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ABSTRACT

The purpose of this study is to investigate science achievement of Australian students and how this achievement can vary from school to school. The proposition that gender and socioeconomic inequities in Australia are the result of school systems designed to reproduce an unequal social order is be examined with reference both to current sociological literature and methodological techniques which account for the hierarchical nature of students nested in schools. Additionally, student-level and school-level variables are investigated for their ability to explain gender and socioeconomic differences in science achievement, as well as general student variability. Even after adjusting for the students' individual characteristics and home backgrounds, as well as the context of the school, there were significant gender and socioeconomic differences in science achievement across Australian schools. The importance of variability in science achievement between schools is shown in this study, with specific reference to how this variability can be attributed to the school system. Contains 54 references and an appendix that describes student and school level variables. (Author/MDH)

Socioeconomic Effects on Science Achievement: An Australian Perspective

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EDUCATIONAL INEQUALITY IN AUSTRALIA

> *Generalisations about men and women, or boys and girls, including their education, without reference to social class, are as limited as those about the social classes without reference to sex.* *(King, 1987, p. 298)*

The belief in the 1940s that educational inequality is based upon innate differences in the student's own ability and intelligence was prevalent in Australia, despite evidence that the amount of schooling which children receive was closely aligned to the size of their parents' income. At the end of the war, there was an increased demand for more equal educational opportunities, irrespective of social class, accompanied by the growing belief that education was the right of all. However, schools continued to be criticised for giving students from the working classes a different and inferior education and, subsequently, reduced life opportunities. Some pointed to the alignment of Australian schools with the middle classes, while the working classes became more and more distant in terms of style and values. Providing the same education for all social classes implicitly meant that this education was more relevant to the upper classes. The underlying assumption of inequality, that the working classes were deficit, ignored the school system and focused upon the student' s home:

> There wasn't enough ambition, or stimulation, or loving-kindness, or patience, or whatever, in the homes of the lower strata . . . Apart from being insulting, such accounts . . . were conspicuously lopsided. (Connell et al., 1982, p. 26)

In the 1970s, there was a conceptual shift from the inequality/deficit approach to the 'Reproductive Approach' in which schools act as active reproducers of the structure of inequality. That the fault lay with society and the school system, and not with the individual, was a new concept enthusiastically accepted. The problem with the reproductive theory lay with the inability for teachers to bring about any change in the inequities of education and society. The focus on the school system reproducing inequality and inequity had the unfortunate outcome of reinforcing the status quo (Bowles & Gintis, 1976, pp. 102-103; Connell et al., 1981; Connell et al., 1982, pp. 27-28; Kessler et al., 1985).

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> The simplest, and not the silliest, answer to the question 'why educational inequality?' is that the schools are designed to produce it. They are set up to 'sort and sift', to give elite training to the children of the rich, to prepare others for the assembly line, and to legitimate the results. . . . To produce educational inequality is the proper business of schools performing their function of reproducing an unequal social order. (Connell et al., 1982, pp. 189-190)

The role of the Australian school system in establishing gender and social inequity has been examined by recently by Banks who, in a comprehensive analysis of the school effectiveness research (1992a, 1992b), asserted that:

> The school characteristics identified in the literature do have an influence on student performance. However, no characteristic was ever significant [in all settings], an indication that there is no global panacea. . . (Banks, 1992a, p. 203)

Importantly, some schools appeared to be more effective than others and some schools appeared to be more equitable than others. In this study, gender differences and socioeconomic differences in academic achievement were investigated using a multilevel model which separates the variability between schools and within schools. These differences were then adjusted for school and student characteristics which may account for the variability in achievement. The achievement measure in this study was a science test consisting of 46 multiple choice test items from all cognitive and science content areas.

SCHOOL EFFECTIVENESS RESEARCH

In early research, there was considerable emphasis on the ability and family background of the student in determining academic performance. The Coleman Report (Coleman et al., 1966, p. 296) estimated that the percentage of school influence on student achievement was about 10 to 20 percent of the total variance, yet the methodology used by Coleman did not account for the hierarchical nature of students nested in schools. Coleman's findings were repeated in further large-scale studies (Jencks et al., 1972, 1979; Hauser, Sewell & Alwin, 1976), which suggested that (1) school level variables, including physical resources, account for small amounts of variability in student achievement and (2) student characteristics such as socioeconomic status and home background should be used to adjust student achievement in statistical analysis of large-scale studies.

In Britain, research into schools became prominent during the 1980s with Fogelman's findings that the amount of schooling received by students was directly related to their academic achievement (1978, 1983). While early British researchers analysed the effects of academic and social backgrounds of students, there was some doubt about whether control for differences in student intake was adequate (Reynolds, 1976; Reynolds & Sullivan, 1979; Rutter et al., 1979). Reynolds reported large school level differences in attendance rates, even when students came from similar social and economic backgrounds. More recent studies, which included student information prior to school entry and better analytic techniques, reported substantial variations between schools (Mortimore et al., 1988; Smith & Tomlinson, 1989; Nuttall et al., 1989). The improvement of analytical techniques more adequately addresses the hierarchical nature of the data, that is, to separate the variability between schools and within schools (Bryk & Raudenbush, 1986; Goldstein, 1984, 1987).

While early British research by Reynolds (1982) and Rutter et al. (1979) indicated that schools affect students equally, later studies by Aitken and Longford (1986) found significant differences in school effects for students of different socioeconomic backgrounds. Further, Cuttance (1992) reported that school effects were significantly greater for students from more affluent home backgrounds, when compared with students from poorer homes.

The examination of social and gender differences in United States schools has led researchers such as Levine (1992) to recommend that multiple measures of students' social and economic background be used to control for social class influences on achievement. Levine et al. (1979) found that the frequently used US indicator, students' subsidised lunch status, was not useful due to highly variable reporting by principals. Levine also urged that schools be examined for their effectiveness in equalising the academic achievement of minorities and disadvantaged groups. The importance of examining the equity of the school, as well as the school's effectiveness, was advocated by US researchers who found that a school could be identified as highly effective, yet have lower class and minority students with poor academic performance (Brookover, 1985; Shoemaker, 1984; Lezotte, 1986).

STUDENT CHARACTERISTICS

In addition to the finding that home background factors influence a student's academic performance, Young (1991), Young and Fraser (1992a, 1992b) and Keeves and Morgenstern (p. 136-40, 1992) clearly showed that measures of attitude towards science was a useful explanatory variable in the investigation of science achievement. While home background and average school home background are the most powerful factors explaining student academic performance, the aptitude of the student was also a significant predictor of science achievement. Keeves and Kotte (1992, p. 159) describe a causal model for the influence of these student variables on science achievement (Figure 1), which show the relationship between student aptitude and attitude with science achievement.

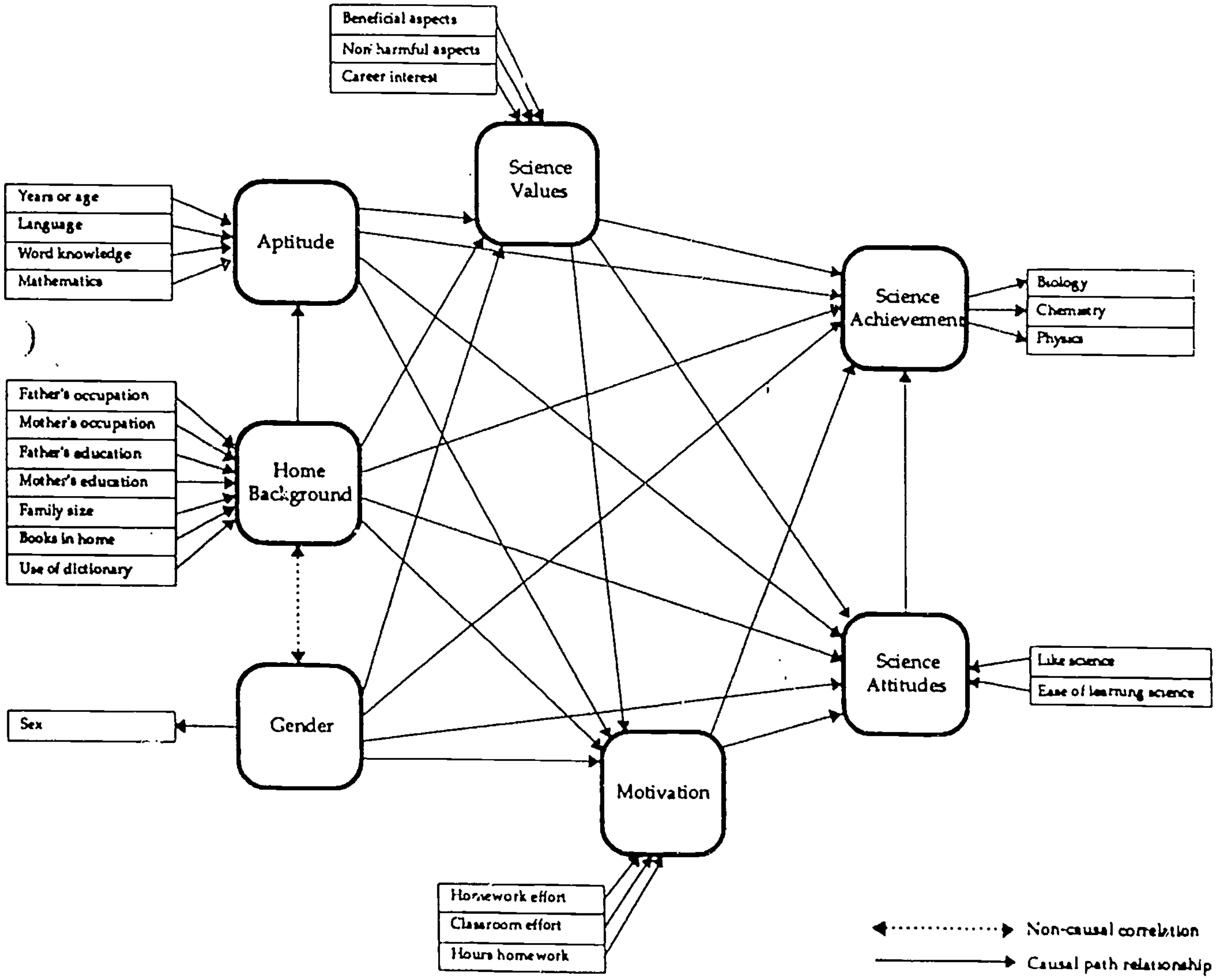

Figure 1. Path model for the effects of gender and attitudes on science achievement.
(Keeves and Kotte, 1992, p. 137)

SCHOOL CHARACTERISTICS

The analysis of student differences in science achievement must take into account variations from school to school unless inferences are to remain doubtful. Raudenbush and Bryk (1986) point out the fallacies of research findings which ignore the potential effects of the school or classroom as sociological units, citing many research studies with doubtful inferences. These researchers introduced the concept of the hierarchical linear model (HLM), which accommodated both school and student level differences. Their reanalysis of data from a random sample of United States high schools illustrates technical and conceptual advances facilitated by HLM and showed that the relationship between socioeconomic status and mathematics achievement varied substantially across US high schools and that much of this variation was attributable to school type (public versus Catholic). Distinguishing between micro parameter variance (such as school or classroom) and the sampling variance was possible with HLM, thus enabling the partitioning of the socioeconomic effect into within- and between-group components which yielded an estimate of the school type effect substantially different from earlier estimates. Similarly, Lee's (1986) reanalysis of data from High School and Beyond study (Coleman et al., 1966; Haertel et al., 1987) revealed that differences between public and Catholic schools were attributable to the curriculum and the discipline policies of the schools.

Raudenbush and Bryk assert that there are two main aspects to modelling school level variables. Firstly, the specification of the ‘compositional’ or ‘contextual’ variables involves the average student background and school composition. Secondly, the specification of the ‘policy’ variables such as school and classroom policies, practices and processes which produce effectiveness (Raudenbush & Bryk, 1989, p. 206). In this study, the school level contextual model will be investigated, along with one policy measure, that is, the amount of practical science learning which takes place in the science classrooms.

RESEARCH QUESTIONS

In the gender and social class literature, the theory that schools reproduce inequity was presented. While this has been examined in US and British studies, there has been little substantive research in Australia. This study sought to investigate the gender and social equity of Australian high schools by investigating the following research questions:

1. Do girls and boys in Australian schools perform differently in science? If so, is this difference explained by socioeconomic factors? Do school characteristics also explain variability in science achievement?
2. Do Australian school students from different socioeconomic backgrounds perform differently in science? If so, can this difference be explained by school level effects?
3. Do students from private Australian schools (Catholic and other independent schools) outperform students from public Australian schools (government schools)? Is the school type (private/public) confounded by the social class of the school? Do these contextual effects explain gender and socioeconomic differences to any extent?
4. Where science is taught using practical or laboratory classes, is the performance of students enhanced? Does practical science teaching affect gender differences in science achievement? Does practical science teaching improve the performance of students from poorer home backgrounds in science achievement?

DESCRIPTION OF SAMPLE

The Second International Science Study sampled students from every Australian state and from three age groups: 10-year-old, 14-year-old and year 12 students (Rosier & Keeves, 1991; Postlethwaite & Wiley, 1992; Keeves, 1992). In this study, the 14-year-old student sample was analysed. While there were 4917 14-year-old students in this sample (2565 girls and 2352 boys) selected from 233 schools, the target population of 14-year-old Australian students consisted of 246,132 students within 2144 schools at the time of this survey (1983/84). The sample design used in this study was a stratified two-stage cluster design, with schools selected randomly from within each of 24 strata (the eight Australian states and territories and the three school types: government, Catholic and independent) and approximately 20 students selected randomly from within each school. This complex sample design meant that the normal assumptions of simple random sampling could not be made if statistical significance was to be tested in a valid manner. For this reason, a multilevel model was developed which accounted for the nested nature of the data. In addition, student data from each strata was weighted according to the proportion of students being represented.

The range of variables available in the SISS from which selection could be made included school resources and environment, teacher and student characteristics and opinions. For the 14-year-old student population, there were more than 350 separate student variables to choose from. The magnitude of this database has provided educational researchers with a remarkable opportunity to examine science education in Australia.

VARIABLES

While the authors acknowledge that science achievement tests are not the only measures of student performance in schools, this report leaves other measures such as attitudes and motivation for future discussions. In this study, the outcome measure was science achievement. This measure consisted of 46 multiple choice science test items. This measure of science achievement is only one type of assessment in science, yet it is used predominantly in many countries as the sole measure of student performance. Student background variables included sex of the student, attitude towards science, ethnicity of the student (constructed from 2 variables: country of birth and language spoken at home), verbal ability, quantitative ability, socioeconomic status and prior ability (usual marks in science). At the school level, contextual variables investigated in the analysis of science achievement were the size of the population in the local school area and the school type (private/public). Additionally, the composition of the school student body was examined. Two compositional measures used in this study were average socioeconomic status and average mathematical ability. Finally, a classroom process measure was analysed for its ability to reduce gender and socioeconomic differences in science achievement. This measure was average practical science learning reported by students sampled in each school.

Table 1. Description of Variables

Type of Indicator	*Variable Description*	*Variable Name*
School	Size of population of school area	areapopn
	School type	schtyp
	Average socioeconomic status	avses
	Average maths ability	avmaths
	Average practical science	avprac
Student	Science achievement	science
	Gender (sex)	sex
	Socioeconomic status	ses
	Attitude towards science	enjsci
	Ethnicity (home language)	ethnty
	Verbal ability	tot2v
	Quantitative ability (maths)	tot2q
	Prior ability - marks in science	marksci

METHODOLOGY

The Hierarchical Linear Model

The use of powerful computers to analyse large databases during the First International Mathematics Study focused on the home and school variables influencing student achievement, while using the student as the unit of analysis (Husén, 1967). However, this type of analysis did not adequately address the variability of schools contributing to statistical tests of significance. Studies in the United States tried to compensate for this problem by only looking at the school differences; for example, Coleman et al. (1966) used the school as the unit of analysis. Further, a large database was analysed by Peaker (1967) in England by examination of between-school means (aggregated student data) and pooling between students. However, these studies ignored the differences between students within-schools which can contribute towards explaining the variance.

The controversy over the most appropriate unit of analysis has continued until the importance of a different approach to educational research was first proposed by Cronbach:

> The majority of studies of educational effects – whether classroom experiments, or evaluations of programs, or surveys – have collected and analysed data in ways that conceal more than they reveal. The established methods have generated false conclusions in many studies. (Cronbach, 1976, p. 1)

Most educational research revolves around students who receive schooling in classrooms located within schools, within school districts, within states, etc. The grouping of students, classes and schools occurs in a hierarchical order with each group influencing the members of the group in thought and behaviour. The nature of these hierarchical structures produces multilevel data. Theories about the effects of the multilevel structure of education (the different levels of the educational hierarchy) should lead to attempts to specify models which involve the analysis of multilevel educational data. Burstein (1980) believes that these theories eventually will replace experimental design and analysis with the natural design and analyses that evolve from the multilevel structure of data.

The amount of variation in estimates of variables affecting academic achievement across different levels of analysis cannot be ignored by serious educational researchers. In particular, the socioeconomic status of the student and of the school have been shown to consistently account for a large amount of variation in achievement both between students and between schools.

Traditional linear models on which most researchers rely require the assumption that errors are independent, yet most subjects are 'nested' within classrooms, schools, districts, states and countries so that responses within groups are group dependent. To ignore the nested structure of this type of data ultimately will give rise to problems of aggregation bias (within-group homogeneity) and imprecision (Raudenbush, 1988).

This Hierarchical Linear Model (HLM) provides an integrated strategy for handling problems such as aggregation bias in standard error estimates and erroneous probability values in hypothesis testing of school effects. For this study, HLM was chosen as the model most appropriate to study school and student effects relating to science achievement, and HLM2 (Bryk, Raudenbush, Seltzer & Congdon, 1989) was selected as the computer package most suited to analyse the large amount of data in SISS. The use of the HLM in order to investigate the influence of the organisational structure of the school on student performance has been documented by Bryk and Raudenbush (1989, pp. 159-204), Lee and Bryk (1989) and Raudenbush and Bryk (1986). The present study sought to examine the role of school effects in explaining student differences in science achievement. Research on school effects has been conducted with a set of data analysed at the individual student level, with the assumption that classrooms and schools affect students equally. However, when the effects vary among individuals and their contexts, this type of statistical analysis can be misleading (Bryk & Raudenbush, 1987). Ordinary least squares analysis provides information about the total variance, but does not break this total variance into the between- and within-classroom effects. This study endeavoured to explain variations in student outcomes by first decomposing observed relationships into between- and within-school components.

Rasch Analysis

In addition to using hierarchical modelling analytic techniques, this study also incorporated the Rasch analysis model for the construction of the science achievement scale (Rasch, 1960). The importance of Rasch analysis was the capacity for all 46 science test items to be included in the analysis (whether the items were rotated between students or common core test items), thus maximising scale reliability. The 46 science test items consisted of 20 common core test items answered by all students and 26 rotated test items responded to by different subgroups of students. The purpose of the Rasch analysis was to make the science achievement scores independent of the sample and the item difficulty; some of the rotated test items may have been more difficult than others. The science test items also represented biology (20 items), chemistry (12 items) and physics (14 items) content areas. For each student in this study, 46 science achievement items were selected from the SISS databases and a Rasch calibration produced a single measure incorporating all 46 items. The calibration was made using TITAN (Adams & Khoo, 1991), a Rasch analysis computer software package for calibrating items which are independent of student ability and item difficulty (this software package has now been renamed QUEST).

RESULTS AND DISCUSSION

The Unconditional Model

The partitioning of variance in science achievement among students into the within- and between-school components was achieved using the HLM2 computer package (Bryk, Raudenbush, Seltzer & Congdon, 1989). A random average science achievement estimate was specified for the within-school model:

$$Science_{ij} = \beta_{0j} + R_{ij} \qquad \text{Equation 1}$$

where $i = 1, \ldots, nj$ students in school j, $j = 1, \ldots, J$ schools, $Science_{ij}$ represents science achievement of student i in school j, β_{0j} represents the mean science achievement for students in school j and R_{ij} represents random error of student i in school j. At the school level, the school mean science achievement is a function of the grand mean, γ_{00}, with random error, μ_{0j}:

$$\beta_{0j} = \gamma_{00} + \mu_{0j} \qquad \text{Equation 2}$$

The grand mean in this analysis is estimated to be 0.768 with a standard error of 0.032. The 95% confidence interval for the grand mean is:

$$\begin{aligned} &= 0.768 \pm (1.96)(0.032) \\ &= 0.768 \pm 0.063 \\ &= (0.705,\ 0.831) \end{aligned}$$

In the analysis of this random model, the variance in science achievement was found to be 16 percent at the school level ($\hat{\tau}_{00} \approx 0.191$), while 84 percent of the variance was related to student level differences ($\hat{\sigma}^2 \approx 1.002$); these estimates indicate that most of the variation in the outcome is at the student level, although a substantial proportion is between schools. The intra-class correlation, that is the proportion of variance in science achievement between schools, is estimated by substituting the estimated variance components:

$$\begin{aligned} \hat{\rho} &= \hat{\tau}_{00}/(\hat{\tau}_{00} + \hat{\sigma}^2) \\ &\approx 0.191/(0.191 + 1.002) \\ &\approx 0.16 \end{aligned}$$

The estimated reliability of the mean science achievement of students in a school was found to be 0.98 by the following calculation:

$$\begin{aligned}\hat{\lambda} &= \hat{\tau}_{00}/[\hat{\tau}_{00} + (\hat{\sigma}^2/n_j)] \\ &\approx 0.191/[0.191 + (1.002/233)] \\ &\approx 0.98\end{aligned}$$

This indicated that the sample means tended to be very reliable as indicators of the true school means. Table 2 also shows that the school level variability has a significantly large χ^2 distribution (1154.3) with 232 degrees of freedom, indicating that there is significant school level variation.

Table 2. One-Way ANOVA Model of Science Achievement

Fixed Effect	*Coefficient*	*Standard Error*
Average school mean, γ_{00}	0.768	0.032

Random Effect	*Variance Component*	*df*	χ^2	*p value*
School mean, μ_{0j}	0.191	232	1154.3	0.000
Level-1 effect, r_{ij}	1.002			

Conditional Model: Student Characteristics

In order to examine how science achievement varied from school to school, along with how gender differences and social differences in science achievement varied from school to school, a random-coefficient regression model was used. In addition, each covariate was centred around its respective school mean, with the intercept, β_{0j}, now the adjusted mean outcome in school j after controlling for student background differences. The estimation of science achievement involved the following coefficient regression model, with fixed covariates and randomly varying intercept:

$$\begin{aligned} \text{Science}_{ij} = {} & \beta_{0j} + \beta_{1j}(\text{Sex}_{ij} - \bar{X}_{sex.j}) + \beta_{2j}(\text{Ses}_{ij} - \bar{X}_{ses.j}) + \\ & \beta_{3j}(\text{Enjsci}_{ij} - \bar{X}_{enjsci.j}) + \beta_{4j}(\text{Ethnty}_{ij} - \bar{X}_{ethnty.j}) + \\ & \beta_{5j}(\text{Verb}_{ij} - \bar{X}_{verb.j}) + \beta_{6j}(\text{Math}_{ij} - \bar{X}_{math.j}) + \\ & \beta_{7j}(\text{Marks}_{ij} - \bar{X}_{marks.j}) + r_{ij} \end{aligned}$$

$$\begin{aligned} \beta_{0j} &= \gamma_{00} + \mu_{0j} \\ \beta_{1j} &= \gamma_{10} + \mu_{1j} \\ \beta_{2j} &= \gamma_{20} + \mu_{2j} \\ \beta_{3j} &= \gamma_{30} \\ \beta_{4j} &= \gamma_{40} \\ \beta_{5j} &= \gamma_{50} \\ \beta_{6j} &= \gamma_{60} \\ \beta_{7j} &= \gamma_{70} \end{aligned}$$

Equation 3

where *Science* represents student science achievement (an ability estimate ranging from -4 to +4), *Sex* represents sex of the student (1 for males and 0 for females), *Ses* represents socioeconomic status of the student (a measure of socioeconomic status consisting of parents' educational background and occupation), *Enjsci* represents the student's attitude towards the science, *Ethnty* represents the student's ethnic background (a combination variable measuring English spoken at home and country of birth being white Anglo-saxon origin), *Verb* represents the verbal ability of the student and *Math* represents the quantitative ability of the student and *Marks* represents the science marks usually attained by the student, or prior ability of science.

Each school's distribution of science achievement was characterised by the parameters: the intercept, β_{0j}, and the slopes, β_{1j} and β_{2j}. Preliminary analysis of a completely random model determined that variability of the other slopes was negligible, so these covariates were kept fixed. In this analysis, science achievement was centred around the school mean, so that the intercept, β_{0j}, was the expected outcome for a student whose has a value on X_{ij} equal to the school-mean, $\bar{X}_{j.}$.

The random slopes are described as follows:

β_{0j} is the mean science achievement for students in school *j* after controlling for student background; and
β_{1j} is the expected gender differences in science achievement in school j; and
β_{2j} is the expected socioeconomic differences in science achievement among students in school j; and
β_{3j} is the fixed effect of student attitude towards science; and
β_{4j} is the fixed effect of student's ethnic background; and
β_{5j} is the fixed effect of student verbal ability; and
β_{6j} is the fixed effect of student maths ability; and
β_{7j} is the fixed effect of student prior ability in science, that is, science marks.

A model of science achievement should have a high mean science achievement, large positive β_{0j}. That is the overall grand mean science achievement should be high. A gender equitable model should result in a small gender gap, that is a small negative β_{1j}. If social equity is desirable, then it is hoped that the science achievement of students from poorer backgrounds is similar in distribution to students from more affluent backgrounds and that students from ethnic backgrounds attain similar scores when compared with students from white Anglo-saxon backgrounds. This equity would result in weak differentiating socioeconomic and ethnic effects, that is small positive β_{2j} and β_{4j}.

Table 3. Random Coefficient Regression Model of
Gender and Social Distribution of Science Achievement

Fixed Effect	*Coefficient*	*Standard Error*	*t ratio*
Average school mean, β_0	0.766	0.032	23.858
Gender, β_1	0.267	0.028	9.391
Socioeconomic status, β_2	0.280	0.030	9.404
Attitude towardsscience, β_3	0.223	0.032	7.069
Ethnicity, β_4	-0.149	0.051	-2.909
Verbal ability, β_5	0.040	0.002	17.024
Quantitative ability, β_6	0.121	0.004	31.610
Science marks, β_7	0.209	0.021	10.084

Estimation of Variance Components

Random Effect	*Variance Component*	*df*	χ^2	*p value*
Intercept slope	0.21307	199	1616.8	0.000
Sex slope	0.03720	199	258.86	0.003
Sel slope	0.00064	199	271.14	0.001
Level-1 rij	0.55582			

Parameter Reliability Estimates:

Interecept = 0.886
Sex = 0.190
Sel = 0.185

The results are presented in Table 3, showing that the average school achievement was estimated as 0.766, and the average gender gap was 0.267 points. This means that male students were scoring 0.267 points on average ahead of female students with similar backgrounds. Student socioeconomic status was positively related to science achievement (β_{2j}=0.280), while ethnicity was negative and weakly related to science achievement (β_{4j}=-0.149). This means that students from higher social classes, as indicated by their parents' education and occupation, and of Anglo-saxon English speaking backgrounds tended to have higher science achievement, although there was a much weaker slope for ethnicity than socioeconomic status.

The estimated variances of the random effects at student and school levels are also reported in Table 3. The Level-1 variance was reduced from 1.002 in the random effects ANOVA model to 0.556, after adjusting for gender, ethnicity, socioeconomic status and other student background effects. The proportion of variance explained by this Level-1 model is:

$$(1.002 - 0.556)/1.002 = 0.445$$

The homogeneity of variability in the gender differences in science achievement across schools was significant, as was the social distribution of achievement. These covariates were allowed to remain random in further analyses of school effects. While all of the Level-1 predictors had a significant relationship with science achievement to retain them as fixed effects (as indicated by their fixed effect estimates, standard errors and t ratios), gender and socioeconomic status covariates were allowed to remain random in further analyses of school effects, as indicated by their large and significant chi-squared tests of homogeneity.

Contextual Model: School Effects and Equity

In order to examine the influence of organisational effects on equitable science achievement in Australian schools, an explanatory model was developed, similar to the model proposed by Lee and Bryk (1989). Equitable science achievement at will be measured in this study in terms of the degree to which gender and socioeconomic differences vary from school to school. The model used examined social and gender equity simultaneously by allowing both of these to vary across schools in the random coefficient regression model, while keeping the other covariates fixed.

The combined effects of school typ (often referred to as sector) and context were investigated in this analysis, in order to explain the social distribution of achievement in public and private schools. The school context was measured by the size of the population in the immediate area, the average socioeconomic status and average mathematical ability of students attending the school.

While the original Level-1 model from Equation 3 was retained for the purposes of this investigation, the following Level-2 model was incorporated in order to examine the school effects on equity of science achievement (only β_{0j}, β_{1j} and β_{2j} were allowed to vary across schools with the rest of the slopes kept fixed):

$$
\begin{aligned}
\beta_{0j} &= \gamma_{00} + \gamma_{01}\mathrm{Area}_j + \gamma_{02}\mathrm{Schtyp}_j + \gamma_{03}\mathrm{Avses}_j + \gamma_{04}\mathrm{Avmaths}_j + \mu_{0j} \\
\beta_{1j} &= \gamma_{10} + \gamma_{11}\mathrm{Schtyp}_j + \gamma_{12}\mathrm{Avses}_j + \mu_{1j} \\
\beta_{2j} &= \gamma_{20} + \gamma_{21}\mathrm{Schtyp}_j + \gamma_{22}\mathrm{Avses}_j + \mu_{2j} \\
\beta_{3j} &= \gamma_{30} \\
\beta_{4j} &= \gamma_{40} \\
\beta_{5j} &= \gamma_{50} \\
\beta_{6j} &= \gamma_{60} \\
\beta_{7j} &= \gamma_{70} \qquad \text{Equation 4}
\end{aligned}
$$

For the HLM analysis using the model specified in equation 2, the estimated coefficients are reported in Table 4 and discussed in the following sections.

Table 4. Estimated Effects of School Type and Context

Fixed Effect	*Coefficient*	*Standard Error*	*t ratio*
Mean science achievement, γ_{00}	-1.361	0.190	-7.153*
Areapopulation, γ_{01}	-0.036	0.015	-2.359*
School type, γ_{02}	0.033	0.050	0.649
Average socioeconomic status, γ_{03}	0.506	0.092	5.506*
Average maths ability, γ_{04}	0.165	0.014	12.242*
Gender slope, γ_{10}	0.284	0.032	8.869*
School type, γ_{11}	-0.144	0.087	-1.662*
Average socioeconomic status, γ_{12}	0.073	0.128	0.566
Socioeconomic status slope, γ_{20}	0.288	0.036	7.966*
School type, γ_{21}	-0.007	0.076	-0.095
Average socioeconomic status, γ_{22}	-0.070	0.128	-0.547
Attitude towards science slope, β_{30}	0.225	0.032	7.122*
Ethnicity slope, β_{40}	-0.145	0.051	-2.829*
Verbal ability slope, β_{50}	0.040	0.002	17.054*
Quantitative ability slope, β_{60}	0.120	0.004	31.354*
Prior ability slope, β_{70}	0.207	0.021	10.035*

Random Effect	*Variance Component*	*df*	χ^2	*p value*
Intercept slope	0.05293	195	549.09	0.001
Gender slope	0.03500	197	254.74	0.004
SES slope	0.00066	199	271.07	0.001
Level-1 rij	0.55671			

Parameter Reliability Estimates:

Base = 0.658
Gender = 0.181
SES = 0.188

School Science Achievement. The average socioeconomic status of students attending the school was strongly and positively related to school mean science achievement ($\hat{\gamma}_{03}$ = 0.506, t = 5.506), while the school type had negligible effect. This means that students from more affluent backgrounds tended to have higher scores, irrespective of whether the school was public or private. The estimate of the slope for average mathematical ability of students in the school was also a positive effect, indicating that, where peer ability was high in mathematics, the student was likely to have higher achievement in science $\hat{\gamma}_{04}$ = 0.165, t =12.242). The size of the population in the area surrounding the school appeared to negatively affect the science achievement of students in the school, although the effect was weak $\hat{\gamma}_{01}$ = -0.036, t = -2.359). That is, students attending schools in smaller populated areas tended to outperform students attending schools located in more densely populated areas.

Gender Gap. The proposition that gender differences in science achievement are determined by school characteristics and socialisation was examined in this study by investigating how gender differences in school means varied from school to school. In this analysis, gender differences in science achievement were found to vary across schools, with boys outperforming girls by 0.284 points on average. Of particular importance, was the proposition that gender differences varied with school type and social status of the school.

In order to examine the gender gap for private and public schools, the difference in science achievement was calculated by substituting the group mean centred gender code (male = 0.5, female = -0.5, mean = 0), school type codes (private = 1; public = 0) and average socioeconomic status (high = 1, low = -1) into the regression equation described in Table 4:

$$\begin{aligned}
\mathrm{Science}_{ij} &= \beta_{0j} + \beta_{1j}(\mathrm{Sex}_{ij} - \bar{X}_{sex.j}) + \beta_{2j}(\mathrm{Ses}_{ij} - \bar{X}_{ses.j}) \\
\beta_{0j} &= \gamma_{00} + \gamma_{01}\mathrm{Area}_j + \gamma_{02}\mathrm{Schtyp}_j + \gamma_{03}\mathrm{Avses}_j + \gamma_{04}\mathrm{Avmaths}_j + \mu_{0j} \\
\beta_{1j} &= \gamma_{10} + \gamma_{11}\mathrm{Schtyp}_j + \gamma_{12}\mathrm{Avses}_j + \mu_{1j} \\
\beta_{2j} &= \gamma_{20} + \gamma_{21}\mathrm{Schtyp}_j + \gamma_{22}\mathrm{Avses}_j + \mu_{2j}
\end{aligned}$$

$$\begin{aligned}
\mathrm{Science}_{ij} = {} & (-1.361 - 0.04\mathrm{Area} + 0.03\mathrm{Schtyp} + 0.51\mathrm{Avses} + 0.17\mathrm{Avmath} + \\
& 0.05) + (0.28 - 0.14\mathrm{Schtyp} + 0.07\mathrm{Avses} + 0.04)(\mathrm{Sex}) + \\
& (0.29 - 0.01\mathrm{Schtyp} - 0.07\mathrm{Avses})(\mathrm{Ses}) + 0.56
\end{aligned}$$

$$\begin{aligned}
\mathrm{Science}_{ijgap} &= \mathrm{Science}_{ijMale} - \mathrm{Science}_{ijFemale} \\
&= [(0.28 - 0.14\mathrm{Schtyp} + 0.07\mathrm{Avses} + 0.04)(0.5)] \\
&\quad - [(0.28 - 0.14\mathrm{Schtyp} + 0.07\mathrm{Avses} + 0.04)(-0.5)]
\end{aligned}$$

Gender gap in private schools (school type = 1):
$\mathrm{Science}_{ijgap} = 0.18 + 0.07\mathrm{Avses}$

Gender gap in public schools (school type = 0):
$\mathrm{Science}_{ijgap} = 0.32 + 0.07\mathrm{Avses}$

Table 5. Comparison of Gender Differences in Science Achievement
By School Type and Socioeconomic Status of the School

School Type and Average SES	Adjusted Mean	Male Mean	Female Mean	Gender Gap
Private/high average socioeconomic schools:	-0.21	-0.09	-0.34	0.25
Private/low average socioeconomic schools:	-1.23	-1.18	-1.29	0.11
Public/high average socioeconomic schools:	-0.24	-0.07	-0.42	0.35
Public/low average socioeconomic schools:	-1.26	-1.16	-1.37	0.21

Note: High SES coded +1 and Low SES coded -1

While the gender gap was greater in more affluent schools, it can readily be seen that the mean science achievement was also higher (Table 5). So, although students obtained more equitable science achievement scores in the poorer schools, they also attained lower scores. The implications here are that girls would be advantaged by attending a more affluent school, but the boys would be even more advantaged. Caution should be exercised when advocating equity at the expense of enhanced performance. While the gender gap was smaller for the poorer schools, girls attending high SES schools appeared to attain higher scores than girls attending low SES schools.

Socioeconomic Differentiation. The socioeconomic differences in science achievement is often purported to be jointly influenced by school type and average socioeconomic status of students attending the school. In previously published research (Young, 1993), the effect of school type was negligible on science achievement when compared with the effect of the social class of the school. In the present study, the estimated effect of the average socioeconomic status on science achievement was large and positive ($\hat{\gamma}_{03} = 0.506$, $t = 5.506$), indicating that students attending schools in more affluent areas tended to outperform students from poorer schools. Additionally, the Level-1 SES slope was large and positive showing that students from more affluent home backgrounds had higher scores than students from poorer homes ($\hat{\gamma}_{20} = 0.288$, $t = 7.966$). This student effect was not influenced by the social class of the school or the type of school ($\hat{\gamma}_{21}$ and $\hat{\gamma}_{22}$ were small and nonsignificant).

Practical science and equity

The increased use of laboratory classes and practical science in order to teach science more effectively is often purported to enhance student achievement and reduce gender and socioeconomic differences in science achievement. In order to examine the effect of this school process variable, practical science, on student achievement, the reported amount of practical science learning in science classes was aggregated to the school level. The contextual model was then analysed with the inclusion of the average practical science learning in the school. Table 6 shows that, when average practical science learning was tested both at the intercept and on the gender and SES slopes, there was a strong and negative effect on the SES slope ($\hat{\gamma}_{23} = -0.788$, $t = -2.119$).

CONCLUSIONS

This analysis of the Australian student database, the Second International Science Study (SISS), established the relative importance of school-level and student-level variables in explaining student differences in science achievement. A combination of Rasch analysis and the hierarchical linear model (HLM) was used to demonstrate the relationship between contextual and process school factors and student achievement and how they are inextricably woven into the student's own characteristics. While some school effects were more useful than others in explaining student differences in science achievement, aggregated student level variables cannot be ignored.

While most of the unexplained variance was at the student level, student variables particularly reduced this almost by half. Student characteristics found to explain 44.5% of the variance between students included: sex of the student, attitude towards science, ethnicity, verbal ability, quantitative ability and socioeconomic status.

Similarly, the portion of school-level unexplained variance was significantly reduced by the school-level variables, population of the area, school type, average socioeconomic status and average maths ability. These variables accounted for 75% of the differences between school means.

The implications here that girls would be advantaged by attending a more affluent school, should be tempered by the observation that the gender gap was smaller for the poorer schools. Similarly, students from poorer homes were significantly advantaged by having a greater degree of practical science, while students from more affluent homes were significantly disadvantaged.

Table 6. Estimated Effects of Practical Science Learning on Science Achievement

Fixed Effect	*Coefficient*	*Standard Error*	*t ratio*
Mean science achievement, γ_{00}	-1.326	0.235	-5.632*
Areapopulation, γ_{01}	-0.037	0.016	-2.369*
School type, γ_{02}	0.035	0.051	0.677
Average socioeconomic status, γ_{03}	0.506	0.093	5.482*
Average maths ability, γ_{04}	0.166	0.014	12.015*
Average practical science, γ_{05}	-0.054	0.235	-0.231
Gender slope, γ_{10}	0.332	0.249	1.331
School type, γ_{11}	-0.143	0.088	-1.612*
Average socioeconomic status, γ_{12}	0.080	0.133	0.604
Average practical science, γ_{13}	-0.067	0.351	-0.191
Socioeconomic status slope, γ_{20}	0.842	0.264	3.188*
School type, γ_{21}	0.022	0.077	0.284
Average socioeconomic status, γ_{22}	-0.006	0.131	-0.048
Average practical science, γ_{23}	-0.783	0.372	-2.119*
Attitude science slope, β_{30}	0.226	0.032	7.138*
Ethnicity slope, β_{40}	-0.145	0.051	-2.842*
Verbal ability slope, β_{50}	0.040	0.002	17.025*
Quantitative ability slope, β_{60}	0.121	0.004	31.441*
Prior ability slope, β_{70}	0.207	0.021	9.989*

Random Effect	*Variance Component*	*df*	χ^2	*p value*
Intercept slope	0.05330	194	549.99	0.000
Gender slope	0.03574	196	254.96	0.003
SES slope	0.00065	199	271.08	0.001
Level-1 rij	0.55634			

Parameter Reliability Estimates:

Base = 0.660
Gender = 0.184
SES = 0.187

In summary, while specific school characteristics were notably influential, they appeared relatively weak in comparison to the student's own personal characteristics and the characteristics of the student's own peers. However, the gender gap varied significantly across schools indicating that, even when adjusting the gap for school type and average socioeconomic status of the school, there were some school level effects which could either enhance or reduce this gap. The ability of a school to reduce the gender differences would seem possible, yet dependent upon the school's ability to alter its own characteristics - this is not always possible. Additionally, while there were small variations in socioeconomic differences across schools, the effect was strong at the student level. This indicated that students from affluent homes outperformed students from poorer homes and that this gap did not vary significantly across schools.

Although the present study is basically a preliminary one, further path analysis and use of the hierarchical linear model for all 23 countries participating in the SISS is likely to provide useful information regarding the relationship between student achievement, attitudes towards science and other home and school environment characteristics.

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APPENDIX

DESCRIPTION OF STUDENT AND SCHOOL LEVEL VARIABLES

Student Level Variables		*Codes*
Science	Science achievement score calibrated for student ability and item difficulty using the Rasch model - 46 multiple-choice items	
Sex	Sex of student	1 = Male 0 = Female
Enjsci	Attitude towards science scale - 16 items	1 = agree 0 = disagree or not sure
Ethnty	Ethnicity composite scale - home language	1 = English 0 = not English
	- student's country of birth	1 = Australia, UK, Ireland, USA, Canada, New Zealand 0 = Europe, Asia, South America, Central America, Africa, Oceania
Tot2v	Verbal ability	
Tot2q	Quantitative ability	
Ses	Socioeconomic status composite scale - father's education & occupation - mother's education & occupation - number of books in the home	

School Level Variables		*Codes*
Schtyp	School type - government or Catholic/independent	1 = Private (I, C) 0 = Public (G)
Areapopn	Approximate population of the area where your school is located	
Avses	Average socioeconomic status of students attending the school - aggregated variable from student Ses	
Averb	Average verbal ability of students attending the school - aggregated variable from student Tot2v	
Avmath	Average quantitative ability of students attending the school - aggregated variable from student Tot2q	