Classroom and Teacher Effects in Mathematics Achievement: Results from TIMSS

Stephen Lamb
Australian Council for Educational Research
<lamb@acer.edu.au>

Sue Fullarton
Australian Council for Educational Research
<fullarton@acer.edu.au>

Recent work on classroom and school effects in Australia has suggested that teacher effects account for up to 50 per cent of variation in mathematics achievement. The present study used data from the Third International Mathematics and Science Study (TIMSS) to look at classroom and school differences in mathematics achievement at both primary and secondary school levels. It found that while classroom differences account for about one-quarter of the variation in student achievement, little of this was due to teachers. Most of the classroom variation was due to compositional and organisational factors. This has important implications for policy regarding the improvement of mathematics achievement in schools.

Introduction

How much difference do teachers make to variations in achievement in mathematics? The work of Hill and his colleagues suggests that teachers may make a huge difference (Hill, 1994; Hill & Rowe, 1996; Hill, Rowe, Holmes-Smith, & Russell, 1996; Rowe & Hill, 1994). In their three-year longitudinal study of educational effectiveness known as the Victorian Quality Schools Project they examined student, class/teacher and school differences in mathematics and English achievement. The study began with 13,909 primary and secondary students and 931 teachers in 90 schools. Using multi-level modelling procedures to study the interrelationships between different factors at each level—student, classroom, and school—the authors found in the first phase of their study that at the primary school level 46 per cent of the variation in achievement in mathematics was due to differences between classrooms, and at secondary school level the rate was almost 39 per cent. Follow-up work found that between-class differences were also important in student growth in mathematics achievement. Differences in achievement progress located at the classroom-level ranged from 45 to 57 per cent (Hill, Rowe, Holmes-Smith, & Russell, 1996; Rowe & Hill, 1998).

In explaining the large classroom-level differences in student achievement in mathematics, Hill and his colleagues highlighted the role of teacher quality and teacher effectiveness. They contended that while not fully confirmed they had "evidence of substantial differences between teachers and between schools on teacher attitudes to their work and in particular their morale" (Hill, 1994) and this supported the view that "it is primarily through the quality of teaching that effective schools make a difference" (Rowe & Hill, 1994). In further work that examined the impact of teacher professional development on achievement they again argued that differences between teachers helped explain much of the variation in mathematics achievement (Hill, Rowe, Holmes-Smith, & Russell, 1996; Hill & Rowe, 1998).

However, alternative explanations for the large classroom-level differences were also provided by Hill and his team. They pointed to the possibility that classroom-level pupil management practices such as streaming and setting accounted for the class effects. This was not pursued by the authors who stated that in all of the schools they surveyed the classes were of mixed ability (Hill, 1994; Rowe, & Hill, 1994). Another possibility was an under-adjustment for initial differences, that is, they did not control adequately for prior achievement differences. A further explanation considered was the possibility of inconsistency in teacher ratings used in the measure of student achievement in mathematics.

This possibility was also deemed by Hill and his colleagues as unlikely to have had a major bearing, though its influence was not ruled out. However, the authors did not use, or argue for the use of, more objective, independently assessed mathematics tests.

Do teacher quality and teacher effectiveness account for classroom-level variation in mathematics achievement or are other factors more important? The current study aims to look at this question using data from the national samples of students, teachers and schools participating in the Third International Mathematics and Science Survey (TIMSS). It examines patterns of mathematics achievement in both primary and secondary schools and partitions variance using multi-level modelling procedures to estimate the amount of variance that can be explained at the student, classroom and school levels. By introducing different classroom and teacher variables it is possible to test the extent to which factors linked to teachers and those linked to classroom organisation and practice influence mathematics achievement.

The results of this work are important. If Hill and his colleagues are right and differences in mathematics achievement are heavily influenced by variations in the quality of teachers and teacher effectiveness then there are major policy implications for schools and school systems in terms of changing the provision and quality of teacher training, taking more care in teacher selection practices, re-shaping and investing more heavily in teacher professional development, and reforming the way schools deploy teachers and monitor their effectiveness. Alternatively, if other features of classrooms and schools explain more of the variation then schools and school systems may not obtain expected changes in mathematics achievement by targeting teachers.

Data and Method

Data

TIMSS—the Third International Mathematics and Science Study—was sponsored by the International Association for the Evaluation of Educational Achievement (IEA) and was conducted in 1996 (Lokan, Ford, & Greenwood, 1996). It set out to measure, across 45 countries, mathematics and science achievement among students at different ages and grades. In total, over half a million students from more than 30 000 classes in approximately 15 000 schools provided data. Not only were comprehensive mathematics and science tests developed for the study, there were also questionnaires developed for students, their teachers and their school principals. Prior to the development of the tests, an extensive analysis of textbooks and curriculum documents was carried out. Mathematics and science curriculum developers from each country also completed questionnaires about the placement of and emphasis on a wide range of mathematics and science topics in their country's curricula. Together the data provide a unique opportunity to examine an extensive range of contextual variables that influence mathematics and science achievement.

TIMSS investigated mathematics achievement at three stages of schooling with the following target populations:

- Population 1: adjacent grade levels containing the largest proportion of nine-year-old students at the time of testing;
- Population 2: adjacent grade levels containing the largest proportion of thirteen-year-old students at the time of testing; and
- Population 3: the final year of schooling.

In Australia, at the Population 1 level, over 11 000 students were tested from more than 540 classes in 179 primary schools (Lokan, Ford, & Greenwood, 1997). At the Population 2 level, almost 14 000 students were tested from almost 600 classes in 180 schools (Lokan, Ford, & Greenwood, 1996). At both levels, the number of schools was intentionally over-sampled from the smaller states to derive more reliable state estimates.

This study utilises data from the Australian samples of Population 1 and Population 2 students. For Populations 1 and 2, the original TIMSS design specified a minimum of 150 randomly selected schools per population per country, with two classes randomly selected to participate from each of the adjacent grade levels within each selected school. However, due to the cost of collecting such data, most countries were unable to achieve this position, and Australia, the United States and Cyprus were the only countries which selected and tested more than one class per grade level per school. The importance of the sampling design used in Australia is that it enables differences between schools to be separated from differences between classes within schools. In this way we are able to analyse school and classroom differences. The final sample numbers are presented in Table 1.

Table 1
The Sample Sizes

	Population 1 (Age 9)	Population 2 (Age 13)
Students	11248	13922
Classrooms	542	599
Schools	179	180

Method

This study aims to look at the effects of classrooms and teachers after controlling for student-level and school factors. An appropriate procedure for doing this is hierarchical linear modelling or HLM (Bryk & Raudenbush, 1992). This procedure allows modelling of outcomes at several levels (e.g. student level, classroom level, school level), partitioning separately the variance at each level while controlling for the variance across levels.

In the present study the interest is on variability within and between classrooms and schools. Two main sets of analyses were undertaken to measure the levels of variation. The first set was based on Population 1 (primary school) data and modelled mathematics achievement at age 9 years. In the analyses several models were tested each adding successively a new group or layer of variables. The first involved fitting a variance-components model to estimate the amount of variance due to the effects of students (level 1), within classrooms (level 2), within schools (level 3) by running the models without any explanatory variables. The second model introduced a group of student background variables comprising sex, socioeconomic status, family size, ethnicity and number of books in the home. The third model added a set of mediating variables to the student background variables. The mediating variables included results on a standardised word-knowledge test, and attitudes towards mathematics. The fourth model contained grade- or year-level and a set of classroom composition variables relating to mean word-knowledge score, and mean socioeconomic status (SES). The next model added a set of teacher variables including the sex of the teacher, age, qualifications, and scores on six scales related to attitudes and practices in mathematics teaching. The final model added a school-level factor, the mean SES of the school.

By examining changes in the size of the variance components estimates after the addition of each group of variables it was possible to measure the effects of teacher, classroom and school-level factors that influence mathematics achievement. In this way it was possible to estimate the extent to which factors linked to teachers rather than classroom composition and organisation shape differences in mathematics achievement.

The second set of analyses was based on data from Population 2 (secondary schools) and modelled achievement at age 13 years. The same sequence of models was applied, except that scores on a scale measuring student views on the importance of mathematics were added to the model introducing the student-level mediating variables. Additional variables were also added on classroom composition to identify whether classes were in the top-band if they were set or streamed, or if the classes were in schools which did not set or stream in mathematics. To the classroom teacher variables was added a measure of the years of teaching. Additional variables included in the school-level model were school size and a school-level policy to set or stream in mathematics. Table 2 lists and describes the variables included at each level.

Table 2
Student, Classroom and School Variables

	Population 1	Population 2
STUDENT LEVEL		
Student background variables		
Sex	Student's gender	Student's gender
Books	Number of books in student's home	Number of books in student's home
Family size	Number of people living in student's home	Number of people living in student's home
Ethnicity	A composite of student's birthplace, birthplace of parents and language spoken at home	A composite of student's birthplace, birthplace of parents and language spoken at home
Socioeconomic status	A composite variable representing family wealth	A composite variable representing family wealth
Student mediating variables		
Word knowledge	Verbal ability as measured by the word knowledge test	Verbal ability as measured by the word knowledge test
Attitude to mathematics	A composite variable reflecting the student's attitude towards mathematics.	A composite variable reflecting the student's attitude towards mathematics.
Importance of mathematics		A composite variable reflecting the perceived importance of mathematics to the student.
CLASSROOM LEVEL		
Grade-level and classroom composition variables		
Grade or Year level	Grade or year level of class	Grade or year level of class
Mean word knowledge	Average score on Word Knowledge test for the class	Average score on Word Knowledge test for the class
Mean SES	Average SES for the class	Average SES for the class
High band		Whether student is in one of the two the top streams in mathematics
No band		Whether classroom is non-set or non-streamed
Classroom teacher variables		
Age	Teacher's age	
Gender	Teacher's gender	Teacher's gender
Education. qualifications	Teacher's qualifications	Teacher's qualifications
Years teaching		Number of years teaching
Factor 1	Problem-solving approach to teaching	Problem-solving approach to teaching
Factor 2	Discipline oriented approach to teaching	Discipline oriented approach to teaching
Factor 3	Process oriented approach to teaching	Process oriented approach to teaching
Factor 4	Eclectic approach to teaching	Eclectic approach to teaching
Factor 5	Algorithmic approach to teaching	Teacher satisfaction with job
Factor 6	Teacher satisfaction with job	
SCHOOL LEVEL		
School variables		
School size		Measure of the number of students in the school.
Policy to stream		Whether the school has an explicit streaming policy
Mean SES	Average SES for the school	Average SES for the school

Results

Table 3 presents the results of the HLM analyses for students in primary schools. The variance components estimates are presented in column 2. The third column presents the percentages of variance (intraclass correlations) in mathematics achievement located at each of the levels—student, classroom and school. The final column contains the percentages of variance explained at each level after controlling for the different groups of variables.

As a first step, a fully unconditional (null) model was tested. This model, the equivalent of a one-way ANOVA with random effects, estimates variances in the outcome variable at the student, classroom and school levels. The results suggest considerable variation in mathematics achievement at the student and classroom levels. Approximately two-thirds (66.4 per cent) of the estimated variation occurs at the student-level. However differences between classrooms also account for a substantial amount of variance—24.5 per cent. This figure is lower than that reported by Hill (1994) for class/teacher effects in primary schools (44 per cent) but is still substantial. Differences between schools accounted for the remaining 9.1 per cent of variance. This suggests a moderate though significant level of variation between schools.

The next step in the analysis involved adding the student-background predictors (SES, gender, ethnicity, family size, number of books at home) to the model of mathematics achievement. This allowed differences between classrooms and schools to be adjusted for differences at the individual level. The results presented in column 4 show that differences in the background characteristics of students accounted for 10.1 per cent of the estimated variance at the student-level, 9.4 per cent of the variance between classrooms, and 49.3 per cent of the variance at the school-level.

Table 3
Variance in Mathematics Achievement Explained by Three-level HLM Models: Population 1, TIMSS

	Variance	Variance between levels	Variance explained at each level
		%	%
Variance within classrooms (level 1 variance)	5774.3	66.4	
After controlling for:			
Student background variables	5190.2		10.1
Student mediating variables	3750.3		35.0
Variance between classrooms (level 2 variance)	2126.8	24.5	
After controlling for:			
Student background variables	1926.3		9.4
Student mediating variables	1132.6		46.8
Grade-level and classroom composition variables	418.1		80.3
Classroom teacher variables	360.3		83.1
Variance between schools (level 3 variance)	792.7	9.1	
After controlling for:			
Student background variables	402.1		49.3
Student mediating variables	230.0		71.0
Grade-level and classroom composition variables	128.5		83.8
Classroom teacher variables	127.4		83.9
School-level variables	120.9		84.8

Adding the student mediating variables (word knowledge scores, attitudes towards mathematics) in the next step substantially increased the percentages of explained variance at each level. When achievement is adjusted for the student background and mediating variables the amount of variance explained at the student-level increases to 35 per cent. At the classroom-level the amount of variance explained increased to 46.5 per cent, and at the school level the amount rose to 71.0 per cent. These results suggest that intake characteristics account for most of the variance at the school-level, but also a major part (almost half) of the variance between classrooms.

The next step involved the inclusion of the grade-level and classroom-composition variables—mean word-knowledge, mean SES. It produced substantial increases in the percentage of variance accounted for at the classroom-level. The between-classroom variance explained jumped from 46.8 per cent to 80.3 per cent. At the school-level, the amount of variance explained increased from 71.0 to 83.8 per cent. It shows that much of the variation in maths achievement in TIMSS at the primary school level was linked to the grade-level of a student and to the social and ability composition of the classroom.

Teacher effects would appear to be quite small, at least based on the changes that occur after adding in the available teacher variables—age, sex of the teacher, qualifications, and views on mathematics teaching. This group of variables increased the explained variance at the classroom level by about 3 per cent (from 80.3 to 83.1 per cent). The school-level variables also added little to the explained variances.

Table 4 presents the results for Population 2 (students and classes in secondary schools). The variance components or null model results show that the amount of variance due to differences between classrooms was larger than at the primary school level—27.8 per cent as against 24.5 per cent respectively. The effects of school were also greater (15.2 per cent for secondary schools compared to 9.1 per cent for primary). This suggests that intake factors were less influential in secondary schools than in primary schools, at least in terms of achievement in mathematics. Classroom and school differences were larger in the secondary school sample, a finding that for mathematics achievement ran counter to the results of Hill (1994, p. 4) who found larger effects in the sample of primary school students and classes.

Table 4
Variance in Mathematics Achievement Explained by Three-level HLM models: Population 2, TIMSS

	Variance	Variance between levels	Variance explained at each level
		%	%
Variance within classrooms (level 1 variance)	5129.7	57.0	
After controlling for:			
Student background variables	4698.0		8.4
Student mediating variables	3754.9		26.8
Variance between classrooms (level 2 variance)	2495.8	27.8	
After controlling for:			
Student background variables	2131.0		14.6
Student mediating variables	1371.4		45.1
Grade-level and classroom composition variables	435.2		82.6
Classroom teacher variables	425.7		82.9
Variance between schools (level 3 variance)	1368.1	15.2	
After controlling for:			
Student background variables	761.0		44.4
Student mediating variables	547.5		60.0
Grade-level and classroom composition variables	105.4		92.3
Classroom teacher variables	95.7		93.0
School-level variables	92.8		93.2

The student background and student mediating variables when included in the HLM models did not help explain as much variance among students as they did in the primary school sample. After including both groups of variables, the percentage of variance in mathematics achievement explained at the student-level was 26.8 per cent (about 10 per cent less than for the primary school students). However, the two groups of variables help explain almost half (45.1 per cent) of the variance at the classroom level and 60 per cent of the variance at the school level.

The classroom composition variables used in the models involving the secondary school sample included measures for setting or streaming as well as the measures used for the primary school sample (mean word knowledge, mean SES, year-level). After adjusting for the grade- or year-level and the classroom composition variables, the percentage of variance explained at the classroom level increased almost 40 points—from 45.1 per cent to 82.6 per cent. Variance explained at the school level also increased substantially—from 60 to 92.3 per cent.

These results suggest that the large classroom effects were due mainly to intake factors, year-level and to student grouping practices. Indeed, when the teacher variables were added to the models, there was little change in the percentage of variance explained at the classroom level. The findings support the view that classroom differences in mathematics achievement are largely due to the students in the classrooms rather than their teachers. School-level pupil management practices such as setting or streaming contribute to the classroom effects by shaping classroom composition.

The results also suggest that composition and intake factors account for most of the between-school differences.

Conclusion

The findings from the current work suggest that some of the difference in mathematics achievement between students is indeed at the classroom level. However, this difference is not due mainly to variations in the quality of teachers or teacher effectiveness, but rather to classroom composition and year-level. About a quarter of the variation in mathematics achievement for students in both primary and secondary schools is due to differences between classrooms. Of this variation at the classroom level, over 80 per cent is explained by grade- or year-level and compositional factors such as the mean SES background of students, the mean level of language skills of students, and whether or not the classes are streamed or set.

These findings do not support the view of Hill and his colleagues that it is the differences in quality of teachers and teacher effectiveness that accounts for much of the classroom variation in mathematics achievement. Rather they support an alternative explanation, that the types of pupil grouping practices schools employ shape the classroom learning environments in ways that affect student progress and student achievement, and it is these kinds of differences that more significantly influence classroom effects. By this, it is not suggested that the quality of teachers does not matter or that all teachers have the same effectiveness. Indeed in a further paper using TIMSS results we identify several teacher-related factors that contribute significantly to differences in mathematics achievement (Fullarton & Lamb, 2000). What the TIMSS results suggest simply is that the organisational and compositional features of classrooms have a more marked impact on mathematics achievement.

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