achievement. The student's attitude towards a subject can influence achievement and vice versa (Vermeer & Seegers, 1998): attitude is a determining factor in the amount of learning time and effort made in a particular subject and this will influence the achievement level for that subject. A high achievement level in its turn will have a positive effect on the learner's attitude towards the subject. The way students perceive their learning environment is also important for their learning and, consequently, for their academic results. In this study, we examine whether students perceive their learning environment as constructivist. In the constructivist view, the learner is responsible for his/her own learning processes (Boekaerts, 1999). The constructivist approach has received some empirical support (de Jager, Creemers & Reezigt, 2002). Furthermore, the study programme the students follow or the track they belong to seems to be important too. Research in Flanders shows that the study programme is a significant explanatory variable for differences in the level of achievement (Van Damme, Van Landeghem, De Fraine, Opdenakker and Onghena, 2000). In Flanders, there is a streamed educational system. In the general stream of grade 8 (to which this study is restricted) the optional subjects can be grouped into three kinds of programmes: programmes with classical languages (Latin/Greek), programmes with extra hours of general subjects and programmes with technical subjects. In principle, all students have the same curriculum for mathematics. In practice, the better students follow a programme with classical languages, the least academically adept take technical subjects and those in the middle take more general subjects.

Class characteristics

The classroom climate (e.g., a quiet class, a class with disruptive students, a study-oriented class) appears to affect the achievement level of the students. There is also some indication that the experience of a teacher has a small positive effect (Hedges, Laine & Greenwald, 1994). It may be expected that more experienced and/or older teachers can more easily create the 'right' climate in the classroom. The teaching method seems important as well. In this study, the extent to which the testing is based on a constructivist view of learning according to the teacher (in comparison with the perception of the students) is examined. Furthermore, several studies found that classroom composition with regard to the ability of the students can influence achievement (e.g., Dar & Resh, 1986; Leiter, 1983; Opdenakker et al., 2002).

School characteristics

Besides the climate of the class, the school climate (e.g., problematic behaviour of the students) can also influence the achievement level of the students (Anderson, 1982; Levine & Lezotte, 1990). General results of TIMSS-R reveal that shortcomings in schools can affect the mathematics achievement of the students (Mullis, Martin, Gonzalez, Gregory, Garden, O'Connor, Chrostowski & Smith, 2000). Absenteeism of students seems to be another important factor at the school level. Regarding the

effect of written reports and other forms of monitoring the progress of the students, the research results are not as straightforward (see e.g., the meta-analysis of Scheerens and Bosker, 1997).

Variables

In this section the operationalisation of the student, class and school characteristics is described. In the TIMSS-R international student questionnaire, a question regarding the educational level of their father and mother was included. In the first cycle of TIMSS (in 1995), the same question was asked, but 16% (19%) of the students did not respond to this question and 29% of those who did respond indicated that they did not know the educational level that their parents attained (Van den Broeck, Opdenakker, Hermans & Van Damme, 2003). To obtain a more accurate indication of parental education, a question about the highest educational level attained was included in the parent questionnaire of the Flemish extension. The TIMSS-R student questionnaire contained a question about several items that the students could own at home. The variable 'possessions at home' was derived from the responses. A numerical and spatial intelligence test was one of the national extensions of TIMSS-R, so that ability could be factored into the multilevel analyses. In the international questionnaire, the students were asked how often they speak the language of the test at home. The answers were recoded to a binary variable (whether they (almost) always vs sometimes or never speak Dutch at home). In the extension of the student questionnaire, several questions about the student's attitude towards mathematics and the perception of his/her learning environment as constructivist were added (for more information about the construction of the variable 'attitude towards mathematics': see Van Damme, Opdenakker & Van den Broeck, 2004). The information about the programme chosen by the students was collected through the secretariat of the school.

To ascertain class characteristics, questions on classroom climate (a class with disruptive students, a quiet class and a study-oriented class) and the constructivist learning environment were included in the extension of the teacher questionnaire. Information referring to the age and the experience of the teacher was gathered through the international questionnaire. The average intelligence score of the class was calculated to make the group composition with respect to ability operational.

Several questions about the seriousness and the frequency of problematic behaviours of students, general shortcomings in schools and specific shortcomings for mathematics instruction and absenteeism (percentage of absent students on a regular schoolday) were part of the international questionnaire for the principal. In Flanders, the principal questionnaire was extended with questions about forms of monitoring. The following variables were derived from these additional questions: the frequency of individual 8th grade student progress reports, the frequency of written reports, the frequency of discussions with the parents about the student's progress.

SAMPLE DESIGN, DATA AND METHOD

In Flanders, the TIMSS-R sample design differed from the general design (Foy &

Joncas, 2000). Because there were two selected classes per school, it was possible to implement a multilevel model with three levels (i.e., student, class and school).

The Flemish dataset contains valid data of more than 4000 students in about 260 classes and about 130 schools. In the analyses, the dependent variable is the Rasch-score for mathematics. Because there were several versions of the test booklets, each containing a different combination of items, IRT scaling was used (Yamamoto & Kulick, 2000).

The software MLwiN (Rasbash et al., 2000) was used to conduct the multilevel analyses.

RESULTS

Proportion of variance of mathematics scores at the different levels

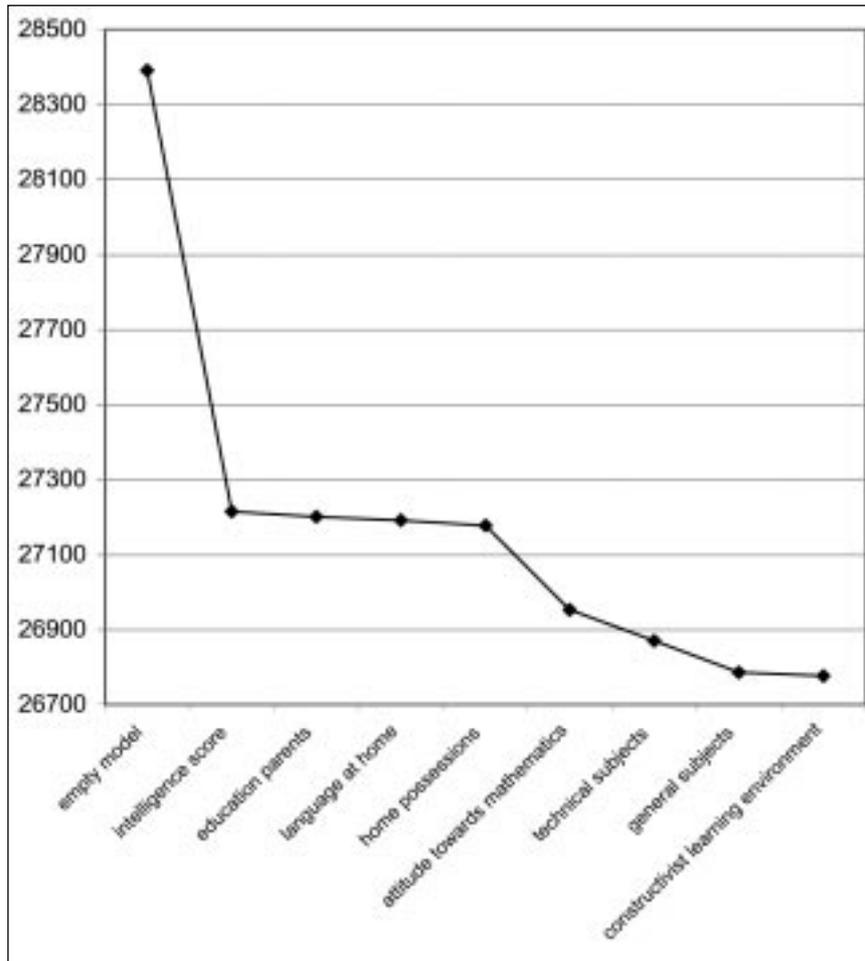
By means of an empty model, it was found that almost 58% of the total variance in mathematics scores is situated at the student level, 28% is due to differences between classes and 14% is due to differences between schools. So, more than 42% of the variance is situated at the higher levels. Thanks to the selection of the second class per school, it could be determined that the proportion of the variance at the class level is greater than the proportion of the variance at the school level.

Student characteristics as explanatory variables

First, a model was built with the student background variables. Subsequently, the other student variables were added one by one. Adding variables one by one will decrease the deviance (this is a measure for lack of fit between the model and the data) gradually. Figure 1 represents the decrease of the deviance. (Because of missing data with respect to student, class and school variables, separate models were built for each of these variables and one for all these variables together. For each model, the maximum set of available observations was used and an empty model was estimated. So, deviances of the different empty models are not comparable because the models are based on different data sets.)

This figure shows clearly the considerable decline in deviance once intelligence scores are introduced as the only explanatory variable. The deviance does not really decrease when the other background characteristics are introduced. The introduction of the variable 'attitude towards mathematics' after the background characteristics produces another decline in the deviance. The variables for the optional programmes reduce the deviance even further. These results are in accordance with the results of another study of Van den Broeck, Opdenakker and Van Damme (manuscript submitted for publication), where it was found that the intelligence score reduced the variance in mathematics achievement to a large extent at all levels, and that the variable 'attitude towards mathematics' and the variables regarding the programmes reduced the variance to a small extent.

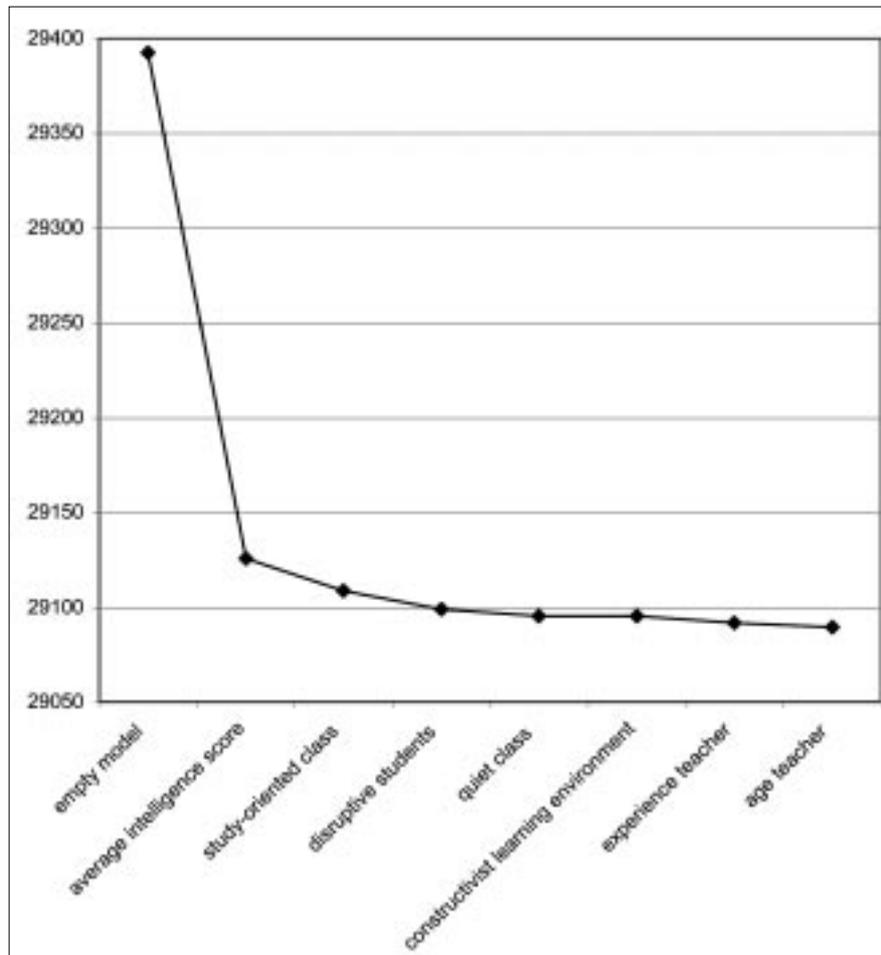
Figure 1: Model With Student Characteristics As Explanatory Variables: Decrease Of Deviance



Class characteristics as explanatory variables

The introduction of the average intelligence score as the only (class) characteristic in the model produces a very pronounced decline in the deviance (see Figure 2). Once the variables 'study-oriented class' and 'disruptive students' are added as well, there is no longer any significant decrease in the deviance. These three class characteristics together (as the only explanatory variables) can explain more than 90% of the variance at the class level and more than a third of the variance at the school level. This is almost a third of the total variance.

Figure 2: Model With Class Characteristics As Explanatory Variables: Decrease Of Deviance



School characteristics as explanatory variables

Figure 3 shows the reduction of the deviance when the different school characteristics are successively added to the empty model. The reduction of the deviance is no longer significant once the variables 'absenteeism' and 'frequency of problematic behaviour' are taken into account. Through the introduction of these two variables, half of the variance at the school level can be explained. This is 7% of the total variance.

Student, class and school characteristics as explanatory variables

In the last model, the following variables are retained: intelligence score of the students, educational level of the parents, language at home, attitude towards

mathematics, optional programme, average intelligence score of the class, study-oriented class, disruptive students (in the class), absenteeism (in school) and frequency of problematic behaviour. When all these variables are successively introduced into the model, the deviance remains the same after the introduction of the background variables, the other student characteristics and the average intelligence score of the class (see Figure 4). These variables explain more than a fourth of the variance at the student level, more than 95% of the variance at the class level and more than 45% of the variance at the school level. This means that almost half of the total variance can be explained. (For detailed results of the successive models: see Van den Broeck, Opendakker and Van Damme, forthcoming.).

Figure 3: Model With School Characteristics As Explanatory Variables: Decrease Of Deviance

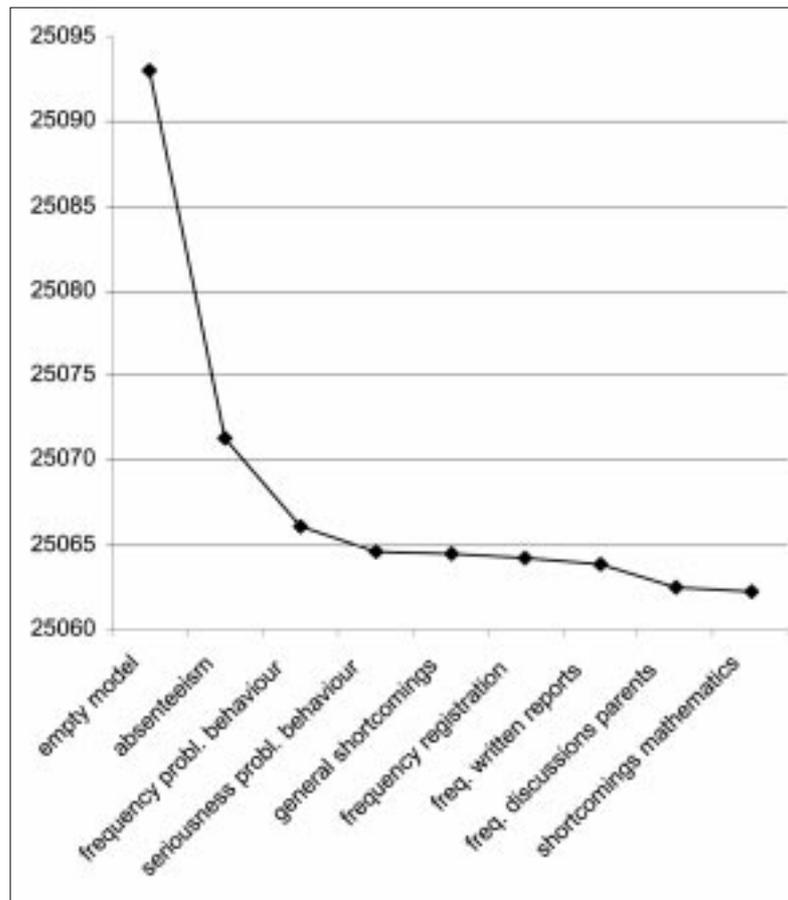
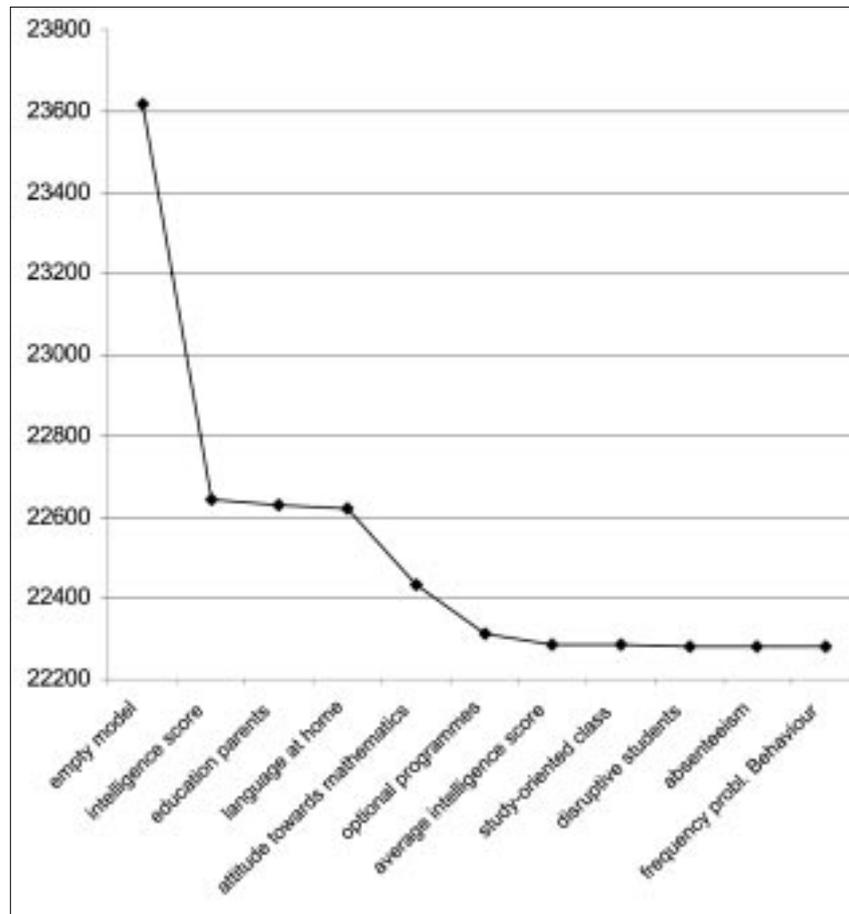


Figure 4: Model With Student, Class and School Characteristics As Explanatory Variables: Decrease Of Deviance



CONCLUSIONS

Because of the selection of two classes per school, the distribution of the variance across the student, class and school level could be determined. It appeared that the variance at the class level is larger than the variance at the school level. In a sample design with only one class per school, this distinction can not be made. It can be suggested that several classes per school are used in the next cycles of TIMSS or other IEA studies, to allow for multilevel analyses with three levels.

With respect to the background characteristics of the students, the numerical and spatial intelligence score appears to be the most important variable to reduce the variance in mathematics scores. The results are in accordance with the literature about the strong correlation between intelligence and achievement. Given the importance of the numerical and spatial intelligence as an intake characteristic, it may be valuable that an intelligence test is included in TIMSS.

Regarding the other student characteristics, the attitude towards mathematics seems important as well. Including a reliable measure for this variable in the TIMSS questionnaire is advisable. Although some class and school characteristics can explain the variance, after taking into consideration the student characteristics, the effects of the class and school characteristics no longer retain any significance. It can be argued that more effort must be made to develop relevant class and school variables for the questionnaires of future TIMSS data collections.

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