THE RELATIONSHIP BETWEEN TEACHER QUALIFICATIONS AND CHEMISTRY ACHIEVEMENT IN THE CONTEXT OF OTHER STUDENT AND TEACHER/SCHOOL VARIABLES: APPLICATION OF HIERARCHICAL LINEAR MODELLING

ROBERT B. GARDINER

0-612-42384-0

The Relationship Between Teacher Qualifications and Chemistry Achievement in the Context of Other Student and Teacher/School Variables: Application of Hierarchical Linear Modelling

Robert B. Gardiner B.Sc., B.Ed.

A thesis submitted to the school of Graduate Studies in partial fulfilment of the requirements for the degree of Master of Education

Faculty of Education

Memorial University of Newfoundland

1998

Abstract

The subject matter knowledge required of teachers to teach various courses is sometimes a contentious issue with both teachers and students. This study attempts to determine the relationship between teacher chemistry subject matter knowledge, as well as general qualifications, and student achievement in a common criterion referenced test.

Chemistry achievement of 2453 level 2 and 3 (Grade 11 and 12) students being taught by 97 teachers were analyzed in relation to various student-level and teacher/school-level variables to determine the relative importance teacher qualifications had on chemistry achievement, in the context of these other factors. The use of Hierarchical Linear Models (HLM) showed that student-level measures, in particular prior achievement, accounted for the most of the variance in students' achievement. Other student-level variables related to chemistry achievement were the grade level of the student, gender, and the number of science courses completed by the student (a measure of aptitude).

The inclusion of teacher/school-level variables had a minimal effect in accounting for the between-school variance. Of the fifteen teacher/school level variables used the only two that showed any relation to chemistry achievement were class size and teacher stability.

Acknowledgements

In the completion of this thesis, the first person I would like to thank is Dr. Bob Crocker. Since first meeting with Dr. Crocker, he has certainly given freely of his time. This thesis would certainly not have been fully realized without his invaluable. expertise.advice. and direction.

Secondly, I would like to thank my wife, Mary, and children, Rachel and Ariel. Mary. for having faith in me, and giving me the strength to finish, and Rachel and Ariel, for understanding that their father had "university work" to do for two summers.

Table of Contents

Table of Contents (con't)

List of Tables

List of Figures

CHAPTER 1

INTRODUCTION

The educational process comprises many levels of involvement. At the provincial level, the extent of responsibility ranges from the Department of Education to the actual classroom. As significant as the upper levels of this hierarchy are, what happens in the classroom is of paramount importance to student achievement and the ultimate success of any education system. In keeping with this assertion, the focus of this study was on the knowledge base that teachers bring with them into the classroom and its effect on student achievement.

What are the qualifications required to teach? More specifically, what are the qualifications required to teach specific subjects? Common sense would seem to dictate that a teacher with no science background, would not be expected to teach a high school chemistry course. However, it would also seem plausible that a PhD. in chemistry would not be required.

This study was conducted in an educational system (the Province of Newfoundland) which is characterized by many small schools. There are thus many occasions where a teacher is required to teach a subject with which the teacher may not be comfortable or may not be "qualified" to teach. In a small school a teacher is often required to teach a wide variety of subjects. In high school science, there is often an overlap of science courses taught by individual teachers. A "science teacher" is often called upon to teach a science course in which he or she may have a limited background. Does this lack of subject matter knowledge have an effect on the achievement of the students in these cases? With the downsizing of the education system, due to decreasing enrolment, and clauses in collective agreements pertaining to seniority and lay-offs, this may become an even more relevant issue in the near future.

This study attempts to further clarify the role a teacher's knowledge base, particularly subject matter knowledge, has on the academic achievement of students.

Newfoundland High School System

The Newfoundland high school system is comprised of Level I to III, corresponding to what is normally known as grade 10 to 12. A student must receive a minimum of 36 high school credits to graduate and of these there must be a minimum of 4 science credits and 4 mathematics credits. Students select their courses based on interest and/or ability or the availability of courses. In some smaller schools certain science courses and advanced mathematics may not be offered.

The academic science courses offered are Earth Science/Geology, Biology, Chemistry, and Physics. There are two courses in each science area and each course has a value of two credits toward graduation. For example the Physics courses are Physics 2204 and 3204, the Chemistry courses are Chemistry 2202 and 3202. Students would normally complete the first course in a specific subject before doing the second, however this is not always required. On occasion a student entering Level III may chose to attempt the second level course without completing the first level. Chemistry is the only science course where the first course must be successfully completed before attempting the second. There are three mathematics streams; general, academic, and advanced. The academic stream would consist of Math 1300, 2203, and 3203. The advanced stream would consist of Math 1201, 2201, and 3201. The decision to select either academic or advanced mathematics would again be based on ability and/or interest.

Until 1995 the evaluation for the Level III science and mathematics courses, as well as other academic courses, was based on a shared evaluation in which the students received half their final mark based on school evaluation and the other half based on a common final examination, referred to as a "Public Exam". The public exams were criterion referenced tests made up by three teachers who were teaching the course in question the year the test is administered. It was then validated by other teachers currently teaching the course. To ensure consistency, this research will only use the public exam mark as a measure of student achievement, the dependent variable. The decision to use just the public exam mark, as opposed to the shared evaluation mark, was primarily based on a desire for uniformity in grading. It is realized however that this form of evaluation has its limitations in reflecting student learning. Certain aspects of the curriculum, such as higher level concepts and laboratory work may be better evaluated by the individual teacher.

An Educational Productivity Model

It is commonly recognized that student achievement is influenced by a variety of factors. It would be much too simple a premise to assume the knowledge base a teacher brings into a classroom is the ultimate determining factor in the success of the students. The knowledge base is obviously just one component of a very intricate web of factors. The research presented here will reflect a nine-factor productivity model developed by Walberg and colleagues (Fraser, Walberg, Welch & Hattie, 1987; Wang, Haertel, & Walberg, 1990, 1993). Given Walberg's contribution to the development of the model, this study will continue to refer to the model as Walberg's model. The model was devised to include only those factors that were determined to have the greatest influence on student learning. This allows for the recognition of the complexity of human learning, while at the same time maintaining a manageable number of factors. The nine factors included in Walberg's model are; ability, development, motivation, quantity and quality of instruction, home environment, classroom or school environment, peer group environment, and mass media environment. The development of the model, the model itself, as well as the research base for the model will be discussed in more detail in the literature review.

Teacher Knowledge Base

The role of the teacher permeates Walberg's model, particularly with respect to quality of instruction. It is the purpose of this study to determine the effect a teacher knowledge base has on this quality of instruction and more particularly it's effect on student academic achievement.

A teacher knowledge base incorporates many different components. Shulman (1986a; 1986b) has proposed that a teacher's content knowledge base encompasses three domains; subject matter content knowledge, pedagogical content knowledge, and curriculum knowledge. Subject matter content knowledge involves the knowledge of concepts and principles of the subject area as well as an understanding as to how knowledge in the discipline evolves. This type of knowledge should be obtained in an undergraduate degree program specific to that subject. In its simplest form, pedagogical content knowledge can be considered to be the fusion of subject matter knowledge and general pedagogical knowledge. It is knowing both the subject as well as the most proficient methods which allow learners to master it. Curriculum knowledge involves the knowledge of programs and instructional materials.

Within this domain of teachers' knowledge, and given the data bases available, the primary focus of this study involves the actual subject matter knowledge a teacher possesses and its effect on student achievement, with other relevant factors controlled for. Teacher academic background, particularly degree major, provides a measure of subject matter knowledge.

The Data Base

This study includes data pertaining to schools, teachers, and students. All data came from files obtained from the Newfoundland and Labrador Department of Education. The school and teacher level data, came from the "Annual General Return" and the "Educational Staff Record." These are forms required by the department to be completed each year by schools and teachers. These data bases include demographic information about the schools and teachers as well as teacher information concerning teaching schedule and academic background.

The student data came from student achievement files. These files include the complete high school academic record for a student. The variables used from these files included: average mark in completed science courses (a measure of prior achievement), gender, participation in advanced mathematics, grade level of student, and test score on chemistry public exam.

The Analysis

Of great importance here is the fact that some variables are at the student-level and some are at the teacher/school-level. The use of traditional linear models does not provide an accurate representation of such data (Burstein 1980, Bryk & Raudenbush 1992, Raudenbush 1988). In a regression analysis the student-level data would have to be aggregated to the school-level, or the school-level data to the student-level. In the first instance, much of the student variability is lost when averaging and assigning this average to the school. In the second instance, the school-level variable must be assigned to every student in the school. This to is not a desirable technique, because the data points for each individual are not independent of each other, as required by most statistical procedures.

To overcome this dilemma a hierarchical linear model (HLM) is used. This form of analysis has been developed by Bryk and Raudenbush (1992) specifically for the type of data used in this study. The computer program used to carry out this multilevel analysis is the HLM2 and was developed by Bryk, Raudenbush, Seltzer, and Congdon (1989).

Research Questions

This study primarily focuses on the effect teacher qualifications, particularly teacher subject matter knowledge, has on the chemistry achievement of students. Given the data base available, which includes many student-level and teacher/school-level variables, the study also investigates how these other variables impact student achievement. More specifically the study is organized around four questions:

1. What proportion of variance in student chemistry achievement is at the student-level and what proportion is at the teacher/school-level?
2. What is the relative predictive power of selected student-level variables and teacher/school-level variables, particularly subject matter knowledge, on student chemistry achievement?

3. What proportion of the within-school variance can be explained using the selected student-level variables?

4. What proportion of the between-school variance can be explained using the selected teacher/school-level variables?

Overview of the Report

Chapter 2 reviews the related literature concerning the many aspects of this research. To provide a theoretical basis for the research, initially the development of an educational productivity model is examined. This is followed by a review of research that lends credibility to the model. The next aspect deals with a theoretical basis concerning a teacher's knowledge base. Once this is established research in the area of teacher subject matter knowledge and student achievement is reviewed. Finally the literature review examines the role of Hierarchical Linear Models in the area of education.

Chapter 3 provides a detailed description of the methodology used in the research. A description of the sample and data used is followed by a proposed model and descriptive statistics. Finally a detailed outline as to how Hierarchical Linear Models are to be used and interpreted is presented.

Chapter 4 works through and discusses six HLM models using different student-level and teacher/school-level variables. Chapter 5 is a conclusion summarizing the findings and discussing any relevant implications.

CHAPTER 2

LITERATURE REVIEW

To put this research into its proper perspective it is necessary to examine several aspects of the literature. Initially an overview of the theoretical perspective, which has led to current research practices in the area of student achievement, is presented. This will include a detailed examination of a model for education productivity, which provides a framework or structure in which a teacher's knowledge base is nested.

The basic educational productivity model used in this study is that developed by Walberg and his associates (Fraser, Walberg, Welch & Hattie, 1987; Walberg, 1981; Wang et. al., 1990, 1993). More than a decade of research, meta-analyses and theoretical deliberation has been devoted to the development and refinement of this model. Recognizing the complexity of human learning, this model converges on the least number of factors that strongly and consistently predict student outcomes. In presenting this model the first step is to provide a brief review of previous work which form a theoretical framework for the model. The model itself is then reviewed in some detail. Finally, some research which tests and supports the model is examined.

Following the review of the models, the focus shifts to an examination of subject matter knowledge. This begins with finding the place of subject matter knowledge within the theoretical framework of required teacher knowledge. This theoretical framework has been the subject of much review. Much of the writing in this area, although using differing terminology, generally has many commonalities. A detailed overview of Shulman's conceptions of required teacher knowledge (Shulman 1986a, 1987, Grossman, Wilson, & Shulman 1989) is presented with reference to other ideas in the area.

The research in the area of teacher qualifications, more specifically teacher subject matter knowledge, and its effect on student academic achievement is limited. Some of the research in this area uses direct measures and is quantitative in nature. Most of the prior research however is qualitative in nature and is concerned more primarily with teacher qualifications and the effect these qualifications have on classroom practices and teaching styles. Both areas of the literature are reported on.

Finally a review to enlighten the domain of hierarchical linear modeling is presented. Initially a review of a study by Mullens, Murnane, and Willett (1996) is presented because of its relevance to this study with respect to both the focus of the study as well as the use of a HLM. The rationale for the use of HLM concludes the literature review.

Educational Productivity Model

Starting Point

Lewin's (1963) psychological theory seems to be the starting point for Walberg's nine-factor productivity model. Lewin's theory proposed behavior as a function of personality and environment.

$$B = f(P,E)$$

Using Lewin's theory as a basis a similar theory was adopted for learning (Walberg, 1981). This theory proposed learning as a function of individual aptitude, instructional treatment, and environment.

$$L = f(A,T,E)$$

Using this as a foundation, Walberg (1981) initially proposed seven groups of variables to account for student achievement. These were: ability, motivation, quality of instruction, quantity of instruction, class environment, home environment, and age.

Walberg's model also derives much of its foundation from many previous models of student achievement. Carroll (1963) proposed what is referred to as a time model. He suggests that the degree of learning is a function of time spent divided by the time needed. Carroll's model involves five elements which include student aptitude, ability, and perseverance as well as opportunity for learning and quality of instruction. A mastery learning model proposed by Bloom (1976) emphasized the cognitive characteristics the learner brought with him. Bloom's model focused on the student cognitive entry level and the quality of instruction required to compliment this entry level. He suggested that with the appropriate modifications any learner can succeed. Glaser (1976) focused on the learning processes. His model emphasized the transformation process from beginning to final state. According to Glaser the development of competence is facilitated by four components: analysis of competent performance, description of initial state, conditions that foster the acquisition of competence, and assessment of the effects of instructional implementation. Certain elements of all these models are present in Walberg's model.

Walberg's Model

In reviewing eight models of student learning (including the three mentioned above) Haertel, Walberg, and Weinstein (1983) identified four major building blocks integral to these models. These include; ability, motivation, quality and quantity of instruction. Four factors of lesser significance were also identified. These include classroom environment, home environment, peer influence, and mass media effects.

The educational productivity model used here (Fraser et. al., 1987, Wang, Haertel, & Walberg, 1990, 1993) seems to encompass all of the various aspects of the models mentioned above. The model consists of nine factors grouped into three larger categories.

Student aptitude variables
1. ability (prior achievement)
2. development (age)
3. motivation

Instructional variables
4. quantity of instruction
5. quality of instruction

Educationally stimulating psychological environment
6. home environment
7. classroom or school environment
8. peer group environment outside of school
9. mass media environment (ex. t.v.)

These nine factors in Walberg's model can be best represented by the diagram in Figure 2.1 (Fraser et al., 1987, p.158). This diagram shows the relationship between the different

variables and illustrates Walberg's model. It shows the direct influence on learning by aptitude, instruction and environment (shown by arrows X,Y, and Z). It also shows the influence these three classifications have on each other (shown by arrows a,b, and c). Finally all of these are influenced by feedback from learning (illustrated by the broken arrow).

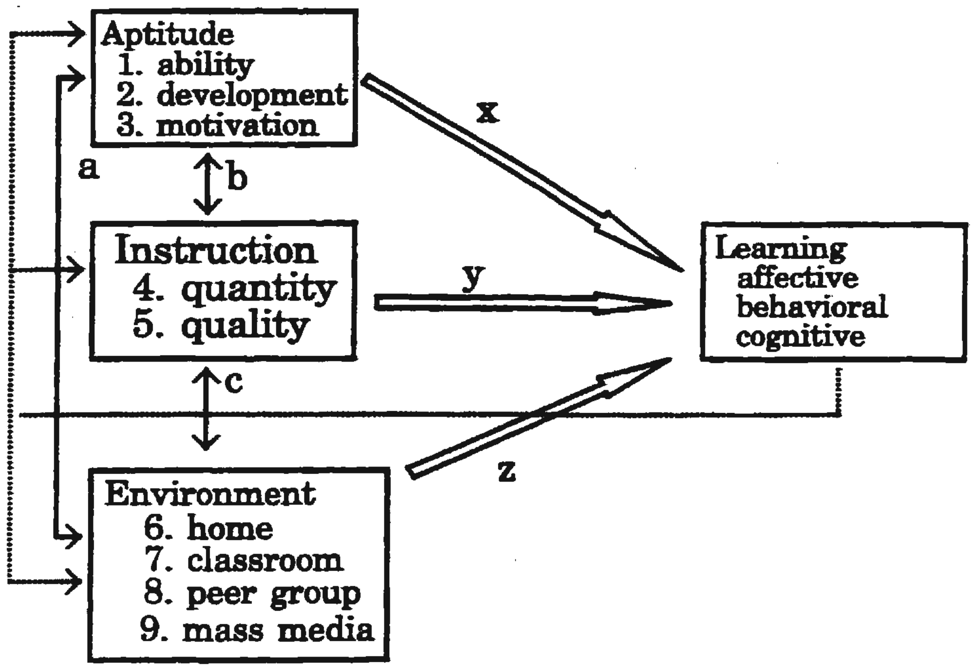

Figure 2.1 - Walberg's Model (Fraser et al., 1987, p.158)

Support for the Model

Over the years, Walberg and his colleagues have placed much emphasis on testing the model. This research has taken many forms, including meta-analyses of prior bivariate studies, multivariate studies, and reviews and syntheses of handbook and review annuals.

Fraser et al. (1987), in an extensive research study, provided much support for Walberg's model. This research involved meta-analyses of prior bivariate and multivariate studies to identify variables consistently correlated with student learning. Part of this research included a detailed examination of results obtained from the syntheses of about 2575 individual studies first reported by Walberg (1986). The mean correlations between student achievement and the three aptitude factors were: age (0.47), ability (0.71), and motivation (0.34). The results for instructional variables and environmental variables were reported as mean effect sizes. For quality of instruction 26 variables were used. These included such things as reinforcement, personalized instruction, higher-order questions, teacher expectations, and class size. The mean effect size for all 26 variables was 0.42. Instructional time had a mean effect size of 0.38 and the mean effect size for 8 variables used to represent the environmental factors was 0.37.

Part of the study by Fraser et al (1987) included a particular focus on the subject of science. In this case the factors were organized and examined according to contextual and transactional variables and took into consideration many meta-analyses. Contextual variables included student and teacher characteristics, curriculum materials, facilities/equipment, home environment, school climate, societal imperatives, and goals. Transactional variables included student and teacher behaviors, instructional resource exposure, classroom climate, and external intrusions. One such study reported involved a meta-analysis by Malone and Fleming (1983) which focused on student characteristics. This study showed ability consistently and positively related to student achievement ($r=0.43$, $n= 42$). It also showed a weak relationship between gender and student achievement (effect size of 0.16, males over females, $n=45$). From additional meta-analyses used, other contextual variables that showed moderate impact on student achievement included; curriculum materials and home environment. Contextual variables showing slight or very slight impact included; facilities/equipment, societal imperatives, and goals. Transactional variables having a strong impact included; student behaviors, instructional resource exposure, and classroom climate. Teacher behaviors showed only a slight impact.

Reporting on factors influencing student achievement Fraser et al (1987) used the synthesis of 134 meta-analyses, which was based on 7827 studies and 22.155 correlations. The results obtained are summarized in Table 2.1.

Table 2.1

Summary of Relationships to Achievement (adapted from Fraser et al, 1987)

class of variable	average correlation
school factors	0.12
social factors	0.19
instructor factors	0.21
instruction factors	0.22
pupil factors	0.24
methods of instruction	0.14
learning strategies	0.28
average correlation	0.20

A large multivariate study by Fraser et al (1987) provides even more support for Walberg's model. Fraser and colleagues used the science achievement of 17, 13, and 9 year olds on the National Assessment in Science in the US for 1981-82. This secondary analysis involved approximately 18000 students in about 700 schools. The sample was chosen to ensure proportional representation by regions, gender, racial groups, and size and type of community. The productivity factors used were ability, motivation, quality and quantity of instruction, class and home environment, television viewing, gender, and race. Analysis first considered simple correlations and then used a multiple regression analysis to take into account the combined influence of all factors on an outcome and an estimate of the impact of each individual factor when the others were held constant. The results for simple correlations and multiple regressions were consistent, and each of the factors was shown to be a statistically significant predictor of science achievement at one or more of the age levels when the other factors were held constant. Similar results and support for the model were found when the same data was the basis for another report focusing just on the 17 year-olds (Walberg, Fraser, & Welch, 1986).

In a comprehensive review and synthesis of handbooks and review annuals in search of factors most important on student achievement, Wang et al. (1990) provided more support for Walberg's model. A total of 179 sources were included in the study. These included; 86 chapters for annual review studies, 44 handbook chapters, 20 government documents and commissioned reports, 18 book chapters, and 11 review articles in journals. The variables related to learning (a total of 228) were organized into 30 scales, which were included in 6 broad categories. These categories (listed from more distal to proximal) included; state and district variables, out of school contextual variables, school-level variables, student variables, program design variables, implementation, classroom instruction and climate variables. The overall findings confirmed policy variables (at both the state and school-level) can be classified as distil variables, as they are less important to student outcomes than more proximal variables. The proximal variables included those more directly related to student engagement with the material to be learned. Those identified as most important to good learning outcomes were student metacognition, effective classroom management, quantity of instruction, student/teacher interactions, positive classroom environment and peer culture.

In a direct test of Walberg's nine-factor productivity model, Reynolds and Walberg (1991) used a national probability sample consisting of 3,116 seventh grade students. They incorporated data from students, teachers and parents to construct a latent variable model of student achievement. This study can be considered a rigorous test of the model in that it used structural equation modelling, a national probability sample, a longitudinal design, and multiple indicators of the productivity factors. The data were collected in three stages. Data collected in the fall of 1997 and 1998 involved achievement tests using science achievement items developed by the National Assessment of Education Progress (NAEP) as well as self reported student data concerning such things as motivation, homework, and peer environment. In the spring of 1987, data was collected from students, teachers and parents concerning other factors.

Factors that showed a direct effect on student achievement included prior achievement (Science-7), peer environment, instructional time, and instructional quality. Indirect effects were found for different factors. The effect of these direct and indirect factors on student achievement are summarized in Table 2.2 (Reynolds and Walberg, 1991, p. 104).

Table 2.2

Standardized Effects for Science Achievement for Revised Model (Reynolds and Walberg, 1991, p. 104)

Variable	Direct Effect	Indirect Effect	Total Effect
Home environment	-	.454	.454
Motivation	-	.209	.209
Science-7	.729	.082	.811
Mass media	-	.118	.118
Peer environment	-.171	.109	-.062
Class environment	-	.116	.116
Instructional time	.323	-	.323
Instructional quality	.098	-	.098

Knowledge Base for Teaching

"Knowledge Growth in Teaching'" was a 4-year longitudinal study whereby Shulman and his colleagues examined how teacher knowledge developed (Grossman et al, 1989; Shulman, 1986a, 1987). The study showed that, over time, some novice teachers developed a knowledge which allowed them to present the required material to their students in a more effective way. The study by Shulman and his colleagues reflect other research which show experienced teachers with better cognitive structures than their inexperienced counterparts (Leinhardt & Greeno, 1986; Borko & Livingston 1989). Both studies showed beginning teachers, although having sufficient subject matter content knowledge, lacked the ability to make a lesson flow smoothly, and constructively answer student questions.

Shulman (1986a, 1987) described a framework for the knowledge base of teachers that consisted of knowledge in eight domains. These areas of knowledge include content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners, knowledge of educational contexts, and knowledge of educational ends, purposes, and values. The three categories of content knowledge for teachers are subject matter content knowledge, pedagogical content knowledge, and curriculum knowledge. These are the areas most relevant to this study.

Since Shulman's initial concept of pedagogical content knowledge, the idea has received much attention in the literature (Marks, 1990; Lederman & Gess-Newsome, 1992; Abd-El-Khalick & BouJaoude, 1997; Sanders, Borko, & Lockard, 1993; Lee, 1995; Ball & McDiarmid, 1990; Anderson & Mitchner, 1994). Pedagogical content knowledge, in its simplest form can be considered the melding of content knowledge with that of general pedagogical knowledge. This idea of pedagogical content knowledge stresses the difference between subject matter knowledge required for teaching and subject matter knowledge in its own right. Shulman (1986a) characterized pedagogical content knowledge as content knowledge, "but of the particular form of content knowledge that embodies the aspects of content most germane to its teachability" (Shulman, 1986a, p.9). Shulman elaborated this definition by stating it includes

> for the most regularly taught topics in one's subject area, the most useful forms of representation of these ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations - in a word, the ways of representing and formulating the subject that make it comprehensible to others....also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and

> preconceptions that students of different ages and backgrounds bring with them to those most frequently taught topics and lessons. (Shulman. 1986. p.9)

McDiarmid, Ball, & Anderson (1989) advocated the use of representations by teachers in order for students to develop a flexible understanding of subject matter. McDiarmid et al. suggest that the activities of teachers, such as explaining, asking questions. responding to pupils, developing and selecting tasks. and assessing what pupils understand.

> emerge from a bifocal consideration of subject matter and pupils. framed by the teachers' own understandings and beliefs about each and shaped further by their ideas about learning and their role in promoting learning. as well as their understanding and assumptions about the content (p. 194).

This concept of representations parallels Shulman's pedagogical content knowledge.

Curriculum knowledge entails the knowledge of programs and instructional materials relevant to the course of study. There are two other aspects of curriculum knowledge. First, a teachers' familiarity of students other coursework and the ability to relate it to topics in their own class. Secondly, the awareness of topics and issues, in the same subject area, that have been discussed in prior years as well as those that will be discussed in later year (Shulman, 1986).

Although the realm of content knowledge discussed here is varied, it is important to note the significance subject matter knowledge has on both pedagogical content knowledge and curriculum knowledge. In identifying this relationship a certain element of caution must be emphasized. In no way is subject matter knowledge to be equated with pedagogical content knowledge and curriculum knowledge, it is merely a basis for them. Shulman (1986) purported that content knowledge, as learned in undergraduate classes, is not adequate for teaching. This position is widely accepted in the literature (Ball & McDiarmid, 1990; Conant, 1963; Feiman-Nemser & Parker, 1990; Kennedy, 1998; Leinhardt & Smith, 1985).

It is acknowledged, however, that subject matter knowledge is certainly the starting point. In addressing the question, "What must beginning teachers know?" Grossman et al (1989) conclude that, "teachers need to possess a foundation of subject matter knowledge upon which greater subject matter competence can be built" (p. 27). In investigating recent research on science teaching van Driel, Verloop, & de Vos (1998) identified teaching experience as a major source of pedagogical content knowledge, with adequate subject matter knowledge a prerequisite. Similarly, Peters (1977) argued, "If anything is to be regarded as a specific preparation for teaching, priority must be given to thorough grounding in something to teach" (p. 151).

Teacher Qualifications and Achievement

The research done on the relationship between teacher subject matter knowledge and student achievement is often part of a larger focus dealing with teacher qualifications. The search for a significant link between teacher qualifications and student achievement has eluded researchers. However, the domain of teacher qualifications has been addressed in the literature in several ways. There is a limited amount of research concerning the direct effects of teacher qualifications and student academic achievement. Much of the research however has focused on the role teacher qualifications has on teachers' planning, classroom activities, instructional methodologies and reflections.

At best most quantitative research shows only a marginal relationship. In a meta-analysis of studies examining teacher characteristics as the independent variable and both teaching behavior and student outcomes as the dependent variable Druva and Anderson (1983) failed to uncover a significant relationship. The meta-analysis included 65 studies of science classes from grades K-12 from the United States and the results were reported as Pearson product moment correlations.

Teacher characteristics included such things as gender, age, science training, education and performance, and attitudes. These were then correlated with student outcomes and effective teaching. Effective teaching was arrived at by the development of an "effectiveness scale", which was comprised of various teaching behaviors believed to represent positive classroom actions. The relevant results are summarized in Table 2.3 where r is the arithmetic mean of correlations, s_r is the standard deviation of correlation, and n is the number of correlations in the study.

The results show a positive relationship between student cognitive outcomes and many teacher variables. The magnitude of all these correlations are low, however the correlation with science training, which included the number of science courses in total as well as science courses in selected disciplines, was higher than those concerned with other teacher characteristics.

Table 2.3

Correlations Between Teacher Characteristics and "Effective Teaching" and Student Cognitive Outcomes (adapted from Druva and Anderson, 1983)

predictor	effective teaching			student cognitive outcomes		
	r	s_r	n	r	s_r	n
gender	.04	.12	20	.04	.06	4
age	-.07	.17	23	.13	.2	7
science training	.13	.23	28	.19	.25	24
education and performance	.08	.26	47	.10	.28	23
attitudes	.15	.32	14	.10	.21	6

A study by Monk (1994) attempted to determine, among students with the same entry level math (or science) knowledge, the effect the subject preparation of the teacher made in terms of student subsequent learning. It also investigated the effects of such things as degree level and experience. This study included data from 2829 students, in public schools, from 51 randomly selected localities. The selection process took into consideration geographic region and community type. Student achievement was measured using the National Assessment of Educational Progress (NAEP). Using least squares regression estimates, the study showed student learning gains in mathematics and science were positively affected by how much a student's teacher knew about what he or she was teaching. For both mathematics and science there was a positive effect noted for the relationship between the number of undergraduate mathematics and science courses completed and student achievement in mathematics and science respectively. For mathematics, in the junior year, it was found an additional mathematics course (for teachers having up to a maximum of five mathematics courses) attributed to an increase of 1.2% in a students achievement score, when the increase is figured at the mean. For those teachers with more than five mathematics courses the increase in achievement per mathematics course drops to 0.2%. This seems to indicate a nonlinear relationship between mathematics courses taken by teachers and student achievement. There would appear to be a "cut point" or "threshold" whereby teachers would need a minimum of subject courses after which additional subject courses would have a minimal or diminishing effect. A similar, yet smaller, effect was found for science with "cut points" occurring at six courses for life science and four for physical sciences.

Further to the results reported above, Monk (1994), also found ambiguous results in the effect of having a subject major. Having a mathematics major appeared to have no bearing on student achievement, yet a science major affected student achievement slightly. Advanced teacher training appeared to have no effect or a negative effect on student performance. The attainment of a masters degree or masters degree plus actually had a negative effect.

A more recent study by Chidolue (1996) actually showed teacher qualifications as having a negative effect on student achievement. This study included eleven biology teachers, from eleven schools in Nigeria, and included 375 students. The students were given pre and post tests which were constructed by the author, based on the objectives of the course, and validated by six high school biology teachers and two university biology teachers. When controlling for socioeconomic status, the results showed teacher qualifications correlated significantly ($p < .05$) and negatively with students' mean gain in achievement (-.47). Chidolue noted that this negative correlation may partly be due to the fact that the majority of teachers in the study were young and relatively inexperienced. Another relevant finding here is the positive correlation between teacher experience and student mean gain in achievement (0.78).

Most of the research in the area of teacher qualifications has been of a qualitative nature. Researchers have tried to determine the effect teacher qualifications has on the way they function as a teacher; how they plan lessons, their methods of teaching and evaluating, and their reflections. In an attempt to trace the effects of subject matter knowledge on aspects of their planning and simulated teaching, Hashweh (1987), focused on six experienced teachers, three physics teachers and three biology teachers. All teachers were assessed with respect to two topics; one in physics (levers) and one in biology (photosynthesis).

The assessment of the teachers subject matter knowledge with respect to these topics included summary statements, concept mapping, and sorting of questions based on concepts required to answer them. The results of this assessment were not surprising. Within their field of expertise teachers generally had a more detailed topic knowledge as well as more knowledge of other discipline concepts. These teachers also had more knowledge of higher order principles and ways of connecting the topic to other concepts in the discipline. Leinhardt, Putnam, Stein and Baxter (1991) also found teacher's mental plans varied form skeletal to detailed depending, in large part, on their familiarity with the content taught. Given this difference, Hashweh explored the effect of this on teacher planning and simulated teaching.

Teachers' planning assessment involved thinking aloud, as well as questions on evaluation plans, possible exam questions, adjustments for time constraints, and the use of representations. Teachers were also questioned with regard to their handling of bright students, student difficulties and student prior knowledge. The knowledgeable teachers generally made more constructive plans. They were able to make deletions, additions, and modifications that would make the topic easier to relate to. These teachers also were able to enrich the material in question. Outside their area of expertise, teachers followed the text closely with few, if any, alterations. This relationship between teacher knowledge and use of curricular materials is prevalent in the literature (Ball & Feiman-Nemser, 1988; Lantz and Kass, 1987). In studies involving mathematics it was noted that teachers who lacked subject matter knowledge were more apt to represent mathematics as arbitrary and rule-governed. Teachers with adequate subject matter knowledge were more likely to stress higher level reasoning and alternate ways of solving problems (Ball, 1991). In terms of evaluation Hashweh (1987) found knowledgeable teachers were more apt to use higher level questions, whereas outside their area of expertise teachers focused primarily on recall questions based on the text. Similar results were obtained in a study by Doby and Schafer (1984).

Hashweh (1987) also examined simulated teaching, which involved presenting the teacher with a critical incident and asking how the teacher would handle it. Within their subject area, teachers were more likely to detect student misconceptions, take advantage of the opportunity to discuss additional concepts, and better handle class difficulties. Teaching outside their subject area led to failure to detect student misconceptions and often the reinforcement of these prior conceptions. Similar findings have surfaced in research on exemplary teachers. It was found that exemplary teachers (as determined by a nomination process) when teaching outside their area of expertise often exhibited nonexemplary practices (Happs, 1987; Tobin & Fraser, 1990, 1991). These studies found that exemplary teachers, in this circumstance, made errors and were unable to constructively address students' academic needs. Happs (1987) went so far as to suggest that students have a great tendency to accept the misrepresentations put forth by exemplary teachers because they are just that, exemplary teachers.

In a more recent study examining teachers teaching within and outside their area of expertise. Sanders, Borko, and Lockard (1993) found teacher performance was significantly determined by their knowledge of the subject matter. Their study involved three experienced high school teachers with teaching duties both in and out of their area of expertise. The teachers were observed and interviewed while teaching classes in their area of certification, and in another science area they were teaching for only the first or second time. The observations took place over a two week period with five consecutive days in each area. In their planning for the noncertification area, teachers had difficulty determining what was important, how to sequence the content. and anticipating problem areas. While teaching in their area, the lessons flowed smoothly. the teachers talked less and used more student centred activities. The same was not true in teaching outside their area. These lessons involved rapid and frequent changes and if lesson got bogged down it led to both teacher and student frustration. Also in these cases the teachers were sometimes unable to constructively answer student questions and they used less risky activities such as more lecturing. It is important to also note that in reflection teachers focused more on students when reflecting on lessons in their area and more on themselves on lessons outside their area.

Observing and interviewing a teacher with an undergraduate degree in social studies and a limited background in science, Lee (1995), reported the teacher as relying on strict classroom management with a major dependence on text book and seat work. The teacher reported she avoided whole-class discussion because of her concerns about inadequate knowledge of science content.

As opposed to focusing on teachers outside their area of expertise, Tobin and Fraser (1991) examined the strategies of 13 exemplary science teachers and 7 exemplary mathematics teachers. It was found these exemplary teachers: (1) used management strategies that facilitated sustained student engagement, (2) used strategies that encouraged students to participate in learning activities, and (3) used strategies designed to increase student understanding of science and mathematics. In two cases involving chemistry teachers it was especially evident the teachers were effective due to their strong content knowledge, which allowed the teachers to probe for misunderstandings, clarify, and elaborate.

The Use of Hierarchical Linear Models

Hierarchical linear modelling is a relatively new approach to data analysis, appropriate when the analysis involves data at more than one level, such as student and teacher. A study by Mullens, Murnane, and Willett (1996) had a similar focus to that of the research in this study. This piece of research is pursued for two reasons. First, although it examines a grade three context, it does concern itself with teacher qualifications and student achievement. Second, this piece of research is used to demonstrate, in some detail, the use of hierarchical linear models.

Mullens et al. were searching for a relationship between student learning and various student, teacher, and school variables. The variables used are given in Table 2.4.

Table 2.4
Variables Used in HLM
(adapted from Mullens et al, 1996)

Variable	Variable label
T_TRAIN	is the teacher trained
T_ACAD	does the teacher have a secondary education
T_MATH	subject matter competence (as measure by BNSE (Belize National Selection Examination))
C_URBAN	how remote is the school
C_DAYS	how many days school open
T_EXPER	number of years teaching experience
T_FEMALE	is the teacher female
S_FEMALE	is the student female
S_BOOK	is there a math book in the student home

The study took place in Belize and included 1043 grade 3 students and 72 teachers. The students were given a pre-test in October and a post-test the following May. The tests were comprised of questions categorized as either basic or advanced. Using HLM, the within-classroom model (level 1 model) described the relationship between D_{ij}, the pretest-posttest difference of the i^{th} student in the j^{th} classroom, and selected student-level background characteristics; for example:

$$D_{ij} = \beta_{0j} + \beta_{1j}(S\_FEMALE_{ij}) + \beta_{2j}(S\_BOOK_{ij}) + \varepsilon_{ij}$$

where ε_{ij} are random errors. The coefficients β_{1j} and β_{2j} represent the effect the variables

S_FEMALE and S_BOOK have on the learning of that student in that particular classroom, D_{ij}.

In the level 2 model the between-class variation in student learning was accounted for by treating the β's from the level 1 model as dependent variables which vary across classrooms, each as a function of selected class and teacher level variables.

One level 2 model used by Mullens et al was:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(C\_URBAN)_j + \gamma_{02}(C\_DAYS)_j + \gamma_{03}(T\_EXPER)_j + \gamma_{04}(T\_FEMALE)_j + \gamma_{05}(T\_TRAIN)_j + \gamma_{06}(T\_ACAD)_j + \gamma_{07}(T\_MATH)_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_{2j} = \gamma_{20}$$

where u_{0j} and u_{1j} are class-room level error terms. The coefficients γ_{01} to γ_{07} represent the effect the corresponding variable has on student learning. The level 1 model was retained throughout the analysis and several level 2 models were explored using different combinations of variables. There was no significant relationship between any variables and student learning on basic concepts, therefore results were only reported for student learning advanced concepts. Three models were reported: model 1 (M1) used no teacher or classroom variables, model 2 (M2) used all possible variables, and model 3 (M3) used all variables with the exception of T_MATH. The results are reported in TABLE 2.5 and show students learned advanced concepts more rapidly if their teachers had an increased subject matter competence (model M2: $\gamma_{07}=3.64$, $p<.001$). Although this study is concerned with a grade three level, using hierarchical linear modeling, it does show a relationship between teacher subject matter competence and student learning.

Table 2.5

Estimated Coefficients Describing the Relationships Between Student-Level and Classroom and Teacher-Level Characteristics and Student Learning of Advanced Concepts

(Mullens et al. 1996, p.154)

Level 1 Parameter	Level 2 Parameter	Model		
		M1	M2	M3
Fixed effects:				
β_{0j}, intercept	γ_{00},intercept	4.89***	1.94	9.42
	γ_{01},C_URBAN	--	-1.05	-.43
	γ_{02},C_DAYS	--	-.04	-.05
	γ_{03},T_EXPER	--	.93	.41
	γ_{04},T_FEMALE	--	.70	-.36
	γ_{05},T_TRAIN	--	.40	.67
	γ_{06},T_ACAD	--	1.38	2.27*
	γ_{07},T_MATH	--	3.64***	--
β_{1j},S_FEMALE	γ_{10},intercept	--	.59	.67
β_{2j},S_BOOK	γ_{20},intercept	--	.71	.64
Random effects:				
σ^2, residual variance		23.60	21.75	21.77
σ^2_{u0}, residual variance		17.86	11.24	17.62
σ^2_{u1}, residual variance		--	5.75	5.74
Percentage of between-classroom variation in student achievement gain explained by level 2 predictors		--	37.1	1.3

* p<.05. *** p<.001

The Strength of Hierarchical Linear Models

As discussed earlier hierarchical linear modelling (HLM) is a new statistical technique used to address a problem in research when data are organized at two levels. such as determining relationships between school and classroom characteristics and individual student outcomes (Burstein 1980, Bryk & Raudenbush 1992, Raudenbush 1988). Raudenbush and Bryk (1986) used the HLM in the reanalysis of a study to determine the relationship between socioeconomic status and mathematics achievement. Their reanalysis of data from American high schools, randomly selected, illustrated the statistical superiority when HLMs were used. They showed there was a relationship between socioeconomic status and mathematics achievement that varied across American high schools and this variation was mainly attributable to the type of school (public vs. Catholic). The value of using the HLM, over other statistical techniques, should be evident. The significance of this will be further discussed in the data analysis that follows in this study.

Summary

This review examined several aspects of the literature. A theoretical basis for an educational productivity model was first established. Once this was established, a detailed review of the educational productivity model developed by Walberg and colleagues was presented. This was followed by a comprehensive review of research which supports the model. Following the review of the models the focus shifted to the knowledge base for teaching with particular emphasis on Shulman's idea of pedagogical content knowledge. Finally, much research was examined with respect to the effect teacher qualifications, in particular teacher subject matter knowledge, has on student achievement.

CHAPTER 3

METHOD

Sample and Data

For the school year 1994/95 approximately 3100 students in 105 schools, in the province of Newfoundland, were taking Chemistry 3202. Ten of these schools had more than one teacher teaching Chemistry 3202. Given that the interest of this study is in teacher qualifications, students in these schools had to be assigned to the proper teacher. Class lists were obtained for six of the ten schools in question and therefore four schools (approximately 300 student) were lost from the study. Seven other schools were dropped from the study because class size was extremely small (< 8 students). Finally, there was some missing data for other students, some of whom did not write the public exam that year. The final sample consisted of 2453 students taught by 97 different teachers.

As stated earlier, the primary focus of this study was the effects of teacher subject matter knowledge on student achievement. The theoretical basis for this study is found in the educational productivity model discussed earlier. It is important to note (as can be seen from the model) that the effect of teacher subject matter knowledge on student achievement is not something that occurs in isolation. There are many factors which may influence student achievement. This study explores the effect of teacher subject matter knowledge on student achievement in the context of these many other variables.

The data provides many variables that can be classified as student-level variables or teacher/school-level variables. The grouping of teacher-level variables with school-level variables is done because every student is paired with a particular teacher in a particular school. Given that the variables in question are at two different levels this study uses a multilevel model or hierarchical linear model (HLM). These two sets of variables and their effect on student achievement may be represented as in Figure 3.1.

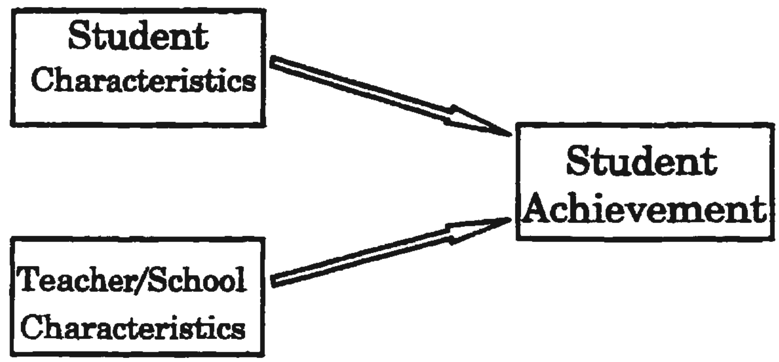

Figure 3.1 - Basic Relationship

To keep the models and the analysis manageable and practical, all of the variables available were not used. At the student-level, the variables used included chemistry 3202 public exam mark (dependent variable), choice to do advanced mathematics (a measure of motivation), grade level, gender, number of science courses completed (a measure of aptitude and motivation), and average mark in completed science courses (a measure of prior achievement). These variables were chosen s they showed some degree of correlation with student achievement, particularly so for prior achievment). Students level I average was not included as a measure of prior achievement for two reasons. First it was highly correlated with the variable student science average ($r=.83$, $p<.001$). Second the student science average was more highly correlated with chemistry achievement than level 1 average ($r=.80$ as compared to $r=.62$, $p<.001$).

The data initially provided 29 teacher/school-level variables. Preliminary analysis of correlations among the variables reduced the number to a more manageable number of 15. This analysis involved the assessment of correlations between the variable in question and student achievemenat as well as with other variables. For example the possession of a Master of Science by a teacher was not used because there were only four such teachers. Given the high correlation between teacher years experience and age ($r=.93$. $p<.001$) only years experience was used. Also the correlation between the number of chemistry credits and the possession of a chemistry major was high enough ($r=.78$, $p<.001$) to justify only using chemistry major as a variable. Other variables were eliminated using similar reasoning such that the final number was reduced to 15 teacher/school-level variables.

Tables 3.1 and 3.2 list the student-level variables used as well as some descriptive statistics. including correlations. Tables 4.3 and 4.4 lists the teacher/school-level variables used as well as their descriptive statistics, including correlations.

TABLE 3.1

Descriptive Statistics: Student-Level Variables

Variable	Description of Variable	Mean	SD
1. ADV_MTH	Is the student doing advanced math (1=yes, 0=no)	.69	.46
2. LVL_3	Is the student in level 3 (1=yes, 0=no)	.54	.50
3. N_SCI_CO	Number of science courses the student has done	5.17	.99
4. SCI_AVE	Student's average mark in science courses completed	73.21	11.04
5. SEX	Gender of student (1=male, 0=female)	.44	.50
6. CHEM_MARK	Student's mark in Chemistry 3202 public exam	56.78	15.10

TABLE 3.2

Correlation Matrix - Student-Level Variables

Variable	1.	2.	3.	4.	5.	6.
1. CHEM_MARK						
2. ADV_MTH	.42**					
3. LVL_3	.10**	.00				
4. N_SCI_CO	.13**	.11**	.07**			
5. SCI_AVE	.80**	.49**	.01	.09**		
6. SEX	.08**	.02	-.05*	.06**	-.02	

* p<.05, ** p <.01

TABLE 3.3

Descriptive Statistics: Teachers/Schools

Variable	Description of Variable	Mean	SD
1. BED	Does teacher have Bachelor of Education (1=yes, 0=no)	.91	.29
2. BSC	Does teacher have Bachelor of Science (1=yes, 0=no)	.96	.20
3. CL_SIZE	Average chemistry class size for a teacher	19.82	5.91
4. CMJ	Does the teacher have a chemistry major (1=yes, 0=no)	.21	.41
5. MED	Does teacher have a Master of Education (1=yes, 0=no)	.19	.39
6. PCT_CHM	percent of teachers teaching assignment teaching chemistry	.44	.24
7. PCT_M_T	percent of teachers in school that are male	.65	.16
8. PR_AD_MT	proportion of students doing advanced math	.36	.17
9. SAME_SCH	Is the teacher teaching in the same school as last year (1=yes, 0=no)	.84	.37
10. SCH_S_AV	School science average	67.69	3.33
11. SEX	Gender of teacher (1=male, 0=female)	.79	.41
12. SR_HIGH	Is the school a Sr. high school (1=yes, 0=no)	.34	.48
13. STD_POP	student population	386	242
14. U_R	Is the school urban or rural (1=urban, 0=rural)	.39	.49
15. YRS_EXP	teachers years experience	12.91	8.87
16. CHEM_MARK	student chemistry 3202 public exam mark aggregated to teacher (class average)	57.72	15.22

TABLE 3.4

Correlation Matrix - Teacher/School-Level Variables

Variable	1.	2.	3.	4.	5.	6.	7.	8.
1. BED								
2. BSC	.11							
3. CL_SIZE	.03	-.10						
4. CMJ	.08	.11	.12					
5. MED	.15	-.03	.15	-.11				
6. PCT_CHM	-.10	.02	.32**	.31**	.10			
7. PCT_M_T	-.04	.17	-.04	-.09	-.05	-.11		
8. PR_AD_MT	-.05	.02	.01	-.06	.06	.01	.22*	
9. SAME_SCH	-.05	-.09	-.07	-.32**	.14	-.19	-.04	-.10
10. SC_S_AV	-.18	.09	-.05	-.09	.01	-.07	.15	.11
11. SEX	-.16	.02	-.21**	.07	-.02	-.07	.16	-.03
12. SR_HIGH	.16	.04	.31**	.01	.05	.37**	.06	.06
13. STD_POP	.00	-.02	.34**	.11	.22*	.54**	-.19	.11
14. U_R	-.04	-.05	.14	.22*	.16	.45**	-.09	.03
15. YRS_EXP	-.33**	.02	-.08	-.14	.29**	.14	.04	-.08
16. CHEM_MARK	-.06	-.03	-.19	-.11	.17	.08	.10	.04

TABLE 3.4 (con't)

Correlation Matrix - Teacher/School-Level Variables (con't)

Variable	9.	10.	11.	12.	13.	14.	15.	16.
1. BED								
2. BSC								
3. CL_SIZE								
4. CMJ								
5. MED								
6. PCT_CHM								
7. PCT_M_T								
8. PR_AD_MT								
9. SAME_SCH								
10. SC_S_AV	-.16							
11. SEX	.05	-.09						
12. SR_HIGH	-.15	-.03	-.01					
13. STD_POP	-.11	.02	-.12	.41**				
14. U_R	-.21*	.02	-.01	.36**	.51**			
15. YRS_EXP	.44**	.04	.31**	.09	.09	.12		
16. CHEM_MARK	.17	.40**	-.04	.09	.14	.06	.10	

* $p<.05$, ** $p<.01$

The dependent variable is student achievement, as measured by the student's chemistry 3202 public exam mark. Hypothesized models are presented in Figures 3.2 and 3.3 which illustrate the proposed relationship between the student-level variables with student achievement and teacher/school-level variables with student achievement. To determine the indirect effects shown in the hypothesized models would require the use of structural equations or path analysis. However given that multilevel nature of the data this study uses hierarchical linear modelling which doesn't allow for the determination of these indirect effects.

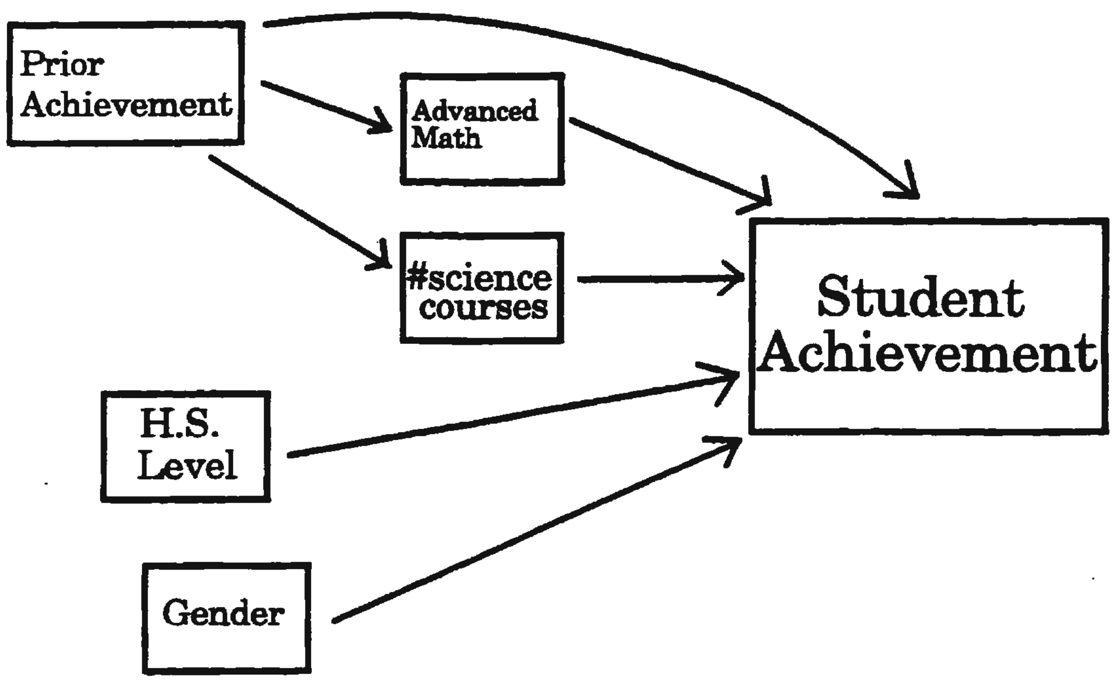

Figure 3.2 - Relationship Between Student Level Variables and Student Achievement

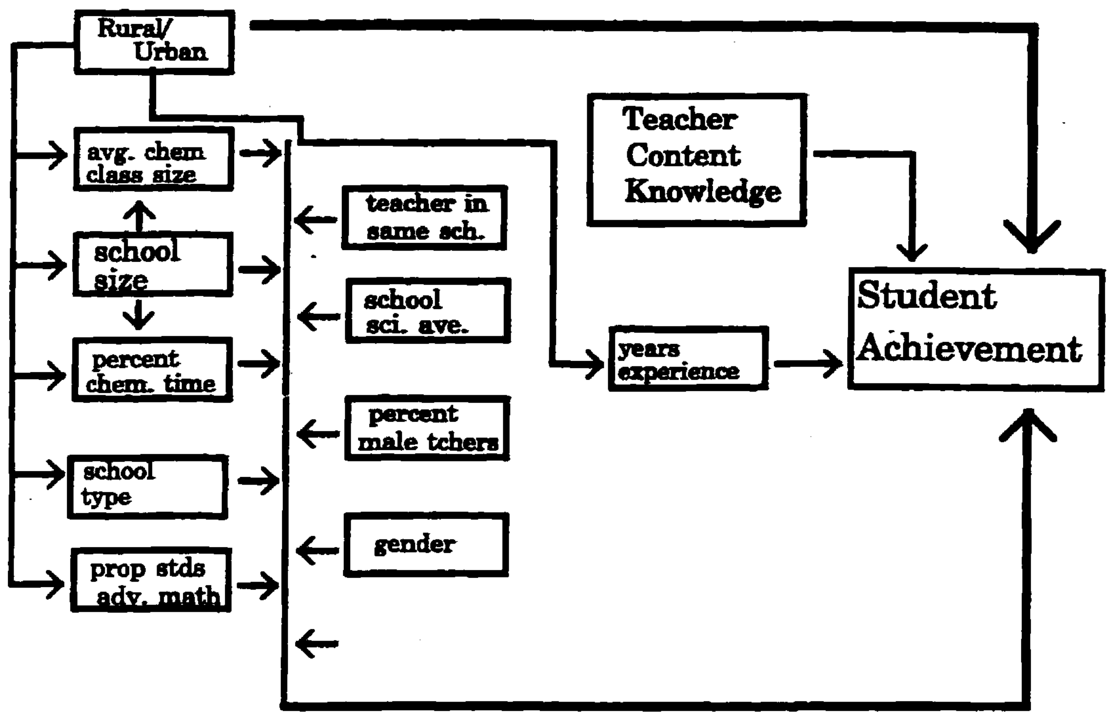

Figure 3.3 - Relationship Between Teacher/School Level Variables and Student Achievement

The Use of Hierarchical Linear Models

In this study some variables are at the student-level and some are at the teacher/school-level. HLM estimates linear equations that explain outcomes of individuals, who are members of groups. It predicts these outcomes for individuals both as a function of the characteristics of the group as well as a function of the characteristics of the individuals. In an educational context there are students within classrooms, within schools, within districts, etc. Given that variables are measured at different levels it is not favorable to include them in an equation that predicts outcomes at only one level. HLM overcomes this obstacle by using a multilevel model.

HLM involves performing regressions on regressions. In this study the level 1 regression involves student achievement for students of a particular teacher, as predicted by several student-level variables. These equations are within-school models and there is one equation for each school. The intercepts and coefficients (β's) from the level 1 model are then used as dependent variables in the level 2 regression equations. In the level 2 model, the between-school model, the teacher/school is the unit of analysis and teacher/school characteristics are the independent variables.

The best way to explain the use of HLM is by way of an example. The following example will use some of the variables that are used in this study to illustrate the set-up and interpretation of HLM. It should be noted that the process followed in this example is only one way of proceeding with the use of HLM, and not the method followed in this study for the final analysis. For illustration purposes only two student-level variables and two teacher/school-level variables are used. The student-level variables are prior science achievement (SCI_AVE) and whether the student is doing advanced mathematics (ADV_MTH). The two teacher/school-level variables used are the possession of a chemistry major (CMJ) and student population of the school (STD_POP). The outcome variable is chemistry achievement (CHEM_MARK).

1. Initially an unconditional model is established. This model is used to determine the relative proportions of variance accounted for at the student-level and the teacher/school-level.

The Level 1 model is:

$$CHEM\_MARK_{ij} = \beta_{0j} + r_{ij}$$

The Level 2 model is:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

where:

$CHEM\_MARK_{ij}$	is the	dependent variable (chemistry achievement for student i in school j)
β_{0j}	is the	intercept, or mean chemistry achievement for students in the j^{th} school
r_{ij}	is the	random error in the j^{th} school. Level 1 error term normally distributed with a mean of 0 and a variance of σ^2
γ_{00}	is the	grand mean of chemistry achievement for students
u_{0j}	is the	random effect associated with school j (set at a mean of 0 and a variance of τ_{00})

From this model we arrive at an estimate of the total variance of the dependent variable, chemistry achievement. The total variance can then be decomposed into student-level variance (σ^2) and school-level variance (τ_{00}).

2. Following the running of the unrestricted model, several different avenues can be probed. One possible scenario would be to include student-level variables in the level 1 model. The level 1 model now becomes:

$$CHEM\_MARK_{ij} = \beta_{0j} + \beta_{1j}(SCI\_AVE)_{ij} + \beta_{2j}(ADV\_MTH)_{ij} + r_{ij}$$

The level 2 model is:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + u_{2j}$$

where:

β_{1j} is the	degree to which a students prior science achievement in school j relates to chemistry achievement
β_{2j} is the	degree to which a students choice to take advanced math in school j relates to chemistry achievement
u's is the	random error terms
γ_{00} is the	intercept, or average chemistry achievement for all schools
γ_{10} is the	intercept, or the average prior science achievement for all schools

In this model the intercept and β coefficients from the within school model (Level 1) become the dependent variables in the between school model (Level 2). This results in the examination of the variation in these within school parameters. This model provides two meaningful outcomes from the HLM. First the change in both the student-level and teacher/school-level variance is shown. By noting the decrease in variance from the unrestricted model to the new model, an estimate of the proportion of the student-level and teacher/school-level variance explained by the student-level variables included in the model is determined. For example if the student-level variance drops by 30%, it is assumed that the student-level variables included in the model were responsible for this reduction.

The second outcome of interest is the actual β coefficients. If these are statistically significant, they represent the degree to which the variable in question, while controlling for the other variable, effects student chemistry achievement.

3. The final step in the HLM process is to include teacher/school-level variables along with the student-level variables. The inclusion of these variables is done to explain the variation in each of these parameters. These between school models produce coefficients (γ's) that estimate the effect of each teacher/school-level variable on either chemistry achievement, the effect of the number of chemistry credits, or the effect of the size of the school across all the schools. The Level 1 model remains the same but the Level 2 model now becomes:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(CMJ)_j + \gamma_{02}(STD\_POP)_j + u_{0j} \quad (1)$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(CMJ)_j + \gamma_{12}(STD\_POP)_j + u_{1j} \quad (2)$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}(CMJ)_j + \gamma_{22}(STD\_POP)_j + u_{2j} \quad (3)$$

where:

γ_{01} & γ_{02}	are the	indicators of the effect the respective school-level variable has on chemistry achievement
γ_{11} & γ_{12}	are the	indicators of the effect the respective school-level variables has on the school-level variations in the differences that prior science achievement has on chemistry achievement.
γ_{21} & γ_{22}	are the	indicators of the effect the respective school-level variables has on the school-level variations in the differences that school size has on chemistry achievement.

For example γ_{11} would be a measure of the effect the possession of a chemistry major has on school-level variations in the differences that prior science achievement has on chemistry achievement. Again for this complete model some change in both the student-level variance and teacher/school-level variance would be noted.

CHAPTER 4

RESULTS and DISCUSSION

Analysis Using HLM

Unrestricted Model

The first step in analysis using the HLM is the unrestricted model. This unrestricted model actually provides a reference indicating the relative proportions of the variance in the outcome variable (CHEM_MARK) accounted for at the student-level and teacher/school-level.

The Level 1 model is:

$$CHEM\_MARK_{ij} = \beta_{0j} + r_{ij}$$

The Level 2 model is:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$CHEM\_MARK_{ij}$ is the chemistry achievement of student i in school j. Results from the unconditional model are presented in Table 4.1.

These estimates indicate that most of the variation in chemistry achievement is at the student-level, $\sigma^2 = 192.88$. The variation at the teacher/school-level is much less, $\tau_{00} = 35.00$. These results indicate that 85% of the variance is at the student-level (192.88 out of a total of 227.88) and 15% (35.00 out of a total of 227.88) of the variance is at the teacher/school-level. Given that there is significant variation among students in different schools this research is interested in determining if this difference is due to the teacher characteristic variables identified.

Table 4.1

Results for Unrestricted Model

Fixed Effect	Coefficient	Standard Error	t-ratio	p-value
Average school mean, (γ_{00})	56.41	0.69	-	
Random Effects	Variance	df	Chi-square	p-value
intercept 1, u_{0j}	35.00	96	546.12	<.001
level 1, r_{ij}	192.88			

Regressions With Means as Outcomes

The next stage of the analysis will be done in two parts. This study is primarily interested in the effect of teacher subject matter knowledge on achievement therefore the first model is used to determine the effect the teacher's possession of a chemistry major has on chemistry achievement and the proportion of variance explained in β_{0j}. Following this a similar model will be set up using a greater number of teacher characteristics.

Chemistry Major Model:

The Level 1 model remains unchanged:

$$CHEM\_MARK_{ij} = \beta_{0j} + r_{ij}$$

The Level 2 model is:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(CMJ)_j + u_{0j}$$

Table 4.2 provides the results for this model. The results indicate no significant association between the teacher having a chemistry major and student achievement in chemistry (γ_{01}=-0.55, t=-0.80). These results also show there is no proportion of variance in β_{0j} explained (τ_{00} in both cases are approximately equal, 35.00 compared to 35.26).

Table 4.2

Results for Chemistry Major Model

Fixed Effect	Coefficient	Standard Error	t-ratio	p-value
Average school mean, (γ_{00})	56.42	0.69	-	
CMJ, (γ_{01})	-0.55	0.69	-0.80	ns

Random Effects	Variance	df	Chi-square	p-value
intercept 1, u_{0j}	35.26	95	539.20	<.001
level-1, r_{ij}	192.86			

The next step is to include more teacher characteristics in the model. Again the level 1 model remains unchanged but the level 2 model includes many more teacher variables.

Teacher Characteristics Model:

The Level 1 model is:

$$CHEM\_MARK_{ij} = \beta_{0j} + r_{ij}$$

The Level 2 model is:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(BED)_j + \gamma_{02}(BSC)_j + \gamma_{03}(CMJ)_j + \gamma_{04}(MED)_j + \gamma_{05}(PCT\_CHM)_j + \gamma_{06}(SEX)_j + \gamma_{07}(YRS\_EXP)_j + u_{0j}$$

The results for the teacher characteristics model are provided in Table 4.3. None of the teacher characteristics are significantly associated with student achievement. The school-level variation also remains relatively unchanged from the unrestricted model.

It appears the addition of teacher characteristics to the model has a negligible effect on any aspect of the model. The next steps in the analysis involves the inclusion of other variables at both the student and teacher/school-level.

Table 4.3

Results for Teacher Characteristics Model

Fixed Effect	Coefficient	Standard Error	t-ratio	p-value
Average school mean, (γ_{00})	56.33	0.69	-	
BED, (γ_{01})	-0.20	0.79	-0.26	ns
BSC, (γ_{02})	-0.00	0.69	-0.01	ns
CMJ, (γ_{03})	-0.53	0.76	-0.70	ns
MED, (γ_{04})	0.89	0.76	1.17	ns
PCT_CHM, (γ_{05})	0.70	0.73	0.95	ns
SEX, (γ_{06})	-0.45	0.74	-0.61	ns
YRS_EXP (γ_{07})	0.50	0.87	0.58	ns

Random Effects	Variance	df	Chi-square	p-value
intercept 1, u_{0j}	35.46	89	483.09	<.001
level 1, r_{ij}	192.93			

Student Variables Models

As was seen in the literature a student's prior achievement is generally a good predictor of student achievement. In this study student prior achievement is measured by student average in science courses the student has done (SCI_AVE). Due to its strong correlation with chemistry achievement ($r=0.80$, $p<.001$), this variable is examined by itself before loading the other student characteristics into the model.

A. Prior Achievement Model.

The Level 1 model is:

$$CHEM\_MARK_{ij} = \beta_{0j} + \beta_{1j}(SCI\_AVE)_{ij} + r_{ij}$$

The Level 2 model is:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

The outcome of this model, which are shown in Table 4.4, illustrate two significant results. First, there exists a significant positive relationship between SCI_AVE and chemistry achievement ($\gamma_{10}=12.03$, $t=46.93$). Second, a significant proportion of the within school variance is explained. The within school variance, σ^2, is reduced from 192.88 for the unrestricted model, to 60.59 for the current model. This is a reduction of 69%. That is, the variable "prior achievement" accounted for 69% of the initial variance.

Table 4.4

Results for Prior Achievement Model

Fixed Effect	Coefficient	Standard Error	t-ratio	p-value
For intercept 1, β_{0j}				
average school mean, (γ_{00})	56.35	0.49	-	
For SCI_AVE slope, β_{1j}				
intercept 2, (γ_{10})	12.03	0.26	46.93	<.001

Random Effects	Variance	df	χ^2	p-value
intercept 1, u_{0j}	20.00	96	799.85	<.001
SCI_AVE slope, u_{1j}	2.85	96	193.41	<.001
level 1, r_{ij}	60.59			

Next all student variables are added into the model to determine their effect on chemistry achievement as well as their effect on further reducing the within school variance.

B. Student Characteristics Model

The Level 1 model is:

$$CHEM\_MARK_{ij} = \beta_{0j} + \beta_{1j}(ADV\_MTH)_{ij} + \beta_{2j}(LVL\_3)_{ij} + \beta_{3j}(N\_SCI\_CO)_{ij} + \beta_{4j}(SCI\_AVE)_{ij} + \beta_{5j}(SEX)_{ij} + r_{ij}$$

The Level 2 model is:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + u_{3j}$$

$$\beta_{4j} = \gamma_{40} + u_{4j}$$

$$\beta_{5j} = \gamma_{50} + u_{5j}$$

When all the student-level variables were included there was a further reduction in within school variance, σ^2, from 60.59 to 53.90 (a further reduction of 11%). The statistically significant predictors of chemistry achievement were LVL_3 (γ_{20}=1.19, t=4.00), N_SCI_CO (γ_{30}=0.92, t=4.03), SCI_AVE (γ_{40}=12.01, t=42.92), and SEX (γ_{50}=1.46, t=7.29). The only student variable that did not have significant impact on student chemistry achievement was the choice of the student to do advanced mathematics (see Table 4.5). It is worth noting that even with the inclusion of the other variables the association between prior achievement and chemistry achievement did not significantly change. Without other variables the coefficient was 12.03; with the inclusion of the other variables the coefficient becomes 12.01.

Worthy of note is the fact that the degrees of freedom for this model is reduced to 55. This is primarily due to the inclusion of the variable LVL_3. The χ^2 tests use only those schools that show variation. In this province there are schools which only allow level 3 students to do chemistry 3202 (29 out of 97). As well, there are some schools that only allow level 2 students to do the course (10 out of 97). These schools would have no variation with respect to the LVL_3 variable. It is important however to include this variable as it appears to be statistically significant in the model (γ_{20}=1.16, t=4.00). This positive relationship reinforces the statistically significant positive correlation between LVL_3 and chemistry achievement previously reported (r=0.10, p<.001). Further to this, the average chemistry 3202 mark for all level 3 students is 58.10, whereas that for all level 2 student's was 55.22. In light of this specific aspect of the research, schools, where possible, should encourage students to complete chemistry 3202 in level 3 to ensure a maximum level of achievement.

Table 4.5

Results for Student Characteristics Model

Fixed Effect	Coefficient	Standard Error	t-ratio	p-value
For intercept 1, β_{0j}				
average school mean, (γ_{00})	56.30	0.49	-	
Student-level variables:				
ADV_MTH, γ_{10}	0.25	0.22	1.13	ns
LVL_3, γ_{20}	1.16	0.29	4.00	<.001
N_SCI_CO, γ_{30}	0.92	0.23	4.03	<.001
SCI_AVE, γ_{40}	12.01	0.28	42.92	<.001
SEX, γ_{50}	1.46	0.20	7.29	<.001

Random Effects	Variance	df	χ^2	p-value
intercept 1, u_{0j}	18.03	55	262.52	<.001
ADV_MTH slope, u_{1j}	0.55	55	51.62	ns
LVL_3 slope, u_{2j}	2.31	55	93.77	.001
N_SCI_CO slope, u_{3j}	1.25	55	76.10	<.05
SCI_AVE slope, u_{4j}	3.35	55	117.78	<.001
SEX slope, u_{5j}	1.18	55	86.56	<.01
level 1, r_{ij}	53.90			

Also emerging from this model is the effect of student gender (γ_{50}=1.46, t=7.29). This would seem to indicate that male students achieve better in chemistry than their female counterparts. The aggregated male average in chemistry 3202 for the entire province was 58.15, whereas that for female students was 55.72. Teachers should be aware of this difference and take appropriate action to encourage female students.

Full Model

The final model includes all student-level variables, with the exception of ADV_MTH, and all teacher/school-level variables. The choice of a student to do advanced mathematics (ADV_MTH), did not show to be significant in the student characteristics model and was therefore dropped from this model.

The Level 1 model is:

$$CHEM\_MARK_{ij} = \beta_{0j} + \beta_{1j}(LVL\_3)_{ij} + \beta_{2j}(N\_SCI\_CO)_{ij} + \beta_{3j}(SCI\_AVE)_{ij} + \beta_{4j}(SEX)_{ij} + r_{ij}$$

The Level 2 model is:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(BED)_j + \gamma_{02}(BSC)_j + \gamma_{03}(CL\_SIZE)_j + \gamma_{04}(CMJ)_j + \gamma_{05}(MED)_j + \gamma_{06}(PCT\_CHM)_j + \gamma_{07}(PCT\_M\_T)_j + \gamma_{08}(PR\_AD\_MT)_j + \gamma_{09}(SAME\_SCH)_j + \gamma_{010}(SCH\_S\_AV)_j + \gamma_{011}(SEX)_j + \gamma_{012}(SR\_HIGH)_j + \gamma_{013}(STD\_POP)_j + \gamma_{014}(U\_R)_j + \gamma_{015}(YRS\_EXP)_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + u_{3j}$$

$$\beta_{4j} = \gamma_{40} + u_{4j}$$

The results of this model are presented in Table 4.6. The final model again shows statistically significant association between chemistry achievement and the included student-level variables. The teacher/school-level variables however finds only two of the variables to provide a statistically significant association. First, class size is negatively associated with chemistry achievement (γ_{03}=-1.27, t=-2.49). This would indicate that smaller classes would in fact lead to improved student achievement. This must be interpreted with the recognition that all class sizes under consideration in this study ranged form a low of 8 to a high of 30. Second, the chemistry teacher teaching in the same school as the previous year is positively associated with chemistry achievement (γ_{09}=1.47, t=2.65). It would appear that a teacher new to a school can expect an adjustment period for both the teacher and students. This is not unexpected, especially with regard to teaching chemistry 3202. If the teacher is new to the school, all the chemistry 3202 students would have been taught the prior chemistry course (chemistry 2202) by a different teacher.

Finally, the inclusion of all teacher/school-level variables (of which only two were statistically significant) reduced the between-school variance (τ_{00}) a further 11%; the student effects explained 48% of the same variance.

Another aspect of the hierarchical linear model is to include the teacher/school level variables in the Level 2 model in the slopes as outcomes equations. When this was done no significant results were obtained.

Table 4.6

Results for Full Model

Fixed Effect	Coefficient	Standard Error	t-ratio	p-value
For intercept 1, β_{0j}				
average school mean, (γ_{00})	56.23	0.44	-	.
BED, (γ_{01})	0.63	0.52	1.21	ns
BSC, (γ_{02})	-0.72	0.45	-1.61	ns
CL_SIZE, (γ_{03})	-1.27	0.51	-2.49	<.05
CMJ, (γ_{04})	0.19	0.51	0.38	ns
MED, (γ_{05})	0.68	0.51	1.35	ns
PCT_CHM, (γ_{06})	0.59	0.57	1.03	ns
PCT_M_T (γ_{07})	0.42	0.50	0.84	ns
PR_AD_MT, (γ_{08})	-0.46	0.46	-0.99	ns
SAME_SCH, (γ_{09})	1.47	0.56	2.65	<.05
SC_S_AV, (γ_{010})	-0.23	0.48	-0.49	ns
SEX, (γ_{011})	0.28	0.48	0.57	ns
SR_HIGH, (γ_{012})	0.21	0.53	0.39	ns
STD_POP, (γ_{013})	0.86	0.58	1.47	ns
U_R (γ_{014})	0.55	0.55	0.99	ns
YRS_EXP (γ_{015})	-0.73	0.63	-1.15	ns
Student-level variables:				
LVL_3, γ_{10}	1.18	0.29	4.09	<.001
N_SCI_CO, γ_{20}	0.94	0.23	4.13	<.001
SCI_AVE, γ_{30}	12.08	0.25	48.65	<.001
SEX, γ_{40}	1.44	0.20	7.16	<.001

Random Effects	Variance	df	χ^2	p-value
intercept 1, u_{0j}	14.46	44	297.85	<.001
LVL_3 slope, u_{1j}	2.18	59	108.63	<.001
N_SCI_CO slope, u_{2j}	1.22	59	88.25	<.001
SCI_AVE slope, u_{3j}	2.62	59	135.38	<.001
SEX slope, u_{4j}	1.18	59	91.19	<.05
level 1, r_{ij}	54.30			

Summary

In determining factors that affect student chemistry achievement the unrestricted model, using hierarchical linear modelling, showed 85% of the variance in achievement at the student-level and 15% at the teacher/school-level. When variables dealing with teacher qualifications were included in the model there were no significant relationships determined and there was no decrease in the between teacher/school-variance. When the variable prior achievement was included in the model, by itself, it showed a significant positive relationship with chemistry achievement and also accounted for 69% of the within-school variance. The inclusion of all student-level variables further reduced the within-school variance a further 11% and all variables, with the exception of student choice to do advanced mathematics, showed a significant relationship with student achievement. The final model included all student-level variables, with the exception of student choice to do advanced mathematics, and all teacher/school-level variables. The student-level variables used again showed a significant relationship with only two teacher/school-level variables providing a statistically significant relationship. These teacher/school-level variables included class size (negatively) and teacher teaching in the same school (positively). The inclusion of all teacher/school-level variables also reduced the between-school variance a further 11%.

CHAPTER 5

CONCLUSION and IMPLICATIONS

Summary

The primary interest of this study was to determine the relationship between teacher subject matter knowledge and student achievement. This was examined in the context of many student-level variables and teacher/school-level variables.

The theoretical basis of this study is largely based on the model developed by Walberg and his colleagues (Fraser et al., 1987; Wang, Haertel, & Walberg, 1990. 1993). The development of this educational productivity model included only those factors that were determined to have the greatest effect on student learning. This model converged on nine groups of factors that included ability, development, motivation, quantity and quality of instruction, home environment, classroom or school environment, peer group environment, and mass media environment. Since the development of the model there has been a great emphasis on testing it. This research has supported the model to a great extent.

The variables used in this study were at two levels; the student-level, and the teacher/school-level. Student-level variables included grade level, number of science courses completed, gender, choice to do advanced mathematics, prior science average, and chemistry achievement. Teacher/school-level variables included teacher possession of

BEd. BSc, MEd, and/or chemistry major, class size, percent of teacher time teaching chemistry, percent of teachers in a school that are male, proportion of school population doing advanced mathematics, student population of school. location of school (rural/urban), teacher years experience, age, and gender, school science average, type of school (is it a senior high), and is the teacher new to the school.

Given that the data was multilevel in nature, hierarchical linear modelling (HLM) was the statistical technique used in the analysis. Six hierarchical linear models were used in searching for significant relationships.

Initially an unrestricted model was run to determine the proportion of variance in student chemistry achievement at the student-level and the proportion at the teacher/school-level. This model showed 85% of the variance at the student-level and 15% at the teacher/school-level. Since teacher subject matter knowledge was of primary interest in this study, the next model sought to determine the effect the teacher possession of a chemistry major had on the results. This variable was included in the level 2 model and the results indicated no significant relationship between the variable and student achievement in chemistry. There was also no decrease in the between teacher/school-variance indicating that this variable did not explain any of this variance. When all teacher characteristics were included in the level 2 model again there were no significant relationships determined and no decrease in the between teacher/school-variance.

Prior achievement has generally been a good predictor of student achievement and was therefore the first student-level variable examined. When this variable was included in the model by itself it showed a significant positive relationship with student chemistry achievement. It also accounted for 69% of the within-school variance. When all student-level variables were included in the model again prior achievement proved to have the greatest effect. Yet all student-level variables, with the exception of student choice to do advanced mathematics, showed some significant relationship. The inclusion of all student-level variables further reduced the within-school variance 11%.

The final model included all student-level variables, with the exception of student choice to do advanced mathematics, and all teacher/school-level variables. Again all student-level variables were shown to be significant. The only teacher/school-level variables to provide a statistically significant relationship were class size (negatively) and teacher teaching in the same school (positively). The inclusion of all teacher/school-level variables also reduced the between-school variance a further 11%.

Conclusion and Implications

This study suggests that educational productivity is associated primarily by individual-level factors. Four of the five student-level variables used showed to be significant whereas only two of the fifteen teacher/school-level variables showed any significance. Also most of the variance in chemistry achievement accounted for was at the student-level rather than the teacher/school-level.

Student-level variables significantly associated with chemistry achievement were prior achievement, sex, number of science courses taken and grade level of student. Of these prior achievement certainly had the greatest effect, which is consistent with prior research. Prior achievement accountd for the greatest reduction of within-school variance.

The inclusion of prior achievement in the model reduced the within-school variance by 69%, whereas the inclusion of the remainder of the student-level variables reduced the variance only a further 11%.

The number of science courses completed (a measure of aptitude and motivation) is a student characteristic, like prior achievement, that a student's current teacher may have little immediate impact upon. The differences in achievement between males and females however is something that chemistry teachers may have some control over. Recent research shows that boys and girls do not necessarily receive the same kinds of science related experiences, even when they are in the same classes. Boys generally demand and receive more attention from teachers. This includes being allowed to call out answers more often than girls, receiving more feedback than girls as well as using science equipment and performing science activities more than girls (Jones & Wheatly, 1989, 1990; Kahle & Lakes, 1983; Whyte, 1984). Teachers should give these findings serious consideration and respond appropriately.

The higher achievement in chemistry by level 3 students over level 2 students is something already discussed. Again schools may want to consider adjusting schedules such that the more difficult classes (such as chemistry 3202) are left until the final year, when the a student has a greater chance of success.

Of the fifteen teacher-school-level variables incorporated into the model only two showed to impact significantly. As was discussed earlier smaller class size and teacher stability or continuity showed a positive association with chemistry achievement.

From the six HLM models used it can be seen (as reported in Table 5.1) that the highest proportion of variation in chemistry achievement is at the student-level and student-level variables are most useful in accounting for any of the variance.

Table 5.1

Variance Components Analysis

Model	Within-school variance (σ^2)	Percentage reduction in variance	Between-school variance (τ_{00})	Percentage reduction in variance
Unrestricted	192.88		35.00	
Chemistry Major	192.86		35.26	
Teacher characteristics	192.93		35.46	
Prior achievement	60.59	69	20.00	43
Student Variables	53.90	72	18.03	48
Full model	54.30	72	14.46	59

Again from the unrestricted model the within-school variance accounts for the highest proportion of variance in chemistry achievement (85%). It is only with the addition of prior achievement that this within school variance gets reduced to any degree. The addition of other student-level variables further reduce this variance by 3%. The between-school variance is reduced with the addition of student prior achievement and reduced a further 5% with the addition of all student-level variables. The inclusion of teacher/school-level variables into the full model only explains a further 3% of the variance.

It would appear from this study that teacher specialization, and generally teacher qualifications, does not have an impact on student achievement. There are two possible ways of interpreting this finding. One possible interpretation would be that most, if not all, teachers in the study had at least a minimum amount of subject matter knowledge in the area of chemistry, that is there is little significant variation. This subject matter knowledge may have come through academic preparation and/or teaching experience. Maybe all that is required to teach a particular science course effectively is a minimum amount of subject matter knowledge. Anything above this minimum amount of knowledge has a negligible effect.

The other possible explanation would be that the public examinations did not reveal the significant impact teacher subject matter knowledge or other teacher characteristics had on chemistry students. The possession of a chemistry major, or extensive chemistry knowledge, may actually affect a student's attitude toward chemistry or a student's future success in the area of chemistry. These aspects were not part of this study and therefore there is no evidence to support the proposal. However this is an area of the research that could be examined later. What exactly are the effects of teacher qualifications on student achievement?

A limitation of this study that may be addressed in future research is the measure used for teacher subject matter knowledge. Teacher possession of a major in a subject area. although relevant to subject matter knowledge, is not a perfect measure for what Shulman (1986a;1986b) termed pedagogical content knowledge. Subject matter knowledge is just one component of this. Concept mapping, teacher observation, and questioning the teacher with respect to planning, reflections are some techniques that may be used to get a more complete representation of teacher subject matter knowledge and pedagogical content knowledge.

REFERENCES

Abd-El-Khalick, Fouad, & BouJaoude, Saouma. (1997). An exploratory study of the knowledge base for science teaching. Journal of Research in Science Teaching, 34(7) 673-699.

Anderson, Ronald D. (1983). A consolidation and appraisal of science meta-analyses. Journal of Research in Science Teaching, 20(5) 497-509.

Anderson, Ronald D. & Mitchner, Carole P. (1994). Research on science teacher education. In D. Gabel (Ed.). Handbook of Research on Science Teaching and Learning (pp 3-45). New York: Macmillan.

Ball, D.L. (1991). Research on teaching mathematics: Making subject matter knowledge part of the equation. In Brophy, J. (Ed.), Advances in Research on Teaching, Volume 2. (pp. 1-48). Michigan: JAI Press.

Ball, D.L., & Feiman-Nemser, S. (1988). Using textbooks and teacher guides: A delima for beginning teachers and teacher educators. Curriculum Inquiry, 18(4) 401-423.

Ball, Deborah Loewenberg, & McDiarmid, G. Williamson. (1990). The subject-matter preparation of teachers. In W. Houston (Ed.). Handbook of Research on Teacher Education (pp 437-449). New York: Macmillan.

Barba, Robertta H., & Rubba, Peter A. (1992). A comparison of preservice and in-service earth and space science teachers' general mental abilities, content knowledge, and problem-solving skills. Journal of Research in Science Teaching, 29(10), 1021-1035.

Bloom, B.S. (1976). Human Characteristics and School Learning. New York: McGraw-Hill.

Borko, H., & Livingston, C. (1989). Cognition and improvisation: Differences in mathematics instruction by expert and novice teachers. American Educational Research Journal. 26(4), 473-498.

Brunkhorst, Bonnie J. (1992). A study of student outcomes and teacher characteristics in exemplary middle and junior high science programs. Journal of Research in Science Teaching, 29(6) 571-583.

Bryk, A.S., Raudenbush, S.W., Seltzer, M., & Congdon, R.T. (1989). An Introduction to HLM: Computer program and users' guide. Chicage IL. University of Chicago Press. (Available from Scientific Software in the USA)

Bryk, A.S., & Raudenbush, S.W. (1992). Hierarchical Linear Models: Applications and Data Analysis Methods. Newbury Park, CA: Sage.

Burstein, L. (1980). The analysis of multilevel data in educational research and evaluation. Review of Research in Education. 8, 158-233.

Carroll, J.B. (1963). A model of school learning. Teachers College Record, 64, 722-733.

Chidolue, Mary E. (1996). The relationship between teacher characteristics, learning environment and student achievement and attitude. Studies in Educational Evaluation, 22(3), 263-274

Conant, J. (1963). The Education of American Teachers. New York: Mcgraw-Hill.

DeRose, James V., Lockard, J. David, & Paldy Lester G. (1979). The teacher is the key: a report on three NSF studies. The Science Teacher, 46(4), 31-37.

Doby. D.C., & Schafer, L.E. (1984). The effects of knowledge on elementary science inquiry teaching. Science Education, 68 39-51

Druva, C.A., & Anderson, R.D. (1983). Science teacher characteristics by teacher behavior and by student outcome: A meta-analysis of research. Journal of Research in Science Teaching. 20(5), 467-479.

Evan. Ruhama, & Tirosh, Dina. (1995). Subject-matter knowledge and knowledge about students as sources of teacher presentations of the subject-matter. Educational Studies in Mathematics, 29, 1-20

Feiman-Nemser, Sharon, & Parker, Michelle B. (1990). Making subject matter part of the conversation in learning to teach. Journal of Teacher Education, 41(3), 32-43.

Fraser, B.J., Walberg, H.J., Welch, W.W., & Hattie, J.A. (1987). Synthesis of educationla productivity research. International Journal of Educational Research, 11(2), 73-145.

Garnett, Patrick J. & Tobin, Kenneth. (1988). Teaching for understanding: Exemplary practice in high school chemistry. Journal of Research in Science Teaching, 26(1), 1-14.

Glaser. R. (1976). Components of a psychology of instruction: Toward a science of design. Review of Educational Research, 46, 1-24.

Grossman, Pamela. (1991). Mapping the terrain: Knowledge growth in teaching. In Waxman, Hersholt C., & Walberg, Herbert J. (Eds.) Effective Teaching: Current Research (pp. 203-215) Berkeley: McCutchan

Grossman, Pamela L., Wilson, Suzanne M., & Shulman, Lee S. (1989). Teachers of substance: Subject matter knowledge for teaching. In M.Reynolds (ed.). Knowledge Base for Beginning Teachers (pp.23-36). New York: Pergamon.

Gudmundsdottir, Sigrun. (1990). Values of pedagogical content knowledge. Journal of Teacher Education, 41(3), 44-52.

Haertel, G.D., Walberg, H.J., & Weinstein, T. (1983). Psychology models of educational performance: Atheoretical synthesis of constructs. Review of Educational research, 53, 75-91.

Haidar, Abdullateef H. (1997). Prospective Chemistry teachers' conceptions of the conservation of matter and related concepts. Journal of Research in Scince Teaching, 34(2), 181-197.

Happs, J.C. (1987). "Good" teaching of invalid information: Exemplary junior secondary science teachers outside their field of expertise. In K. Tobin & B.J. Fraser (Eds.), Exemplary practice in Science and Mathematics Teaching. Perth: Curtain University of Technology.

Hashweh, Maher Z. (1987). Effects of subject-matter knowledge in the teaching of biology and physics. Teaching and Teacher Education, 3(2), 109-120.

Hashweh, Maher Z. (1996). Effects of science teachers' epistemological beliefs in teaching. Journal of Research in Science Teaching, 33(1), 47-63.

Heikkinen, Michael W. (1988). The academic preparation of idaho science teachers. Science Education, 72(1), 63-71

Jones, M.G., & Wheatley, J. (1989). Gender influences in classroom displays and student-teacher behaviors. Science Education, 73(5), 535-545.

Jones, M.G., & Wheatley, J. (1990). Gender differences in student-teacher interactions in science classrooms. Journal of Research in Science Teaching, 27(9), 861-874.

Kahle, J.B., & Lakes, M.K. (1983). The myth of equality in scince classrooms. Journal of Research in Science Teaching, 20(2), 131-140.

Kennedy, Mary M. (1998). Education reform and subject matter knowledge. Journal of research in Science Teaching, 35(3), 249-263.

Lantz, Oliver, & Kass, Heidi. (1987). Chemistry teachers' functional paradigms. Science Education, 71(1), 117-134.

Lederman, Norman G., & Gess-Newsome, Julie. (1992). Do subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge constitute the ideal gas law of science teaching? Journal of Science Teacher Education 3(1). 16-20.

Lederman, Norman G., Gess-Newsome, Julie, & Latz, Mark S. (1994). The nature and development of preservice science teachers' conceptions of subject matter and pedagogy. Journal of Research in Science Teaching, 31(2), 129-146.

Lee, Okhee. (1995). Subject matter knowledge, classroom management, and instructional practices in middle school science classrooms. Journal of Research in Science Teaching 32(4), 423-440.

Leinhardt, G., & Greeno, J. G. (1986). The cognitive skill of teaching. Journal of Educational Psychology. 78 (2), 75-95.

Leinhardt, Gaea, & Smith, Donald A. (1985). Expertise in mathematics instruction: Subject matter knowledge. Journal of Educational Psychology, 77(3), 247-271.

Leinhardt, G., Putnam, R.T., Stein, M.K., & Baxter, J. (1991). Where subject knowledge matters. In Brophy, J. (Ed.), Advances in Research on Teaching, Volume 2. (pp. 87-113). Michigan: JAI Press.

Lewin. Kurt. (1963). Field Theory in Social Science. London: Tavistock.

Malone. M.R., & Fleming, M.L. (1983). The relationship between student characteristics and student performance as viewed by meta-analysis research. Journal of Research in Science Teaching 20(5), 481-495.

Marks. Rick. (1990). Pedagogical content knowledge: From a mathematical case to a modified conception. Journal of Teacher Education, 41(3), 3-11.

McDiarmid, G. Williamson, Ball, Deborah Loewenberg, & Anderson, Charles W. (1989). Why staying one chapter ahead doesn't really work: Subject-specific pedagogy. In M.Reynolds (ed.). Knowledge Base for Beginning Teachers (pp.193-205). New York: Pergamon.

Monk. David H. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. Economics of Education Review, 13(2), 125-145.

Mullens, John E., Murnane, Richard J., & Willett, John B. (1996). The contribution of training and subject matter knowledge to teaching effectiveness: A multilevle analysis of longitudinal evidence from Belize. Comparative Education Review, 40(2), 139-157.

Perkes, Victor A. (1975). Relationships between a teachers background and sensed adequacy to teach elementary science. Journal of Research in Science Teaching, 12(1), 85-88.

Peters, R.S. (1977). Education and the Education of Teachers. London: Routledge & Kegan Paul.

Raudenbush, S.W. (1988). Educational applications of hierarchical linear models: A review. Journal of Educational Statistics, 13(2), 85-116.

Raudenbush, S.W., & Byrk, A.S. (1986). A hierarchical model for studying school effects. Sociology of Education, 59, 1-17

Reynolds, A.J., & Walberg, H.J. (1991). A structural model of science achievement. Journal of Educational Psychology, 83(1), 97-107.

Sanders, Linda R, Borko, Hilda, & Lockard, J. David. (1993). Secondary science teachers' knowledge base when teaching science courses in and out of their area of certification. Journal of Research in Science Teaching, 30(7), 723-736.

Stodolsky, Susan S., & Grossman, Pamela L. (1995) The impact of subject matter on curricular activity: An analysis of five academic subjects. American Educational Research Journal, 32(2), 227-249.

Shulman, L.S. (1986a). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4-14.

Shulman, L.S. (1986b). Paradigms and research programs in the study of teaching: A contemporary perspective. In M.C. Wittrock (Ed.), Handbook of Research on Teaching (3rd ed., pp. 3-36). New York: Macmillan.

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57(1), 1-22.

Tobin, Kenneth, & Fraser, B.J. (1990). What does it mean to be an exemplary science teacher? Journal of Research in Science Teaching, 27(1), 3-25.

Tobin, Kenneth, & Fraser, B.J. (1991). Learning from exemplary teachers. In Waxman, Hersholt C., & Walberg, Herbert J. (Eds.) Effective Teaching: Current Research (pp. 217-236) Berkeley: McCutchan.

van Driel, J.H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. Journal of Research in Science Teaching. 35(6). 673-695.

Walberg, H.J. (1981). A psychological theory of educational productivity. In F.H. Farley and N. Gordon (Eds.), Psychology and Education (pp.81-110). Chicago: National Society for the Study opf Education.

Walberg, H.J. (1986). Synthesis of research on teaching. In M.C. Wittrock (Ed.), Handbook of Research on Teaching (3rd ed., pp. 214-229). New York: Macmillan.

Walberg, H.J., Fraser, B.J., & Welch, W.W. (1986). A test of a model of educational productivity among senior high school students. Journal of Educational Research, 79(3), 133-139.

Wang, M.C., Haertel, G.D., & Walberg, H.J. (1990). What influences learning? A content analysis of review literature. Review of Educational Research. 84(1), 30-43

Wang, M.C., Haertel, G.D., & Walberg, H.J. (1993). Toward a knowledge base for school learning. Review of Educational Research. 68(3), 249-294.

Whyte, J. (1984). Observing sex stereotypes and interactions in the school lab and workshop. Educational Review, 36(1), 75-86.

Wittrock, M.C. (Ed.). (1986). Handbook of Research on Teaching (3rd ed.). New York: Macmillan.

Young, D.J., & Fraser, B.J. (1994). Gender differences in science achievement: Do school effects make a difference. Journal of Research in Science Teaching, 31(8), 857-871.