

THE EFFECTS OF ACCELERATION ON STUDENTS'  
ACHIEVEMENT IN SENIOR SECONDARY  
MATHEMATICS:  
A MULTILEVEL MODELLING APPROACH

by

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## ABSTRACT

### THE EFFECTS OF ACCELERATION ON STUDENTS' ACHIEVEMENT IN SENIOR SECONDARY MATHEMATICS: A MULTILEVEL MODELLING APPROACH

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Despite the vast research on the effects of acceleration programs on student achievement there is little quantitative confirmation of the benefits of these programs and there is no research that investigates the effects of acceleration on students' VCE Mathematics study scores.

This research attempts to fill this gap by considering four years of data provided by the Victorian Curriculum and Assessment Authority (VCAA) relating to achievement in mathematics. Acceleration in this study means the completion of the Year 12 Mathematical Methods study during Year 11. The data constitutes experimental data for content acceleration and the results of students from schools without such acceleration programs provide the corresponding control data. However, the acceleration decision is not taken randomly by schools, so this data is only quasi-experimental in nature. The measures of mathematical achievement (Mathematical Methods and Specialist Mathematics study scores) are carefully audited, and are accepted as reliable and valid by the Victorian education system. Controlling for individual characteristics such as gender and prior knowledge, and allowing for moderation effects due to school sector

(Government, Catholic and Independent) and school class setting (single-sex or coeducational), the effects of content acceleration are measured using multi-level modelling.

This study examines the effects of acceleration on the VCE Mathematics study scores of students who completed both Mathematical Methods (Units 3&4) and Specialist Mathematics (Units 3&4) in Victoria, over a four-year period (2001-2004). On average this involved 5341 students from 341 schools in each year with 829 students included in a content accelerated program.

The results suggest that content acceleration is beneficial, especially for students with higher prior knowledge scores. The quasi-experimental nature of the data means that a causal relationship between acceleration and students' mathematical performance can be claimed. In particular, this study showed that the effect of acceleration on students' Mathematical Methods (the Year 12 study taken in Year 11 by accelerated students) study score was not significant. However, the effect of acceleration on students' Specialist Mathematics study scores was significant. Accelerated students performed, on average, 2.7 points higher (on a 50 point scale) than equal ability age-peers who were not accelerated. Interestingly, for accelerated students who scored in the top 2% for their General Achievement Test, in the mathematics, science and technology component, their Specialist Mathematics study scores were on average, almost 5 points higher (on a 50 point scale) than their equal ability age-peers. The statistical control of other factors means that these results can also be generalised to other states, other countries and, probably, to other subjects.

This is to certify that this thesis contains no material which has been submitted for examination in any other course or accepted for any other award of any other degree or diploma in any tertiary institution and to the best of my knowledge and belief contains no material previously published or written by another person except where due reference is made in the text.

SIGNED.....

ANGELA KOTSIRAS





## DEDICATION

To my loving, caring, supportive and most considerate husband Nicholas Kotsiras who believed in me and encouraged me to continue unrelentingly on this academic path. To my loving children Stavroula (25), Costa (24) and James (16) who have always supported my efforts to complete my thesis and have accepted the fact that it would mean less time to spend with them. Special thanks to Stavroula who spent several hours reading this thesis and providing invaluable feedback. Her assistance with the formatting of this thesis was greatly appreciated.

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## LIST OF TABLES

Table 1: Total scores and weightings of graded assessments for MM and SM (2001-2004)...	5
Table 2: Like School Group .....	9
Table 3: Levels of intellectual giftedness .....	31
Table 4: Measurement of Outcome Variables .....	58
Table 5: Measurement of Predictor Variables .....	58
Table 6: Distribution of Student Gender .....	62
Table 7: Distribution of School Sector .....	62
Table 8: Distribution of accelerated students .....	62
Table 9: Distribution of students in single-sex and co-educational class settings .....	63
Table 10: Distribution of students for the years 2001-2004.....	63
Table 11. Distribution of students based on gender, acceleration and year of completion of VCE.....	64
Table 12: Summary of distribution of students based on acceleration, gender, class setting and sector .....	65
Table 13: Chi-squared tests.....	66
Table 14: Nominal directional measures .....	66
Table 15: Descriptive statistics for continuous variables .....	67
Table 16: Correlations for MM, SM and GATMST .....	76
Table 17: A summary of the measurement bases of the LSG variable.....	81
Table 18: Overall summary of student numbers.....	84
Table 19: Overall summary of mean scores.....	85
Table 20: Descriptives of level 1 and 2 variables for MM (2001).....	91
Table 21: Final estimation of fixed effects for MM based on Model 1(2001).....	91
Table 22. Final estimation of variance and covariance components for MM (2001) .....	92
Table 23: Exploratory Analysis to obtain estimated level-2 coefficients and their standard errors for MM (2001).....	93

Table 24: Final estimation of fixed effects for SM based on Model 2 (2001).....	95
Table 25: Final estimation of fixed effects for SM based on Model 3 (2001).....	97
Table 26: Descriptives of level 1 and 2 variables (2002).....	99
Table 27: Final estimation of fixed effects for MM based on Model 1 (2002).....	100
Table 28: Final estimation of fixed effects for SM based on Model 2 (2002).....	101
Table 29: Final estimation of fixed effects for SM based on Model 3 (2002).....	102
Table 31: Final estimation of fixed effects for MM based on Model 1 (2003).....	104
Table 32: Final estimation of fixed effects for SM based on Model 2 (2003).....	106
Table 33: Final estimation of fixed effects for SM (2003).....	107
Table 34: Descriptives of level 1 and 2 variables (2004).....	109
Table 35: Final estimation of fixed effects for MM based on Model 1 (2004).....	109
Table 36: Final estimation of fixed effects for SM based on Model 2 (2004).....	110
Table 37: Final estimation of fixed effects for SM based on Model 3 (2004).....	112
Table 38: HLM Analysis Significant Coefficients (** $p \leq 0.001$ , * $p \leq 0.05$ ).....	114
Table 39: Descriptives of level-1 and level-2 variables for 2001-2002.....	117
Table 40: Students with GATMST above 45 based on gender and acceleration from 2001- 2002 data.....	118
Table 41: Descriptives of level-1 and level-2 variables for 2003-2004.....	118
Table 42: Students with GATMST above 45 based on gender and acceleration from 2003-2004 data.....	119
Table 49: Summary of results for students with GATMST above 45 (2001-2002).....	120
Table 50: Summary of results for students with GATMST above 45 (2003-2004).....	121
Table 51: Level One Error Variances.....	122
Table 52: HLM Analysis Significant Coefficients for GATMST above 45 (** $p \leq 0.001$ , * $p \leq 0.01$ ).....	123
Table 43: Final estimation of fixed effects for MM (2001-2002) with GATMST above 45- Model 1.....	164

Table 44: Final estimation of fixed effects for SM based on Model 2 (2001-2002).....	164
Table 45: Final estimation of fixed effects for SM based on Mode 3 (2001-2002).....	164
Table 46: Final estimation of fixed effects for MM based on Model 1 (2003-2004).....	165
Table 47: Final estimation of fixed effects for SM based on Model 2 (2003-2004) with GATMST above 45 .....	165
Table 48: Final estimation of fixed effects for SM based on Model 3 (2003-2004) with GATMST above 45 .....	165

LIST OF FIGURES

Figure 1: Model 1 - MM..... 59

Figure 2: Model 2. - SM ..... 59

Figure 3: Model 3. – SM (Including MM as a predictor) ..... 60

Figure 4: Model 1 - Proposed model to predict MM study scores..... 88

Figure 5: Model 2 - Proposed model to predict SM study scores ..... 89

Figure 6: Model 3 - Proposed model to predict SM study scores (incl. MM as a predictor)89

Figure 7: Final model for estimating MM study scores based on Model 1 (2001)..... 94



## LIST OF GRAPHS

<i>Graph 1:</i> Normality of Specialist Mathematics scores.....	68
<i>Graph 2:</i> Normality of Specialist Mathematics scores based on GATMST above 45.....	68
<i>Graph 3:</i> Normality of Mathematical Methods scores .....	69
<i>Graph 4:</i> Normality of Mathematical Methods scores based on GATMST above 45.....	69
<i>Graph 5:</i> Normality of General Achievement Test (Mathematics/Science/Component) (GATMST).....	70
<i>Graph 6:</i> Normal Q-Q plot for the distribution of MM scores for the period 2001-2004...	70
<i>Graph 7:</i> Normal Q-Q plot for the distribution of SM scores for the period 2001-2004 ....	71
<i>Graph 8:</i> Normal Q-Q plot for the distribution of GATMST scores for the period 2001- 2004.....	71
<i>Graph 9:</i> Normal Q-Q plot for the distribution of MM scores (GATMST above 45) for the period 2001-2004 .....	72
<i>Graph 10:</i> Normal Q-Q plot for the distribution of SM scores (GATMST above 45) for the period 2001-2004 .....	72
<i>Graph 11:</i> Scatterplots of the MM and GATMST variables for each of the years 2001-2004, based on acceleration.....	73
<i>Graph 12:</i> Scatterplots of the SM and GATMST variables for each of the years 2001-2004, based on acceleration.....	74
<i>Graph 13:</i> Scatterplots of the MM and SM and Accelerated scores for each of the years 2001-2004.....	75
<i>Graph 14:</i> Line graphs showing mean MM scores for each sector .....	79
<i>Graph 16:</i> Line graphs showing mean MM scores for each gender.....	80
<i>Graph 17:</i> Line graphs showing mean SM scores for each gender.....	80
<i>Graph 18:</i> Boxplots showing the distribution of MM study scores amongst LSG schools..	82
<i>Graph 19:</i> Boxplots showing the distribution of SM study scores amongst LSG schools ...	83

## TABLE OF CONTENTS

Chapter 1 Introduction .....	1
Background Knowledge .....	3
The VCE and the Mathematics Studies.....	3
VCE Mathematics Assessment.....	4
<i>Study Scores</i> .....	5
General Achievement Test (GAT).....	6
The Equivalent National Tertiary Entrance Rank (ENTER) .....	7
Like Schools.....	8
Accelerated Students .....	10
Acceleration programs .....	10
Statement of the Problem .....	12
Purpose and Objectives.....	14
Hypotheses of the study.....	16
Research Hypothesis 1.....	16
<i>Reasons</i> .....	16
Research Hypothesis 2.....	17
<i>Reasons</i> .....	17
Scope of the study.....	18
Significance of the Study .....	18
Limitations of the Study.....	20
Assumptions.....	24
Overview of the Study.....	25
Chapter 2 Literature Review.....	27
The Literature.....	27

Meaning of giftedness .....	29
Acceleration and students' academic achievement .....	31
Previous methodology.....	35
Conclusion.....	37
Chapter 3 Methodology .....	39
Preface.....	39
Hierarchical populations .....	40
Software programs for multi-level modelling .....	41
Analysis of multi-level data.....	41
Method.....	48
Design of the study.....	48
Research Questions .....	50
Data.....	50
Sample.....	52
Developing the Model.....	53
Variables .....	54
<i>Student outcomes (MM and SM study scores)</i> .....	54
<i>Acceleration</i> .....	55
<i>Prior knowledge</i> .....	55
<i>Other factors</i> .....	57
Chapter 4 Results .....	61
Descriptive analysis .....	61
Categorical variables .....	61
<i>Tests for Independence</i> .....	66
Continuous variables .....	67
<i>Normality</i> .....	67

<i>Linearity and homoscedasticity</i> .....	72
<i>Correlation analysis</i> .....	75
<i>A comparison of mean scores</i> .....	78
<i>A comparison of Like School Groups (LSG)</i> .....	81
Multi-level Analysis .....	86
The Research Questions .....	87
Statistical Analysis (2001).....	90
<i>Analysis for MM based on Model 1 (2001)</i> .....	90
<i>Summary for Question 1 based on Model 1(2001)</i> .....	94
<i>Analysis for SM based on Model 2 (2001)</i> .....	95
<i>Summary for Question 2 based on Model 2 (2001)</i> .....	96
<i>Analysis for SM based on Model 3 (2001)</i> .....	97
<i>Summary for Question 2 based on Model 3 (2001)</i> .....	97
Statistical Analysis (2002).....	98
<i>Analysis for MM based on Model 1 (2002)</i> .....	98
<i>Summary for Question 1 based on Model 1 (2002)</i> .....	100
<i>Analysis for SM based on Model 2 (2002)</i> .....	101
<i>Summary for Question 2 based on Model 2 (2002)</i> .....	101
<i>Analysis for SM based on Model 3 (2002)</i> .....	102
<i>Summary for Question 2 based on Model 3 (2002)</i> .....	102
Statistical Analysis (2003).....	103
<i>Analysis for MM based on Model 1 (2003)</i> .....	103
<i>Summary for Question 1 based on Model 1 (2003)</i> .....	105
<i>Analysis for SM based on Model 2 (2003)</i> .....	106
<i>Summary for Question 2 based on Model 2 (2003)</i> .....	106
<i>Analysis for SM based on Model 3 (2003)</i> .....	107
<i>Summary for Question 2 based on Model 3 (2003)</i> .....	107

Statistical Analysis (2004).....	108
<i>Analysis for MM based on Model 1 (2004)</i> .....	108
<i>Summary for Question 1 based on Model 1 (2004)</i> .....	110
<i>Analysis for SM based on Model 2 (2004)</i> .....	110
<i>Summary for Question 2 based on Model 2 (2004)</i> .....	111
<i>Analysis for SM based on Model 3 (2004)</i> .....	112
<i>Summary for Question 2 based on Model 3 (2004)</i> .....	112
<i>Summary of Multi-level Analysis (2001-2004)</i> .....	113
Data analysis with GATMST scores above 45.....	116
<i>Descriptive statistics</i> .....	117
<i>Summary of Multi-level Analysis (2001 – 2002 and 2003 – 2004)</i> .....	119
<i>Summary of Multi-level Analysis (2001 – 2004)</i> .....	122
Reliability, validity and generalisability .....	124
Reliability.....	124
Validity.....	125
Generalisability.....	125
Conclusion.....	125
Chapter 5 Summary, findings and implications.....	127
Summary.....	127
Findings.....	128
Limitations.....	130
Implications for further research .....	131

References .....	133
Appendix A. Aims and Structure of the Mathematics Studies .....	141
Appendix B. The Equivalent National Entrance Rank (ENTER) .....	145
Appendix C. A Questionnaire on Acceleration in Mathematics .....	151
Appendix D. Tables 43 - 48 .....	163

# Chapter 1

## Introduction

No paradox is more striking than the inconsistency between research findings on acceleration and the failure of our society to reduce the time spent by superior students in formal education. – M. J. Gold, *Education of the Intellectually Gifted* (1965)

Despite the plethora of research over the past 80 years, beginning with Terman's longitudinal study in 1925 (Hewton, 2002), the debate amongst educators, administrators and policy makers, about the benefits of acceleration programs in meeting the needs of highly-talented and gifted students, is still continuing. Reviewers of controlled studies have found positive results in relation to the effects of acceleration in terms of student educational and cognitive outcomes. Yet the impact of the research literature on educational decision-making seems limited and there continues to exist great reluctance to implement acceleration programs in schools (Mackenzie-Sykes, 1996).

Over the last 20 years a number of schools in Victoria have implemented acceleration programs to meet the needs of their highly-talented students. However, there is a concern amongst educators, administrators and policy makers, that students who are accelerated will under-perform in their VCE Mathematical Methods study, by completing it a year earlier, compared to their equal ability age-peers who do not participate in an acceleration program and complete this study a year later. If this were true, it would also mean that accelerated students will be disadvantaged in terms of their ENTER scores. Having lower ENTER scores than their age-peers of equal ability who were not accelerated may deny them the same options for course selection at tertiary level. Furthermore with league tables on school performance, becoming more accessible to the

public domain, there are a number of schools in Victoria which are inclined to not offer acceleration programs so that their top students will supposedly perform better in Year 12.

This study provides empirical evidence on the effects of acceleration on students' mathematics achievement (measured in terms of the VCE Mathematics study scores) at senior secondary level. It is assumed that students, who have participated in an acceleration program, have been appropriately selected. A major strength of this study is that the design can legitimately be described as quasi-experimental with control groups at the student and school level and with the study employing analysis of pre-existing data, using the State of Victoria as its 'laboratory'. Experimental designs are difficult to implement in education, but, when possible, can provide compelling evidence of significant differences.

The results of this study, which may be generalised to any other State of Australia or even anywhere in the world where acceleration programs are implemented, will assist educators, administrators and policy makers to make more informed decisions about the implementation of acceleration programs, in particular when considering the effects of acceleration on students' performance in a senior mathematics program.

This chapter will begin by providing background details on how the final two years of secondary schooling in Victoria are structured. Particular focus is provided on the types of mathematics studies offered at this level and how students are assessed. An outline of the structure of the General Achievement Test (GAT), which is undertaken by all students in their last year of schooling, will also be provided. Following this, an explanation of what is meant by the Equivalent National Tertiary Entrance Rank



(ENTER) is provided together with information on how schools are classified into 'Like Schools'. An outline is provided of what is meant by 'accelerated students', how they are identified in this study and the possible acceleration programs undertaken by these students, followed by the statement of the problem, the purpose and objectives, the research hypotheses, the scope and significance of the study, including its limitations and assumptions. In concluding this chapter an overview of the study will be presented.

## Background Knowledge

### *The VCE and the Mathematics Studies*

In Victoria, students entering Year 11 of secondary schooling are beginning the first of a two year course of study, the Victorian Certificate of Education (VCE). The parameters of the course are set by the Victorian Curriculum and Assessment Authority (VCAA) (formerly known as Board of Studies, Victoria, BOS or VBOS), which lead to the achievement of VCE. This certificate is awarded to students on behalf of the Victorian State Government upon successful completion of Year 11 and 12 which allows and determines entry into tertiary institutions.

In Year 12, students' assessment is based on school coursework and external examinations. Outstanding students can extend their studies by undertaking a university subject, known as an extension study, at Year 12. Although this subject is not a VCE unit it contributes towards both their VCE and a tertiary award. For further details on

*Extension Studies in the VCE* refer to the VCAA (2004) website.

The VCE course is divided into units, each of which is studied for one semester. Units 1&2 are studied in Year 11 and Units 3&4 are studied in Year 12. A number of students include a VCE Unit 3&4 sequence in their Year 11 course. For those studies, such as Mathematics, where Units 1&2 are a prerequisite for Units 3&4, students commence their VCE studies in Year 10 to enable them to include a VCE Unit 3&4 sequence in their Year 11 course. Only those students who excel and are proficient in mathematics may be given this opportunity to accelerate their studies in mathematics.

The objectives and structure of the Mathematics studies, specifically Further Mathematics, Mathematical Methods and Specialist Mathematics can be found in Appendix A. It should be noted that MM Units 3&4 (MM) is considered to be the second most challenging mathematics subject. For the remainder of this thesis, the acronym MM will be used to represent the study, Mathematical Methods Units 3&4 as opposed to Mathematical Methods 1&2 study. MM is intended to provide an appropriate background for further study in tertiary studies such as, science, economics or medicine (VBOS 1999 p.126). SM Units 3&4 (SM) is the most challenging mathematics subject. SM study is intended for students with strong interests in mathematics and for those who wish to undertake further studies in mathematics and related disciplines at tertiary level and beyond. The SM study is normally taken in conjunction with the MM study and the areas of study extend and develop from the MM material. The mathematics curriculum in which students participate is highly sequential and cumulative in nature.

### *VCE Mathematics Assessment*

All VCE studies have three graded assessments for each Unit 3 and 4 sequences. The Mathematics studies have two end-of-year examinations and school-assessed course work.

As mentioned in the VCE Study Design for Mathematics (VBOS, 1999 pp13-14), levels of achievement are assessed through school-assessed coursework and examinations with total scores for each assessment and corresponding weightings as outlined in Table 1 below.

*Table 1: Total scores and weightings of graded assessments for MM and SM (2001-2004)*

Assessment	Total Scores		Weighting (%)
	MM Units 3&4	SM Units 3&4	
School-assessed coursework	100	100	34
Examination: (Facts, Skills and applications)	100	100	33
Examination: (Analysis Task)	110	120	33
Total	310	320	100

Assessment grades are reported on an A+ to E, UG (un-graded) scale. An assessment reported NA means not-assessed. Assessment grades are reported by the VCAA for each VCE study. As the purpose of this study was to study the effects of acceleration on the mathematics study scores of students and as the study scores represented a combination of all three tasks, these graded assessments were not used in the analysis.

### *Study Scores*

As outlined in VTAC (2002), the Victorian Curriculum and Assessment Authority, (VCAA) awards study scores to students who satisfactorily complete units 3& 4 of a VCE study. These study scores give students a ranking in the group (or cohort) of students taking that study across the State of Victoria in that year. The ranking of students in the cohort is determined by detailed evaluation of the students' performances in the graded assessments for that study. A study score of 50 indicates that the student has finished at

the top of the cohort. A study score of 0 indicates that the student has finished at the bottom of the cohort. A study score of 30 indicates that the student has finished in the middle of the cohort. Study scores are awarded so that they cluster around 30. For any study, about 65-70% of students get a study score between 23 and 37. This thesis uses the *study scores* of students, a continuous variable, as a measure of student achievement as they incorporate the assessment tasks for each study.

### *General Achievement Test (GAT)*

As part of the VCE assessment process, the Victorian Curriculum Administrative Authority (VCAA) requires that all students who are enrolled in one or more sequences of Units 3&4 must sit the General Achievement Test (GAT) each year. Any student that has completed a Year 12 subject in Year 11 will have had to sit two GAT tests during their VCE course, one at Year 11 and one at Year 12.

The GAT measures levels of general achievement accomplished across the following areas with the given raw scores of:

- 40 for written communication
- 35 for mathematics/science/technology
- 35 for humanities/arts/social sciences

Students are also provided with a standardised GAT score for each area. The standardised score will be calculated and reported using the same scale that is used for study scores, that is a mean of 30 and a standard deviation of 7. GAT results are used by VCAA to monitor school-assessed coursework and school-assessed tasks. Although GAT results do not count directly towards VCE results, they do play an important role in verifying the school assessed coursework and examinations have been accurately assessed.

As outlined on the VCAA (2004) website, verification can be performed because achievement on the GAT is a good predictor of achievement on other assessments. If students have done well on the GAT, then their achievements are likely to be high on their school assessments and examinations. Clearly, some GAT questions relate more closely to achievement in particular studies. The VCAA takes this into account when it calculates students' expected achievements in each study for each school. For the purposes of this study, the GAT results of student's performance on questions relating to Mathematics, Science and Technology (GATMST) will be used as a measure of prior ability.

### *The Equivalent National Tertiary Entrance Rank (ENTER)*

The ENTER is the estimate of where the student came in their relevant age group, taking into account the students who have successfully completed VCE as well as those who moved or left school before Year 12. The ENTER is a number between 0 and 99.95 in intervals of 0.05. Course selection at tertiary level is determined by a students' ENTER score. The higher the ENTER score the more choices of course selection are available for students. For information about the ENTER, how it is calculated refer to Appendix B (VTAC (2002) booklet: ENTER into Tertiary Study. A Guide to the Equivalent National Tertiary Entrance Rank.)

### *Like Schools*

According to the VCE Data Service User Manual (VCAA, 2002 p.4) a more accurate indication of the school's contribution and the effectiveness of the instruction provided can be obtained by comparing the unadjusted results of a given school in relation to schools that have a similar student profile to the school in question. Such schools are referred to as Like Schools.

In Victoria, use has been made of information relating to the proportions of students from backgrounds of poverty, as measured by the Educational Maintenance Allowance (EMA) or Youth Allowance, and of students from non-English speaking backgrounds (NESB), to categorise schools into 'like' groups. The following extract was taken from the VCE Data Service (VCEDS) User Manual:

“Like Schools are defined as schools with similar populations of students. The measures used to classify like schools are the proportion of students speaking LOTE [languages other than English] at home and the proportion of students receiving Educational Maintenance Allowance (EMA) or Youth Allowances”  
(VCAA 2002, p. 16)

By employing this method to categorise schools into 'Like Schools', it enables the performance of schools to be compared with that of like schools. Data was only available for Government and Catholic schools but not for Independent schools (VCAA, 2002 p.32). There are ten categories of 'Like Schools' and these are shown in Table 2.

Like School groups 3 and 3S have similar populations of students except the group of schools in Like School Group 3S are referred to as Select Entry Schools. These are Government secondary schools that provide a 'Select Entry Accelerated Learning Program' to address the learning needs of their gifted and high potential students who are capable of working at a significantly faster pace and in greater depth than their age peers (SOFWeb, 2004). Table 2 was obtained from the VCEDS user manual (VCAA, 2002 p.17)

Table 2: Like School Group

Group	Proportion of LOTE speakers at home	Proportion of EMA/ Youth Allowance recipients	Description
1	0 to <= 0.04	0 to <= 0.28	Nil or very low proportions of LOTE speakers at home- Low proportions of EMA or Youth Allowance recipients.
2	0.04 to <= 0.26	0 to <= 0.28	Low proportions of LOTE speakers at home-Low proportions of EMA or Youth Allowance recipients.
3	above 0.26	0 to <= 0.28	Medium to high proportions of LOTE speakers at home- Low proportions of EMA or Youth Allowance recipients.
3S(=10)	above 0.26	0 to <= 0.28	Medium to high proportions of LOTE speakers at home- Low proportions of EMA or Youth Allowance recipients (Selective Entry Schools).
4	0 to <= 0.04	0.28 to <= 0.43	Nil or very low proportions of LOTE speakers at home- Medium proportions of EMA or Youth Allowance recipients.
5	0.04 to <= 0.26	0.28 to <= 0.43	Low proportions of LOTE speakers at home- Medium proportions of EMA or Youth Allowance recipients.
6	above 0.26	0.28 to <= 0.43	Medium to high proportions of LOTE speakers at home - Medium proportions of EMA or Youth Allowance recipients.
7	0 to <= 0.04	above 0.43	Nil or very low proportions of LOTE speakers at home - High proportions of EMA or Youth Allowance recipients.
8	0.04 to <= 0.26	above 0.43	Low proportions of LOTE speakers at home - High proportions of EMA or Youth Allowance recipients.
9	above 0.26	above 0.43	Medium to high proportions of LOTE speakers at home - High proportions of EMA or Youth Allowance recipients.

### *Accelerated Students*

In regards to mathematics, students who show extraordinary ability and interest in mathematics are given the opportunity to undertake acceleration programs at some schools. These students usually have a remarkable rate of acquiring and retaining complex information compared to their average ability peers. Such students are often referred to by several names such as highly-able, highly-talented, talented, gifted and precocious. The development of such terms are outlined in more detail in Chapter 2. Although there are differences in these terminologies, confusions in their use particularly between talented and gifted are still evident (Montgomery, 1996; Delisle, 1992 as cited in Avila, 2005). ‘Gifted’ which is usually defined in terms of an individual’s innate intelligence or ability, is more often used synonymously to ‘talented’, although the latter requires individuals to have demonstrated achievement or performance in a particular domain (Montgomery, 1996 as cited in Avila, 2005). The differentiation provided, however, is not clear as ‘gifted’ individuals would need to achieve or perform in their specific domain before he or she is considered to be gifted. Hence achievement and performance is not exclusive to talented individuals. To avoid confusion this study will use the terms highly-able, high-achieving, highly-talented, gifted and precocious, synonymously without any qualitative difference and the concept of ‘gifted’ will be focussed on mathematical ability.

### *Acceleration programs*

Braggett (1992) defines accelerated programs (or acceleration programs) as ‘courses of action that are adopted by schools to meet the needs of ‘accelerated learners’ where accelerated learners are referred to as ‘students who have moved ahead of many of their age peers in one or more aspects of their learning because of the speed at which they work or the depth of understanding of which they are capable’. The operational effects



of acceleration may be defined by the attributes, as provided by Kulik & Kulik (1984), of time compression and speeding up of instruction.

Acceleration programs tend to follow the content mastery model or content model. This model according to VanTassel-Baska (1988) is one of the 'curriculum models that has proven to be successful with gifted populations at various stages of development and various domain-specific areas'. The content model 'emphasises the importance of learning skills and concepts within a predetermined domain of enquiry. Gifted students are encouraged to move as rapidly as possible through the content area; thus content acceleration dominates the application of this model in practice' (VanTassel-Baska, 1988 p.9). A typical approach to this type of model is 'one that presets an early mastery level of students, frequently requiring more advanced skills and concepts to be mastered one year earlier than normal' (VanTassel-Baska, 1988 p.10). This program responds to the rate needs of groups of students, allowing the able to advance quicker through the traditional curriculum.

Content and subject acceleration, as also stated by Southern and Jones (1991, pp2-3) is where the student is placed for a part of a day with students at a more advanced grade level for one or more subjects without being assigned to a higher grade. Subject acceleration has many strengths. It allows students 'to learn material rapidly and understand concepts deeply' (Lynch 1994, p.1). There is little opposition to this type of acceleration because students remain with peers of their own age. The content model or content acceleration according to Braggett (1992) can occur in three forms: Individual Progression; Grouping Practices; and Compacting.

*Individual progression* occurs when students can use self-instruction materials and are permitted to work independently. *Grouping practices* can take the forms of ability groups

where students of like abilities work together, or vertical groups, where students of different ages are placed together so that students that have similar abilities can work together and be stimulated intellectually. *Compacting* allows students to reduce the time spent on routine aspects of the curriculum due to earlier learning or faster learning (Braggett, 1992 p.138).

In this study, it will be assumed that students have been given the opportunity to complete a Year 12 mathematics study a year earlier than their equal ability age peers and have participated in any one or more of the forms of content acceleration outlined above. These students will be referred to as accelerated students throughout this study.

## Statement of the Problem

As cited from the Encouraging Achievement-Gifted Education Resources (EAGER) (2004) website “traditionally less than 5% of the population has had access to gifted and talented programs. Current trends in international thinking involve a broader view of the characteristics of gifted and talented students and a higher proportion of the population possibly as much as 15% will be identified for gifted and talented provision”. This means for every 40000 students, which is the approximate number of students who complete their VCE each year, we can expect 6000 students to have superior ability in one or more areas. In Specialist mathematics, the most challenging mathematics study, there are around 5000-6000 students enrolled each year. Of these students about 2% of the total student cohort have been given an opportunity to participate in an acceleration program. What does this mean about the remaining 13% of gifted and talented students? Was acceleration an option for these students?

Acceleration programs have been introduced into a number of Victorian schools for over a decade. By accelerating students in mathematics it has enabled them to undertake a

Year 12 mathematics study a year early than their age peers. Despite the length of time acceleration programs have been operating, there are still concerns from some educators in these schools that students may not perform as well in this study when completed a year earlier. This was particularly evident from an informal survey completed by 18 Heads of Mathematics from Independent schools of Victoria (see Appendix C). When asked if the acceleration program offered at their school was a success, the majority felt it was successful, however, there were some concerns about the advantages of undertaking a Year 12 mathematics study, namely Mathematical Methods (MM) at Year 11 as highlighted in the statements below:

[Referring to accelerated students] Disadvantaged in their 3/4 study score in Yr 11, stressful for some students, fast tracking has meant that skills are not always developed in depth. This results in shallow coverage. Students tend to focus on learning rules rather than be given the opportunity to investigate concepts on their own (Tascone, 2003).

Mixed in with older students, [referring to accelerated students doing a study with students a year ahead] haven't achieved as highly as they could have, had they done enrichment instead (Tascone, 2003).

Too much pushing from parents, kids not mature enough for Mathematical Methods Units 3&4 in Yr 11 (Tascone, 2003).

Too many students being accelerated, results are not as good as they could be, it seems to take place of enrichment (Tascone, 2003).

Results at MM 3/4 are not to the standard they should be. These are talented students who lack maturity and an ability to cope with pressure. They have no other option but acceleration. Doing SM3/4 at the same time as MM3/4 makes MM3/4 easier. There isn't time in an accelerated setting to focus on enough concept development, through investigation and consolidation. Lateral extension and problem solving skills are not explored enough. Most of our Year 11's doing MM3&4 would probably do better if they tackled it in Year 12 (Tascone, 2003).

None of the above responses or concerns have been based on statistical evidence, nor has there been any specific research to support these statements regarding students' mathematics achievement at VCE since within schools there could not be a control group. Yet, there is a tendency for a number of educators, as seen from the responses to this survey and from anecdotal evidence, to think that students do not perform as well in Mathematical Methods Units 3&4 when completed a year earlier. At the same time, although there is no statistical evidence to support these beliefs, there are educators who feel that the needs of talented students are not only met by giving them the opportunity to undertake a Year 12 mathematics study, namely Mathematical Methods (MM), at Year 11, but at the same time they are better prepared for Specialist Mathematics (SM) when undertaken at Year 12.

## Purpose and Objectives

The purpose of this study is to provide statistical evidence that will determine the effects of acceleration on the study scores for SM and MM of students who undertook MM a year earlier than their age peers, as compared to students, of equivalent ability, who undertook MM concurrently with SM at Year 12.

The specific objectives of this study are as follows:

1. To determine if there is a significant difference in the mathematics study scores namely SM and MM, of accelerated students and their age peers (referring to students who are in the same year level, with equivalent GAT score) who were not accelerated.
2. To measure the effect of acceleration on students MM and SM study scores taking into account prior knowledge, gender, school sector and school class setting (single-sex or coeducational).

To achieve these objectives, data was obtained from the VCAA and a multi-level modelling analysis, a methodology that takes into account the effects of student and school level factors simultaneously, was conducted. To the researcher's knowledge, there are no studies that have investigated the effects of acceleration on SM and MM study scores and there are no studies on mathematics achievement of accelerated students that have taken into account both student level and school level factors at the same time. That is, past studies have not taken into account the hierarchical nature of the data. This unique methodology, discussed in chapter 3, extends previous research and adds new knowledge to results from educational research in the area of gifted learners and the consequences of acceleration.

## Hypotheses of the study

The main hypotheses for this study and their rationale are outlined below.

### *Research Hypothesis 1.*

The SM study scores of accelerated students compared to non-accelerated age peers who have equivalent GAT score, will be significantly different and the SM results will be higher for accelerated students.

### *Reasons*

VCE students who undertake Mathematical Methods Units 3&4 (MM), at Year 11 are very capable mathematics students who have been identified by their schools as accelerated learners in the area of mathematics and have been able to complete MM one year earlier than their age peers. In particular, these students, as Braggett (1992 p.18) describes, are capable of progressing at a faster pace than other students and are able to forge ahead of their age-peers in some aspect(s) of their learning, and/or who can work at a deeper level than their age peers. Consequently, accelerated students will be ahead in their mathematics knowledge compared to non-accelerated high-ability students who would not have had the opportunity to do a Year 12 subject at Year 11. Non-accelerated students of high-ability will need to learn faster than their age-peers who are accelerated, as they are learning two mathematics courses at the same time, namely MM and SM, whereas the accelerated students may be better prepared, having done one of the Year 12 courses, that is, MM, a year earlier. During Year 11, accelerated students will have more time to think, reflect and apply their knowledge whereas non-accelerated students will have less time to do this when they encounter the MM study in Year 12. Accelerated students are able to undertake an additional subject at Year 12, expanding their range of

academic experience. Braggett (1992 p.132) also stated that “there is a misconception that accelerated learners will succeed without much additional assistance because of the abilities they possess”. In actual fact as Braggett (1992 p.132) points out, “research and practice both indicate that accelerated learners have *specialised* needs which must be addressed and that, the more advanced their learning, the greater the disadvantage that accrues if appropriate action is not taken”. This suggests that students who have not been accelerated and have high-ability will not perform as well on the same content as their equal ability age-peers who have been accelerated.

### *Research Hypothesis 2.*

The MM study scores achieved in Year 11 by accelerated students compared to MM study scores achieved in Year 12 by non-accelerated equal ability age-peers will be similar. That is, accelerated students will not under-perform in MM for undertaking this study a year earlier than their age peers.

### *Reasons*

Despite the vast amount of research on the positive effects of acceleration in particular for student achievement, there are a number of educators that have concerns about acceleration in regards to students undertaking a Year 12 mathematics subject at Year 11. They believe that accelerated students will not perform as well in MM when completed a year earlier, due to being too young and not ready to handle the pressure of a fast-paced course. In the opinion of the researcher ( a mathematics educator with over 20 years of teaching experience of senior secondary mathematics, co-ordinator of Mathematics at an Independent Girls’ School that offers acceleration and co-ordinator of a network of Heads of Faculty (Mathematics) from secondary schools) of this study, although accelerated students do MM a year earlier, these students have been identified by their

schools as students who can learn content faster and often this is the only Year 12 study that they are doing at Year 11. More time to invest greater effort into this study at Year 11 than their equal ability age-peers who complete all their subjects at Year 12, will compensate for the age difference which has been a major concern of a number of educators.

### Scope of the study

Students involved in this research come from classrooms in rural, suburban and urban settings. These school class settings are from Catholic, Government and Independent school sectors that may have single-sex (boys or girls) or coeducational settings. Since information about the LSG for the Independent sector was not available, this factor was not used in the analysis. As 'student academic ability and gender' are 'two of the most powerful predictors of student performance' (VCAA, 2002, p4) the GAT achievement score in the area of Mathematics, Science and Technology (GATMST) will be used as a predictor of VCE mathematics performance since it provides measures of general knowledge and skills that students have built up during their school years in this area' prior to VCE. Furthermore, since schools from Adult Education sectors differ significantly in the way they are organised and their students have a considerable age difference compared to students in other schools, the results of students from Adult Education and other such providers were not considered in this study.

### Significance of the Study

Although there is no evidence that acceleration undertaken with gifted students and properly conducted and monitored, results in academic, social and emotional difficulties (Benbow & Stanley, 1997 as cited in Gross, 1999; Richardson & Benbow, 1990; Swiatek & Benbow 1991), there are educators, administrators and policy makers who have



concerns about the academic benefit for gifted and talented VCE students who undertake a VCE mathematics study a year ahead of their age peers, in particular the level of achievement in mathematics studies in VCE.

This study aims to provide empirical evidence on how the VCE mathematics study scores of accelerated students compare to their age peers, of equivalent ability, who have not been accelerated. It provides information for educators, administrators and policy makers to use in making more informed decisions regarding the effects of acceleration on the mathematics study scores at the VCE level. The study specifically attempts to answer the following questions:

1. What are the effects of acceleration on students' MM study scores taking into account prior knowledge, gender, school sector (Government, Catholic and Independent) and school class setting (single-sex or coeducational)?
2. What are the effects of acceleration on students' SM study scores taking into account prior knowledge, gender, school sector (Government, Catholic and Independent) and school class setting (single-sex or coeducational)?

This study aims to provide statistical evidence that identifies the effects of acceleration on the VCE mathematics study scores and to provide implications for educators, administrators and policy makers, who may have been hesitant regarding introducing (or the continuation of) an acceleration program because they feared that students' VCE mathematics results will decline due to content acceleration.

The stated hypotheses will be tested for six sets of data. That is, for all students who have:

1. completed their VCE studies in 2001;
2. completed their VCE studies in 2002;
3. completed their VCE studies in 2003;
4. completed their VCE studies in 2004;
5. a General achievement test score for the mathematics, science and technology component (GATMST) above 45 (top 2%) and completed their VCE studies in the period 2001-2002;
6. a GATMST score above 45 (top 2%) and completed their VCE studies in the period 2003-2004;

### Limitations of the Study

The study has several limiting factors. A complete analysis of all effects of acceleration, such as attitude, social, emotional, or behavioural characteristics for students undertaking an acceleration program was not feasible. This study focused primarily on the effects of acceleration on students' mathematics achievement at the VCE level. The study does not attempt to measure the impact of any other academic instruction. The curriculum content, as set by the VCAA, is expected to be the same for all students however, not all students had the same experiences. Therefore teaching experience and instructional methodologies, for example, were not factored in as part of the study. Students' mathematical experiences or involvement in other intervention programs is also not accounted for in this study. It is hoped that these limitations will be accommodated with the sampling process, however, it is also possible that resource access on some aspect of home background could account for some of the observed variance in study scores.

The analysis of data was limited to students who sat for their VCE only in the years 2001, 2002, 2003 and 2004. The years 2001, 2002, 2003 and 2004 have been chosen for the following reasons:

- The accreditation period for the Mathematics Study Design is 2001-2005, hence students' assessments were based on the same content.
- Databases with relevant material were available from the VCAA for all secondary schools for the years (1999-2004) at the time this research was undertaken.
- The database for the year 2000 for all students was not chosen as the data for the 1999 results would also have been needed for the accelerated students. Since all VCE studies were revised by the VCAA in 2000 and 2001, the VCE course design for 1999 would not be the same as the 2000 design.

Another limitation of this study is that not all accelerated students in each year have been included in the study as only data was used from students who undertook both Mathematical Methods and Specialist Mathematics. Students who have been accelerated and have continued with the most difficult mathematics study in Year 12, namely Specialist Mathematics, are more likely to have been appropriately placed in an acceleration program. The methods of selection into an acceleration program were also not identified in this study. Students who did not continue with mathematics after Year 11 and instead decided to broaden their subject choices in their last year of their VCE by choosing another non-mathematical study were also not identified (but since these students did not undertake SM in Year 12 then the results of the analysis will not be affected). Another limitation of the study is that it assumes that accelerated students were correctly identified. The data available does not identify students who have undertaken a university mathematics subject at Year 12. These students may or may not have been accelerated and even though there is no available research to verify this, undertaking a

university mathematics subject would have also affected the study scores in both SM and MM.

It is hoped that students who have been placed in an acceleration program for mathematics enjoy being challenged and would continue with mathematics beyond secondary schooling. Since this study is based on the assumption that students have been correctly placed in an acceleration program, only the results of students who have studied both Mathematical Methods and Specialist Mathematics have been considered and hence the results of this study cannot be applied to students who are not in this category. The fact that students are not identified as accelerated when in fact they may have been, if they fall into the categories mentioned above, should not affect the findings of this study due to the large sample size.

The use of pre-existing or secondary data, that has been accessed with the permission of the VCAA, limits the analysis to the variables collected and presented in the data namely, gender of students, school sector (Independent, Catholic or Government), school class setting (single-sex or coeducational) and the study scores of each mathematics study. This secondary data does not identify the students and the schools they attend. The study also did not include or use data on each student's socio-economic background, their characteristics or their mobility. All of these are known to have effects on student achievement (see for example Goldstein and Sammons, 1997 and van der Eeden et al, 1990). As such, the results are based within these limitations and although the study was restricted to selecting limited instruments, questions and data-gathering techniques, these limitations are offset by the large size and cross-sectional representation of students.

Another limitation for this study is the fact that the GAT score is the only assessment that has been done by all students in the State of Victoria that can be used to identify students of equivalent ability in mathematics. In future research, the recent state-wide results of students' numeracy skills obtained when students are in years 5, 7 and 9 will provide a better indicator of 'prior knowledge'. For this study, prior knowledge has been operationalised by the use of the scores achieved on the mathematics, science and technology component of the GAT. This will be represented by the acronym GATMST.

Furthermore comparison groups, that is, accelerated students and equal ability students that were not accelerated, were not randomly assigned. However for this quasi-experimental design this limitation is overcome since both groups come from the same population (the State of Victoria) and have matching population characteristics like school sectors and school class settings (single-sex or co-educational), were assessed on the same study design, completed VCE the same time, attended a secondary school, undertook two VCE mathematics studies and their assessment of mathematics study scores was reported the same way to all students and schools. Hence both groups can be considered to be 'statistically equal' (Syllabus for JUS 308, 2004) which is what randomisation attempts to do. Hence, any positive findings for the students involved in an acceleration program will imply that the acceleration program had a positive effect.

## Assumptions

In regards to the implementation of accelerated programs it is assumed that:

- All teachers were competent and experienced in the instruction of mathematics.
- All students undertook their examinations under similar conditions.
- All accelerated students have been identified correctly by their schools as being accelerated learners. As Braggett (1992 p.43) summarises, “there is need [for schools] to implement a *continuous* identification process based on:
  - The school’s teaching programs and enrichment activities
  - Teacher nomination based on checklists
  - Achievement tests
  - Parent, peer and self nominations
  - The nomination of outside experts
  - The results of psychometric testing when appropriate

More details about these processes can be found in Braggett (1992 pp36-43).

## Overview of the Study

In this chapter some background knowledge has been provided on how the last two years of secondary schooling in Victoria were structured in 2001-2004. In particular there was a focus on the types of mathematics studies offered at this level and how students are assessed. An outline of the structure of the General Achievement Test (GAT) was provided. Information was then presented on how schools are classified as 'Like Schools' and each of the ten categories of 'Like Schools' were described. How accelerated students have been identified in this study and the possible acceleration programs undertaken by these students were discussed. The statement of the problem, the purpose and objectives, the scope and significance of the study, including its limitations and assumptions were provided. Chapter 2 discusses findings of other studies which are based on achievement of accelerated students and why this study is unique in comparison to past studies. Methodological faults in these studies are noted and reasons as to why a more appropriate analysis, namely multi-level modelling, should be used. In Chapter 3 there is a description on how the data was accessed and how this original data was modified to obtain data that answer the research questions. A detailed discussion on multi-level modelling will be given describing in particular how basic multi-level models are developed and the advantages of using multi-level models to provide relevant answers to the research questions of this study. The results obtained from the analysis will be presented in Chapter 4 whilst in Chapter 5 a summary of findings and implications of this study and for future research are provided.





## Chapter 2

### Literature Review

As mentioned in the introductory chapter, this chapter outlines the findings of past studies which relate to the academic achievement of accelerated students and explains how this study differs from the plethora of available studies on the benefits of acceleration. An outline on how this research was accessed, what is meant by giftedness, what the research says about acceleration, teachers concerns about academic achievement of accelerated students and the effects of acceleration on academic achievement, is provided. Finally this chapter concludes by noting methodological flaws in previous studies and introduces a more appropriate research method, namely multi-level modelling, which is a relatively new method that is used compared to the traditional methods used in past studies relating to acceleration.

### The Literature

An extensive literature search on the effectiveness of acceleration programs on student achievement, and in particularly mathematics achievement, was undertaken. Key words and phrases that were used to search the databases ERIC, Proquest, AEI, American Educational Research Journal (AERJ) and even the World Wide Web using Google Search engine, included:

- academic achievement;
- effectiveness of accelerated programs;
- ‘program or evaluation’ and ‘acceleration and mathematics’ and ‘secondary’
- gifted education;
- gifted and talented learners;

- accelerated learners;
- mathematics achievement;
- accelerative strategies;
- acceleration;
- the effectiveness of acceleration programs on student achievement;
- ability grouping;
- analysis of VCE mathematics results;

This search of the literature yielded many descriptive reports regarding identification and provisions for gifted and talented students. Not many empirical research studies that are qualitative, quantitative, or a combination of the two, and which examine the *effectiveness* in relation to student outcomes, seem to exist in the gifted education literature. This is also confirmed by Callahan (2001a) where he stated that “The research in gifted education can be characterised as largely descriptive ... The field is sorely lacking in student outcome data” (p. 150).

According to the Ministry of Education of New Zealand research paper (2004) a content analysis of publications in gifted education journals conducted by Hays (1993) demonstrates this: of the 1,773 articles published in *Gifted Child Quarterly*, *Roepers Review*, and *The Journal of the Education of the Gifted* from 1958-1989, only 28.8% were based upon empirical research. A more recent analysis on this topic concluded that although there has been growth over the last decade in applied research activities worldwide, there remains a need for an “increase in the quality of research designs and measurement techniques” (Heller & Schofield, 2000, p. 135). This suggests that there is a deficiency in terms of quality as well as quantity in regards to empirical studies concerning gifted education.

### *Meaning of giftedness*

Significant developments in the field of giftedness arose early in the 20<sup>th</sup> century from the work of Terman and associates (1925, 1926, 1947, and 1959) whose longitudinal studies provided information about highly gifted people. This program of research will continue until 2020 so that the entire lives of his original 1528 gifted youth with IQs above 140 can be recorded. His studies have demonstrated that gifted children did not have any marked socially or emotional problems, in fact they have been largely very successful throughout their lives (Hewton, 2002). The work of Hollingworth (1926, 1942) is another significant early influence of the field of giftedness. While age and achievement were considered by these two pioneers, the designation of giftedness relied heavily on testing for high IQ levels. According to Cornell (1984) the broad field that giftedness has become had, at its roots, a narrow definition and middle to upper class aspirations (Hewton, 2002). Most of the key studies of giftedness, like Terman's and Hollingworth's, have been carried out in the United States of America. The following is a comprehensive definition of giftedness provided from the Marland Report to Congress of the United States of America in 1972:

“Gifted and talented children are those...who by virtue of outstanding abilities, are capable of high performance. These...children...require differentiated educational programs and/or services beyond those normally provided by the regular school program in order to realise their (potential) contribution to self and society” Hewton (2002) from the Marland Report.

Hewton (2002) identified that children capable of high performance demonstrate singly or in combination any of the following abilities or aptitudes:

- general intellectual ability
- specific academic aptitude

- creative or productive thinking
- leadership ability
- visual and performing arts aptitude
- psychomotor ability

Renzulli (1978) also provided a definition which received worldwide recognition and was used substantially in the 80s, defining giftedness as an interaction between the three following basic clusters of human traits:

- above average general abilities
- high levels of task commitment
- high levels of creativity

Although Renzulli's definition moves away from the reliance on IQ testing, underachievement remained largely unaccounted for in his definition. Underachieving gifted children may tend not to display high levels of task commitment (Hewton 2002).

Further expansion of the concept of giftedness, as mentioned in Hewton(2002), is seen in Gagne's (1995) theory of giftedness and talent where he proposes a set of aptitudes and gifts which a child develops into talents through interaction with a range of internal and external catalysts. Gagne proposed 'that giftedness should be considered as the translation of natural abilities (aptitude domains), with the help of intrapersonal and environmental catalysts, into high performance talent areas' (Hewton, 2002). Gagne observes that the categories of giftedness that Gross (2000) uses to describe the Intelligence Quotient (IQ) assessments, form only one part of a child's giftedness. As Hewton(2002) stated, Gross 'believes that intellectually gifted children can be classified as mildly, moderately, highly, exceptionally and profoundly gifted. Levels of intellectual

giftedness, as defined by IQ ranges, and the level of prevalence of such children in the general population' (Hewton, 2002), are shown in the Table 3.

Table 3: Levels of intellectual giftedness

Mildly (or basically) gifted	115-129	(1:6 - 1:40)
Moderately gifted	130-144	(1:40 – 1:1000)
Highly gifted	145-159	(1:1000 - 1:10,000)
Exceptionally gifted	160-179	(1:10,000 - 1:1 million)
Profoundly gifted	180+	(Fewer than 1:1 million)

(Hewton, 2002)

The 1993 Queensland Education Departmental policy used the following definition for giftedness “Gifted children are those who excel, or have the potential to excel, in any general or specific ability area” (Hewton,2002).

As mentioned in the introductory chapter, this study will use the terms highly-able, high-achieving, highly-talented, gifted and precocious, synonymously without any qualitative difference and the concept of ‘gifted’ will be focussed on mathematical ability.

#### *Acceleration and students’ academic achievement*

There is over eighty years of research on acceleration and as Mackenzie-Sykes (1996), an educational consultant, indicated “the positive benefits of acceleration have been noted for both short-term and long-term academic performance in most reviews (Benbow, 1991; Southern & Thomas, 1991; VanTassel-Baska, 1992a, 1992b). In fact, it is difficult to find a single research study showing acceleration to be educationally detrimental (Benbow, 1991). Successful programs of acceleration, most notably resulting from the

basic talent search model developed by Stanley and others in the 1970s, have demonstrated a significant positive impact on the learning of gifted students (Benbow & Stanley, 1983; Kulik & Kulik, 1984, 1992).

A broad-based research program has emerged in gifted education, committed to understanding the long-term effects of the educational acceleration of gifted children (Robinson & Janos, 1986; Brody & Benbow, 1987; Brody & Stanley, 1991; Swaitek & Benbow, 1991). These recent investigations continue to show positive educational outcomes from acceleration. Mackenzie-Sykes (1996) also stated that if acceleration is implemented appropriately it can provide long-term academic benefits for gifted children without detrimentally affecting their social and emotional development. This can be justified on both theoretical and empirical grounds. As VanTassel-Baska (1989 p.15) argued "of all the interventions schools provide for the gifted, acceleration is best supported by research".

Dr Sarah Evans (1996) appropriately used a quote from a review of the research by Kieran Hannon in *Gifted* April 1995 which stated:

“The gifted and talented are an exceptional group of children whose potential is not fully realised in the regular classroom. These children require an accelerated curriculum that is appropriate for their fast pace of learning, time with children of similar interests and abilities, and instruction that accounts for their special needs. Acceleration stands as an efficient and effective way to cater for these academic and affective needs.”

A study carried out by Reis, S. M., Westberg K. L., Kulikowich, J. M. and Powell, J. H., (1998) examined the effects of curriculum compacting on the achievement test scores of

a national sample of 336 high ability students from second through to sixth grade heterogeneous classrooms in rural, suburban and urban settings. The results indicated that the achievement tests scores of students whose curriculum was compacted did not differ significantly from students whose curriculum was not compacted. This study indicated that teachers can implement curriculum compacting with capable students without the fears that normative national scores will decline when 40%-50% of the regular curriculum content is eliminated for students who display content mastery.

Southern Jones and Fiscus(1989) also found that one of four major concerns of teachers regarding the possible detrimental effects of acceleration on gifted students was that students would lose their academic advantage in later school years. As with many past studies, a recent study conducted by Margaret Plunkett (2003) showed that students who undertook an acceleration program tended to have better overall VCE performances.

King (1995), Hamdaner (1952), Fregmar (1965), Bregar (1971) as stated in Evans (1996) found that many teachers' negative attitudes towards acceleration were based on misconception and stressed the need for teacher education in the area. They concluded that the single most important factor in allowing gifted students to fulfil or reach their potential is to have well trained teachers who are able to understand both the cognitive and affective needs of young gifted students; to counsel parents and to work in partnership with them.

At her Keynote address presented in Melbourne at the 3<sup>rd</sup> Biennial Australasian International Conference on the Education of Gifted Students, Dr Miraca U.M. Gross, Professor of Gifted Education and Director of the Gifted Education Research, Resource and Information Centre (GERRIC) from the University of New South Wales, in Sydney,

stated ‘...the under-utilisation of acceleration with gifted students in both Australian and American schools is largely from a genuine lack of awareness, among teachers and administrators, of research support for this intervention. Indeed, there are a few issues in gifted education in which the discrepancy between what research reveals, and what classroom teachers believe, is so remarked’ (Gross, 1999) She also stated that ‘the provision of factual information about acceleration can help to reduce teachers’ wariness of this provision’ (Gross, 1999).

This study will aim to contribute to this factual information by providing statistical evidence on the effects of acceleration on students’ academic achievement in mathematics at VCE level. There are many empirical research studies documenting the positive academic and social effects of acceleration. As Dr Gross (1999) pointed out in her keynote address ‘..studies of the academic effects of acceleration provide strong evidence of positive outcomes for accelerated students. A best evidence synthesis of 81 studies, undertaken by Rogers (1991), found significant academic effect sizes (ES above +.30) for... [referring to acceleration forms that were studied] grade skipping(0.78), credit by examination (0.75) and grade telescoping (0.56)’.

Dr Gross(1999) also stated at her keynote address that,“...When researchers compare academic outcomes for accelerated and non-accelerated gifted students, the results tend to favour accelerands over non-accelerands, regardless of which accelerative modality is employed (Swiatek and Benbow, 1991) and the academic advantages remain apparent not only in adolescence and young adulthood but even after many years (Cronbach, 1996).”

A meta-analysis of studies by Kulik and Kulik (1984) on a variety of acceleration programs, showed that, overall, talented students are equally or more successful



academically in accelerated programs compared with talented same-grade non-accelerants and talented older students. In particular the study concluded that talented students gained almost nine-tenths of a grade-equivalent school year over their equal ability same-grade non-accelerant, and were not different in their performance to their new classmates who were one year older. However the studies in the meta-analysis include a number of subject areas, grade levels, types of acceleration, and student selection criteria and the results do not specifically relate to programs in mathematics and, in particular, they do not refer to the mathematics program outlined in this study nor to the forms of academic achievement relevant to VCE.

### *Previous methodology*

Plunkett et al (2003) presented the results of an analysis of an accelerated program offered by a particular Victorian secondary college in response to the Bright Futures policy in 1995 as a means for catering for high ability students. The study evaluated how the acceleration program had impacted on the entire year level, accelerants and non-accelerants. Plunkett et al (2003) found that the acceleration program had been worthwhile and an effective method for students with high academic ability. Benefits of being in such a program included:

- increased motivation to work and to achieve;
- a work ethic that was perceived as significantly different to mainstream classes;
- teachers holding high expectations that motivated them to work harder; and
- a healthy sense of competition among class members.

In regards to academic achievement students' overall VCE performances showed a trend for better overall results. Unfortunately this study could not attribute this academic achievement to the acceleration program as there was no control or comparison group.

This is the case for many individual studies such as this where student academic outcomes cannot be attributed to the acceleration program. Within a school there cannot be a control group as that would mean that the school is denying deserving students the potential benefits of the acceleration program. This was also the case with the study of Mathematically Precocious Youth (S.M.P.Y) at John Hopkins University, Washington D.C. where there was no control group again “because the researchers were reluctant to withhold the likely benefits from a portion of the subjects” (Clarke, 1981 p.18). The S.M.P.Y study, which has been directed by Julian Stanley, Daniel Keating and Lyn Fox (1974), is well known for its promotion of acceleration ideas and the implementation of acceleration programs around the world.

From the research undertaken for this study it was found that no other studies have been located in Victoria that have used multi-level modelling to analyse the VCE mathematics results of students who have been accelerated. This study involves two types of schools in Victoria. Those that offer acceleration programs and those that do not. In particular this study will seek to provide information as to whether or not highly-talented students benefit from undertaking MM one year earlier and whether or not this will improve their SM study scores in Year 12. This benefit will be measured in terms of their MM and SM study scores compared to equal ability age-peers.

The study involves data from a population that has two levels, a student level (level 1) and a school level (level 2 or group level). Such a population is referred to as hierarchical or clustered population. In past studies, the most common approach for the statistical analysis of multi-level data was to first either aggregate data to the group level, thus assigning the same group mean to each individual, or to disaggregate data to the individual level, thus treating individuals without reference to their group. Such

conventional regression methods tend to focus too much on the individual and too little on the social or institutional contexts in which individuals are located. Multi-level models make it possible to analyse the levels of these structures simultaneously so consideration about the appropriate level of analysis becomes redundant (Plewis, 1998). Multi-level modelling analysis, which is a relatively new data analysis technique, has been developed over the past ten years. As mentioned in Heck and Thomas (2000) although there are numerous books to help in understanding univariate and multivariate data analytic methods using conventional methods of analysis, such as the general linear model in conjunction with ANOVA and regression, there are very few books that have integrated an understanding of multi-level univariate and multivariate analytic techniques. Similarly these techniques or part thereof, have only recently been incorporated in standard statistical software programs (refer to Chapter 3 for more details on multi-level modelling). Consequently there are no past studies that have investigated the effects of acceleration on the variance of the Specialist mathematics and Mathematical Methods scores at VCE and there are no studies on accelerated students' mathematics achievement that have taken into account the hierarchical nature of the data.

## Conclusion

Although many studies show that acceleration has a positive effect on student achievement and numerous studies show that acceleration, and, in particular, content acceleration is most suitable for gifted students, there is no statistical evidence, especially in Victoria or in Australia that shows how gifted learners perform in Year 12 mathematics when undertaking a mathematics study a year earlier. This is often due to the setting in which studies have been undertaken, or the sample size or the methodology which is often more qualitative than quantitative.

This study makes use of 4 datasets each with over 5000 students that come from over 300 schools from all parts of Victoria. The effects of acceleration on students' MM and SM study scores, taking into account prior knowledge, gender, school sector and school class setting, is investigated by using a methodology that has not been used in past studies mentioned in this chapter, called multi-level modelling. Multi-level modelling has been developed over the past ten years. With user friendly statistical programs that are now available, the effects of acceleration on students' mathematics achievement, controlling for other student and school factors, can be analysed simultaneously and hence more accurately compared to traditional methods.

This chapter has outlined what past studies have found regarding the academic achievement of accelerated students and gave reasons as to how this study differs from past studies both in sampling and in methodology. Chapter 3 presents the methodology used to answer the following research questions of this study. In providing answers to these questions through the use of a multi-level approach, this study aims to support and to extend previous research in the area of accelerated learners. To enable a better understanding of the multi-level modelling, a preface has been included in Chapter 3 which provides some background knowledge about multi-level modelling, a statistical technique now being used extensively in social science research. Following the preface to this chapter, the design of the study, and a description of the population, student demographics, data collection and methods of analysis, will be presented.

## Chapter 3

### Methodology

To enable a better understanding of the method of analysis used for this study, a preface to this chapter provides some background knowledge about the relatively new statistical technique, multi-level modelling. This preface will firstly outline multi-level modelling and how hierarchical populations are defined. Secondly it will list available software programs for multi-level analysis and the software programs used to conduct the research. Lastly, the development of multi-level models and the advantages of using such models to provide relevant answers to the research questions of this study, will be outlined. Following the preface to this chapter, the methodology including the design of the study, the population and procedure for data collection in developing the sample design, the variables used in the models developed and the proposed models to be tested, will be presented.

#### Preface

Multi-level modelling (also known as hierarchical linear modelling, hierarchical regression, random-coefficient modelling, variance-component modelling or covariance component modelling, mixed-effects, random-effect or mixed linear modelling) is a relatively new technique for conducting research within educational and organisational settings (Heck & Thomas, 2000). 'The use of different labels has emerged from different fields of inquiry' (Kaplan & Elliot, 1997, as cited in Heck & Thomas, 2000). For instance, in some sociological research, multi-level modelling is referred to as multi-level linear models, in biometric applications it is known as mixed-effects models or random-effects models, in econometrics literature it is referred to as random-coefficient regression

models whilst in statistical literature it is referred to as covariance components models (Bryk Raudenbush,1992).

Multi-level modelling is a data analysis technique that generalises ordinary regression modelling to distinguish multiple levels of information in a model. Unlike conventional regression methods, such as the general linear model in conjunction with ANOVA and regression, multi-level modelling is not based on the assumption of independence of observations and it allows for the estimation of both fixed and random effects on more than one level of a hierarchical structure simultaneously (Henderson, 1999). Use of multi-level modelling for the analysis of hierarchical data ensures that standard errors and tests of significance are reliable.

### *Hierarchical populations*

Educational and organisational research presents an opportunity to study phenomena that are multi-level, or hierarchical in nature (Heck & Thomas, 2000). Hierarchical structured populations can be thought of as pyramids with different numbers of levels. In social, medical and biological sciences such populations are the norm (Browne et al, 2001). Data that display a multi-level, hierarchical or nested structure is often found in educational settings. Students (also referred to as the *individual level, the micro level* or *level 1*) are nested within schools (*level 2*), nested within localities (*level 3*) and so on. Units at one level are recognised as being grouped or nested within units at the higher level. Such hierarchies are often described in terms of clusters of level 1 units within each level 2 unit and so on, and may also be termed as a *clustered* population (Browne et al, 2001). In this educational research study, the hierarchical population that will be considered has two levels, namely, the student level (*level 1*) and the school level (also referred to as the *group level, macro level* or *level 2*).

### *Software programs for multi-level modelling*

One of the main reasons why multi-level modelling has not been used in past studies is the lack of availability of computer programs for performing a multi-level analysis. There are now a variety of statistical programs that can be directly used for multi-level analysis and these generally fall into two main groups. One group is the multi-level regression programs, as used for this study, that focus on single outcomes and the investigation of random intercepts and slopes and the other being multi-level covariance structure analysis that focuses on relations among latent variables (Heck & Thomas, 2000).

Software packages that are now available and are constantly being updated, that can be used to apply multi-level modelling techniques include HLM, LISREL, STREAMS , Mplus, MLWin, SAS, AMOS, aML, EQS, EGRET, HLM, MIXREG,S-Plus, SPSS (Centre for Multi-level Modelling-Software reviews of Multi-level Analysis Packages, 2006). A comparison of the above software programs and a description of their strengths and weaknesses are outside the scope of this study. A detailed and updated review of such software can be found at the site developed by the Centre for Multi-level Modelling titled Software reviews of Multi-level Analysis Packages (2006). The programs SPSS version 14 and HLM version 6 were used in this study. SPSS was used for the descriptive analysis of results and then HLM was used to develop the models appropriate for the data used in this study.

### *Analysis of multi-level data*

Until recently the most common approach for the statistical analysis of multi-level data was to first either aggregate data to the group level, thus assigning the same group mean to each individual, or to disaggregate data to the individual level, thus treating individuals without reference to their group. Such conventional regression methods tend to focus too much on the individual and too little on the social or institutional contexts in which

individuals are located. Multi-level models make it possible to analyse the levels of these structures simultaneously so consideration about the appropriate level of analysis becomes redundant (Plewis, 1998). Multi-level modelling explores how a number of level 1 and level 2 variables affect a particular outcome variable. The aim of the analysis is to determine the direct effect of the individual and group level explanatory variables, and to determine if the explanatory variables at level 2 serve as moderators of the level 1 relationships (Hox, 1995). By focusing attention on the levels of the hierarchy in the population, multi-level modelling enables a better understanding of where and how effects are occurring (Browne et al, 2001). Through examining the variation in outcomes that exists at different levels, more refined theories can be developed about how explanatory variables at each level contribute to outcomes. This is why multi-level modelling approaches that allow outcome intercepts (means) to vary across levels have also been referred to as random-effects, mixed effects, and multi-level linear models (Bryk & Raudenbush, 1992).

Breaking up the variance in an outcome variable into within and between group components the intra-class can be determined. The intra-class correlation is a helpful diagnostic tool in determining if a multi-level modelling will be superior to a traditional method, such as regression or ANOVA (Henderson, 1999). Intra-class correlation provides a measure of the clustering and dependence of the data and ranges from 0 (very independent) to 1 (very dependent). It describes the extent of the homogeneity of groups and is calculated by the determining the ratio of the percent of variance that lies between groups and the total variance to be explained (Heck & Thomas, 2000). Usually when the intra-class correlation is over 0.1 dissimilar clusters are present in the data, thus a multi-level modelling model would be a more appropriate data analysis technique. If the intraclass correlation is very low it suggests that the groups are only slightly different so



conventional regression analysis conducted at the individual level would be adequate (Heck & Thomas, 2000). As Henderson (1999) points out, this would not be adequate if estimation of random effects, particularly random regression coefficients, were of more interest to the researcher, as is the case in this study.

To illustrate this point further consider the equations shown below, where the normal convention of using Greek letters for the regression coefficients (Goldstein, 1995) have been used.

Assume  $Y_i$  is the dependent variable and  $X_i$  is the independent variable for student  $i$ .

The equation for the conventional model would be:

$$Y_i = \alpha + \beta X_i + e_i$$

where the standard interpretations can be applied to the intercept ( $\alpha$ ), slope ( $\beta$ ) and the residual ( $e_i$ ) (or error). In this model it is assumed the  $e_i \sim N(0, \sigma^2)$ . The parameters of this model are  $\alpha$ ,  $\beta$ , and  $\sigma^2$ .

To describe the relationship for several groups or schools we can write for school  $j$ :

$Y_{ij} = \alpha_j + \beta_j X_{ij} + e_{ij}$ , for consistency of notation we can replace  $\alpha_j$  by  $\beta_{0j}$  and  $\beta_j$  by  $\beta_{1j}$  (Goldstein, 1995) to represent random variables and write:

$$Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + e_{ij} \quad (1)$$

where  $\beta_{0j} = \gamma_{00} + \gamma_{01}Z_j + u_{0j}$  (2)

$$\beta_{1j} = \gamma_{10} + \gamma_{11}Z_j + u_{1j} \quad (3)$$

- $X$  is a single student predictor (for example, acceleration),  $X$  may be metric or binary ;
- $Y$  is the dependent (outcome) variable (for example, SM scores),  $Y$  must be metric;
- $Z$  is a single school predictor variable (for example, school sector),  $Z$  may be metric or binary;
- Index  $i$  is used to represent individuals (for example, students);
- index  $j$  is used for contexts (for example, schools);
- error terms  $u_{0j}$  and  $u_{1j}$  indicate that the intercept  $\beta_{0j}$ , and the slope  $\beta_{1j}$  will vary over schools;
- $u_{0j}$  measures the deviation in intercept from the predicted intercept,  $\beta_{0j}$ , for school  $j$ ;
- $u_{1j}$  represents the deviation in slopes from the predicted slope,  $\beta_{1j}$ , for school  $j$ ;
- $\gamma_{00}$  is the expected intercept,  $\beta_{0j}$ , when  $Z = 0$ ;
- $\gamma_{01}$  represents the expected  $Z_j$  coefficient for  $\beta_{0j}$ ;
- $\gamma_{10}$  represents the expected regression slope,  $\beta_{1j}$ , across schools when  $Z=0$ ;

- $\gamma_{11}$  represents the expected  $Z_j$  coefficient for  $\beta_{1j}$ ;
- The equations for  $\beta_{0j}$  and  $\beta_{1j}$  include a fixed component,  $\gamma_{00}$  and  $\gamma_{10}$ , and a random component,  $u_{0j}$  and  $u_{1j}$  respectively;
- $u_{0j}$  has a variance,  $\tau_{00}$ ;
- $u_{1j}$  has a variance  $\tau_{11}$ ;
- $u_{0j}$  and  $u_{1j}$  have a covariance,  $\tau_{01}$ ;
- equation (2) demonstrates that the intercept for each school ( $\beta_{0j}$ ) is a linear function of the ( $Z$ ) school variable and random fluctuation;
- equation (3) shows that the slope for each school ( $\beta_{1j}$ ) is a function of the same ( $Z$ ) school level variable and random fluctuation;
- The variances of  $u_{0j}$  and  $u_{1j}$  and their covariance are parameters estimated in the model, and are found in the matrix  $T$ , where:

$$T = \begin{bmatrix} \tau_{00} & \tau_{01} \\ \tau_{10} & \tau_{11} \end{bmatrix}$$

By estimating the elements in the  $T$  matrix, not only can the unique estimates for separate schools be examined more efficiently, than by conducting separate regression equations for each school, but also cross-level interactions can be examined (Henderson,1999). In conventional regression,  $\alpha$  and  $\beta$  are be treated as fixed effects and there is only one random effect, the error term  $e_i$  so the random fluctuations associated with  $\alpha$  and  $\beta$  are not estimated.

As seen from the equations above, the multi-level model (a 2-level model) includes additional random effect terms. This is more appropriate for representing clustered, and therefore dependent data as for an educational setting where data are collected at different levels.

In conclusion, an analysis that models the way in which students are grouped within schools has a number of advantages. As Goldstein (1995) stated, it enables data analysis to obtain statistically efficient estimates of regression coefficients and by using the clustering information it provides correct standard errors, confidence intervals and significant tests. These generally will be more 'conservative' than the ones obtained from traditional analysis, which are obtained by ignoring the presence of clustering and assuming that observations at level 1 are independent of level 2 factors. Dependency for example of students' mathematics achievement within a school must be expected because:

- students within a school sharing the same school environment;
- sharing same teachers;
- affecting each other by direct communications;
- shared group norm; or
- even coming from the same neighbourhood (Snidjers & Bosker, 1999).

A multi-level analysis is therefore essential in this study. The more the achievement levels of students are alike within a school compared to students from other schools, the more

likely it is that causes for achievement are due to the school (level 2 unit) and hence independence cannot be assumed making ordinary regression analyses inappropriate.

Absence of dependence would imply absence of school effects on individual performance (Snijders & Bosker, 1999). Furthermore, by grouping students in schools, the extent to which differences in average examination results between schools are accountable for by factors such as other characteristics of the students or programs implemented by schools, can be explored. It is also possible to study the extent to which schools differ for different kinds of students, for example to see whether the variation between schools is greater for initially high scoring students than for initially low scoring students and whether some factors are better at accounting for the variation between these students (Goldstein, 1995).

This clearly suggests that a multi-level modelling approach is most appropriate for this study because this approach analyses the variation of results of students clustered in schools. For a detailed comprehensive description and development of multi-level modelling, which is outside the scope of this study, see publications by Goldstein (1995), Snijders and Bosker (1999), Heck and Thomas (2000) and Browne et al. (2001).

## Method

The Victorian Curriculum Assessment Authority (VCAA) each year collects a large amount of information on the abilities and achievement of entire cohort of Year 12 students as part of the annual VCE program. The primary purpose of the VCE is the achievement of the certificate and the selection for work and especially for further studies. The VCAA is responsible for keeping all records of students' assessments in their final year of schooling. Approval to conduct this study was granted by the Melbourne Research Office-Human Ethics, University of Melbourne and the Victorian Curriculum and Assessment Authority (VCAA). This study analysed data obtained from the VCAA for mathematics study scores of students completing their VCE in each of the years 2001-2004. The focus was on students' study scores for Mathematical Methods (MM) and Specialist Mathematics (SM) and how they were affected based on whether students were accelerated or not.

### *Design of the study*

The research design selected for this study is a quasi-experimental non-equivalent groups design at the school level where the use of intact groups are similar to the treatment (schools that offer accelerated programs) and control (schools that do not offer accelerated programs) groups (Trochim, 2006). As mentioned in the limitations of the study, in Chapter 1, the treatment and control groups were not randomly assigned (hence the name non-equivalent groups). Both groups of schools can be considered to be approximately 'statistically equal' (Syllabus for JUS 308, 2004) because both groups come from the same population (the State of Victoria) and have matching population characteristics like school sectors and school class settings. In addition these two groups of schools have similar students who were assessed on the same study design, completed VCE at the same time, undertook two VCE mathematics studies; with the same

calculation of mathematics study scores. Hence it will be assumed that any positive findings for the students involved in an acceleration program will imply that the acceleration program had a positive effect and the results of this study may be generalised to any other State of Australia or even anywhere in the world where acceleration programs are implemented.

This design will assist in explaining the effects of acceleration on students' VCE mathematics study scores namely, Specialist Mathematics (SM) and Mathematical Methods (MM), taking into account student and school factors, through the use of multi-level regression modelling analysis. The design was chosen because existing data on an existing population without any further interventions, also referred to as pre-existing or secondary data, was being examined. The advantage of secondary analysis is:

- the availability of data sets that may often not easily be obtained;
- the low cost of these databases when used for secondary analysis; and
- the reduced student response burden on schools by using data collected over a number of years to answer questions on subsequent years without collecting further data from schools and students.

On the other hand, analyses using data often require sophisticated statistical analysis that requires a lot of time to become familiar with the statistical packages and the theory used in the data-analysis. Although this may be a steep learning curve for the researcher the acquisition of this knowledge is always gratifying. Secondary data limits the number of variables that can be studied. The variables used in this study were namely: gender of students; school sector (Independent, Catholic or Government); school class setting (single-sex or coeducational); and the study scores of SM and MM. Although the selection of instruments, questions and data-gathering techniques were limited, these limitations were offset by the large size and cross-sectional representativeness of the

students thus improving the reliability and generalisability of the results found from the analysis.

For the remainder of this chapter, the following will be presented:

- Research questions;
- Procedure for data collection;
- Model development;
- Variables used in the model;
- Proposed model to be tested.

### *Research Questions*

The research questions that are addressed by this study are:

1. What are the effects of acceleration on students' Mathematical Methods study scores taking into account gender, prior knowledge, school sector and single-sex or coeducational class setting?
2. What are the effects of acceleration on students' Specialist Mathematics study scores taking into account gender, prior knowledge, school sector and single-sex or coeducational class setting?

### *Data*

The datasets, for each of the years 2001-2004, which were obtained from VCAA, included information from all students who studied Mathematical Methods Units 3&4



(MM) and/or Specialist Mathematics (SM). The variables that were included in the original data files were:

- student and school identification numbers (the school identification numbers could only be matched for 2001-2002 and for 2003-2004. Identification numbers did not identify any particular student or school);
- student gender;
- study scores for SM and MM ranging from 0-50 (these were recorded for students who were assessed for MM and/or SM);
- year of completion of MM and SM for each student;
- grades(A to NA) (NA=not assessed) for each assessment task that contribute to overall study score for MM and SM respectively (assessment tasks, for each study, included school assessed coursework and two end-of-year examinations as prescribed by the VCAA;
- three standardised scores (ranging from 0-50)corresponding to three components of General Achievement Test (GAT) namely, written communication; mathematics/science/technology; and humanities/arts/social sciences;
- school sector (Government, Catholic, Independent, Adult Provider and Administrative centre and Other providers); and
- 10 categories of Like School Group (LSG) (only available for the Government and Catholic sectors).

Data was recoded so that two more dichotomous variables were added to the each of the four datasets. The variables:

- School class setting, identifying if students attended classes in school that were single-sex (=0) or coeducational(=1) (this variable was created from the available

data based on the gender composition of students completing MM at any particular school); and

- acceleration (whether students were not accelerated=0 or accelerated=1) was created based on the year students completed their MM study.

### *Sample*

All four data files for 2001-2004 were then recoded and modified so that the final sample used for this study comprised of data for students who:

- undertook both MM and SM Units 3&4 in VCE (any cases with missing study scores were not included);
- had a grade allocated for all their assessment tasks (any missing values(=-1) or grades receiving an NA (=0) were not included in the sample);
- came from only the Government, Catholic and Independent sectors (adult provider and others alike were not included);
- had a grade allocated for all their GAT components (cases with missing GAT scores were not included in the sample);
- came from schools with more than 3 students undertaking both MM and SM studies in each school. In order to minimise problem of unreliability of results due to small numbers of students enrolled in a study in a particular school all schools with 3 or less students with complete data were excluded from the analysis (VCAA, 2002 p.6).

Based on past experience of the researcher, class sizes of 3 or less may not be a practical option for a number schools that are considering to offer acceleration. By restricting school numbers to be more than 3 students, the results of this study would be relevant to schools that offer both SM and MM with viable class sizes.

### *Developing the Model*

To develop the model for this study, students' VCE study scores for SM and MM were used as a measure of students' level of achievement. As found in prior research, it is predicted that acceleration, will have a positive effect on students' performance in their VCE mathematics. Previous large scale studies like the Third International Mathematics and Science Study (TIMSS) that sampled thousands of fourth, eighth and twelfth graders in 41 countries have shown that student performance is usually affected by the type of instruction and educational standards they are exposed to, school funding and student demographics that are commonly described by a student's social economic status, ethnicity or gender (Waldron, 2004). As student prior knowledge is also a determining factor influencing achievement (Rohde & Kavanah, 1996, Dowling et al., 2004) this study predicts that prior knowledge as well as other student and school factors will impact student achievement in mathematics. As a result the following functional relationships are proposed:

$$\text{MM study scores} = f(\text{acceleration, prior knowledge, other student factors, other school factors})$$
$$\text{SM study scores} = f(\text{acceleration, prior knowledge, other student factors, other school factors})$$

Each aspect of the above relationships will be discussed in the following section.

## *Variables*

### *Student outcomes (MM and SM study scores)*

Students entering Year 11 of secondary schooling are beginning the first of a two year course of study, the Victorian Certificate of Education (VCE). The parameters of the course are set by the Victorian Curriculum and Assessment Authority (VCAA) (formerly known as Board of Studies, Victoria, BOS or VBOS), which lead to the achievement of VCE. This certificate is awarded to students on behalf of the Victorian State Government upon successful completion of Year 11 and 12 which allows and determines entry into tertiary institutions. As mentioned in chapter 1, these study scores give students a ranking in the group (or cohort) of students taking that study across the State of Victoria in that year. The ranking of students in the cohort is determined by detailed evaluation of the students' performances in the graded assessments for that study. A study score of 50 indicates that the student has finished at the top of the cohort. A study score of 0 indicates that the student has finished at the bottom of the cohort. A study score of 30 indicates that the student has finished in the middle of the cohort. Study scores are awarded so that they cluster around 30. For any study, about 65-70% of students get a study score between 23 and 37.

As study scores are determined by detailed evaluation of the students' performances in the graded assessments for that study and are based on the same study design for the years 2001-2004, then the MM and SM study scores are appropriate measures of students' performance in these studies. Consequently, the variables used for grades of assessment tasks for each study were considered redundant and were not included in the analysis. The acronyms MM and SM will be used to represent the dependent variables, which are continuous variables, as continuous (metric) measures of student's study scores.

### *Acceleration*

Students undertaking SM in Year 12 will need to also undertake MM concurrently or as for accelerated students, MM may be completed a year earlier. Students who complete MM one year earlier (at Year 11) than their age peers, are very competent mathematics students who have been identified by their schools as accelerated learners in the area of mathematics. The variable ACCEL was created (based on students' year of completion of their MM study) to determine whether students were accelerated (=1) or not (=0).

### *Prior knowledge*

As outlined in Chapter 1 one of the requirements for all students who are enrolled in one or more sequences of units 3 and 4 is to sit a General Achievement Test (GAT). This means that any student who has completed a Year 12 subject in Year 11 will have had to sit two GAT tests during their VCE course, one at Year 11 and one at Year 12. The GAT measures levels of general achievement accomplished across the following areas with the given raw scores of:

- 40 for written communication
- 35 for mathematics/science/technology
- 35 for humanities/arts/social sciences

GAT results are used by VCAA to monitor school-assessed coursework and school-assessed tasks. Although GAT results do not count directly towards VCE results, they do play an important role in verifying the school assessed coursework and examinations have been accurately assessed. By 'adjusting for student academic ability in large measure, captures the impact of home background factors, since academic ability measures themselves reflect the effects of unmeasured home and background characteristics' (VCAA, 2002 p.6).

As outlined on the VCAA (2004) website, verification of students' achievement can be performed because achievement on the GAT is a good predictor of achievement on other assessments. If students have done well on the GAT, then their achievements are likely to be high on their school assessments and examinations. Clearly, some GAT questions relate more closely to achievement in particular studies. For the purposes of this study, the GAT results of student's performance on questions relating to Mathematics, Science and Technology (GATMST) will be used as a measure of prior ability and as a basis for comparing students of equal ability. This is a standardised GAT score that has been calculated using the same scale that is used for study scores, that is a mean of 30 and a standard deviation of 7.

Students who have two GAT scores will be allocated the average GATMST score for both years. By taking into account their prior knowledge, as measured by their GATMST score, in Year 11 only, it would not be a good indicator of their prior ability for SM. By taking into account only the GATMST score achieved in Year 12, would not be a good indicator of their prior ability for MM. The average GATMST for the two years was taken to give a more representative score of prior ability for *both* MM and SM and to also be similar to GATMST scores of other students who had not completed a VCE study a year earlier. Hence the acronym GATMST will be used to represent a continuous explanatory variable (0-50) as a measure of student's prior ability.

To account for prior ability, the variable GATMST will be used for the MM model. For the SM model, since MM is a prerequisite to do SM, both the GATMST and MM variables will be used as a measure of prior ability.

### *Other factors*

Two of the most powerful predictors of student performance are student academic ability and gender (VCAA, 2002 p.4). Explanations of student performance, as found in studies such the TIMSS, have also been based on demographic characteristics that are commonly described by students socioeconomic status, ethnicity or gender.

Accordingly, based on the availability of data, the following acronyms which are used to represent student and school (context) characteristics have been included:

- GENDER, to represent boys (=0) and girls (=1) students;
- SETTING to represent a school class setting whether it is single-sex (=0) or coeducational(=1);
- SECTOR to represent a school sector whether it is from the Government (=0), Catholic(=1) or Independent (=2) sectors;

Table 4 and Table 5 provide a summary of the measurement bases of the outcome variables and the explanatory variables used in the data analysis.

Table 4: Measurement of Outcome Variables

Construct	Variable	Measure
<b>Outcome Variables</b>		
Specialist Mathematics study score	SM	The Specialist Mathematics study score (0-50) reported to students by VCAA. (continuous variable)
Mathematical Methods study score	MM	The Mathematical Methods study score (0-50) reported to students by VCAA.  (*also used as an explanatory variable for the SM model)

Table 5: Measurement of Predictor Variables

Construct	Variable	Measure
Acceleration	ACCEL	Assumes the value 1 if student is accelerated and 0 otherwise.
Gender	GENDER	Assumes the value 1 if student is a girl and 0 if a boy.
General Achievement Test (MST)	GATMST	The Mathematics/Science/Technology component of the General Achievement Test (0-50) as reported to students. (continuous variable)
School class setting	SETTING	Based on gender composition of MM class for each school. Assumes the values 0 if single-sex and 1 if coeducational.
Government Sector	GOVT	Assumes the values 1 for Government sector, 0 otherwise.
Independent Sector	INDPT	Assumes the values 1 for INDPT sector, 0 otherwise.

The data outlined above has been used to investigate within a single model, the influence of student level and school level factors on student VCE mathematics study scores and



the relationships that existed between the variables in this model. The 2-level models that will be investigated for each of the MM and SM study scores is provided below (see Figures 1, 2 and 3), using the conventions and notations mentioned earlier in this chapter.

Figure 1: Model 1 - MM

$$MM_{ij} = \beta_{0j} + \beta_{1j}GENDER_i + \beta_{2j}GATMST_i + \beta_{3j}ACCEL_i + e_{ij}$$

and

$$\beta_{0j} = \gamma_{00} + \gamma_{01}SETTING + \gamma_{02}INDPT + \gamma_{03}GOVT + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}SETTING + \gamma_{12}INDPT + \gamma_{13}GOVT + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}SETTING + \gamma_{22}INDPT + \gamma_{23}GOVT + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}SETTING + \gamma_{32}INDPT + \gamma_{33}GOVT + u_{3j}$$

where  $i = 1, 2, \dots, n$  ( $n =$  number of students )  
 $j = 1, 2, \dots, N$  ( $N =$  number of schools)

Figure 2: Model 2. - SM

$$SM_{ij} = \beta_{0j} + \beta_{1j}GENDER_i + \beta_{2j}GATMST_i + \beta_{3j}ACCEL_i + e_{ij}$$

and

$$\beta_{0j} = \gamma_{00} + \gamma_{01}SETTING + \gamma_{02}INDPT + \gamma_{03}GOVT + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}SETTING + \gamma_{12}INDPT + \gamma_{13}GOVT + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}SETTING + \gamma_{22}INDPT + \gamma_{23}GOVT + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}SETTING + \gamma_{32}INDPT + \gamma_{33}GOVT + u_{3j}$$

where  $i = 1, 2, \dots, n$  ( $n =$  number of students )  
 $j = 1, 2, \dots, N$  ( $N =$  number of schools)

Figure 3: Model 3. – SM (Including MM as a predictor)

$$SM_{ij} = \beta_{0j} + \beta_{1j}GENDER_i + \beta_{2j}GATMST_i + \beta_{3j}MM_i + \beta_{4j}ACCEL_i + e_{ij}$$

and

$$\beta_{0j} = \gamma_{00} + \gamma_{01}SETTING + \gamma_{02}INDPT + \gamma_{03}GOVT + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}SETTING + \gamma_{12}INDPT + \gamma_{13}GOVT + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}SETTING + \gamma_{22}INDPT + \gamma_{23}GOVT + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}SETTING + \gamma_{32}INDPT + \gamma_{33}GOVT + u_{3j}$$

$$\beta_{4j} = \gamma_{40} + \gamma_{41}SETTING + \gamma_{42}INDPT + \gamma_{43}GOVT + u_{4j}$$

where  $i = 1, 2, \dots, n$  ( $n$  = number of students )  
 $j = 1, 2, \dots, N$  ( $N$  = number of schools)

The aims of this study are to present and explain two student outcome models based on preliminary hypothesised models. The hypothesised *a priori* models as outlined above are tested first and on the basis of the estimates a post hoc approach is adopted to fit the best model for students' MM and SM study scores with the variables of interest in the study.

In this chapter it was considered necessary to give a brief introduction to the use of multi-level modelling to give the reader some background and justification for the decision to use the more sophisticated methods of data analysis and modelling.

A description of the methodology used in this study, the limitations associated with data previously collected for another purpose and the manner in which the VCAA data were collected, was also provided in this chapter. As well as this, a full description of the construction of variables used for the multi-level analysis and the multi-level models that will be tested were presented. These models are described in further detail in chapter four where the results of the estimation of each model are presented.

## Chapter 4

### Results

The purpose of this chapter is to present the analysis of the data. This study examines the effects of acceleration on students' achievement in senior secondary mathematics, as measured by the Mathematical Methods (MM) and Specialist Mathematics (SM), of study scores. Data from the VCAA was used to provide information on students from Victoria, over a four-year period (2001-2004). Before proceeding to applying multi-level analysis to answer the research questions of this study, a descriptive data analysis is provided for both categorical variables and continuous variables, and the assumptions of normality, linearity, homoscedasticity and independence of variables, is investigated. Descriptive analyses were performed by using the statistical software program SPSS version 14.

#### Descriptive analysis

##### Categorical variables

The study included a total of 21 365 students from schools that have more than 3 students taking both MM and SM at VCE. Descriptive statistics for the sample data is shown in the tables and graphs below. The descriptive statistics for the categorical variables is provided in Tables 6-12.

Tables 6, 7, 8 and 9 show the total distribution of students according to their gender, school sector, whether they are accelerated or not and their school class setting during the 2001-2004 period, respectively.

Table 6: Distribution of Student Gender

	Frequency	Percent
Boys	12897	60.4
Girls	8468	39.6
Total	21365	100.0

Table 7: Distribution of School Sector

	Frequency	Percent
Government	10228	47.9
Catholic	4256	19.9
Independent	6881	32.2
Total	21365	100.0

Table 6 shows that the ratio of boys to girls who study MM and SM is 3 to 2. As seen from Table 7, almost half the students in Victoria are enrolled in Government schools. The remaining students attend Catholic and Independent Schools with 62% ( $=32.2/(19.9+32.2)$ ) of these students attending Independent schools. Table 8 shows that the proportion of students who have been accelerated over the four year period is 15.5% of the population of students who study both MM and SM. Almost three quarters of the students attend co-educational classes, as shown in Table 9.

Table 8: Distribution of accelerated students

	Frequency	Percent
No	18050	84.5
Yes	3315	15.5
Total	21365	100.0

*Table 9:* Distribution of students in single-sex and co-educational class settings

	Frequency	Percent
single-sex	5561	26.0
co-educational	15804	74.0
Total	21365	100.0

Table 10 illustrates that the proportion of VCE students studying both MM and SM each year is consistent from year to year. Although numbers increased from 2001-2003, there were 243 less students in 2004.

*Table 10:* Distribution of students for the years 2001-2004

	Frequency	Percent
2001	5311	24.9
2002	5403	25.3
2003	5442	25.5
2004	5209	24.4
Total	21365	100.0

Table 11 shows the distribution of students from year to year based on gender and acceleration. It can be seen that the proportion of boys to girls (3 to 2) studying both MM and SM is consistent from year to year and the proportion for boys to girls who are accelerated is almost the same. The percentage of accelerated students in the data increased from 14.2% in 2001 to 16.6% in 2004.

*Table 11.* Distribution of students based on gender, acceleration and year of completion of VCE

Year				Student gender		Total
				Boys	Girls	
2001	Accelerated	No	Count	2723	1832	4555
			% of Total	51.3%	34.5%	85.8%
		Yes	Count	479	277	756
			% of Total	9.0%	5.2%	14.2%
	Total		Count	3202	2109	5311
			% of Total	60.3%	39.7%	100.0%
2002	Accelerated	No	Count	2783	1810	4593
			% of Total	51.5%	33.5%	85.0%
		Yes	Count	483	327	810
			% of Total	8.9%	6.1%	15.0%
	Total		Count	3266	2137	5403
			% of Total	60.4%	39.6%	100.0%
2003	Accelerated	No	Count	2790	1770	4560
			% of Total	51.3%	32.5%	83.8%
		Yes	Count	546	336	882
			% of Total	10.0%	6.2%	16.2%
	Total		Count	3336	2106	5442
			% of Total	61.3%	38.7%	100.0%
2004	Accelerated	No	Count	2613	1729	4342
			% of Total	50.2%	33.2%	83.4%
		Yes	Count	480	387	867
			% of Total	9.2%	7.4%	16.6%
	Total		Count	3093	2116	5209
			% of Total	59.4%	40.6%	100.0%

The summarised frequencies for the data are shown in Table 12. The number of schools for the entire period is estimated as the average number of schools in the periods 2001-2002 and 2003-2004. This was necessary because different school identifiers were used for each of these 2-year periods.

Table 12: Summary of distribution of students based on acceleration, gender, class setting and sector

	Number of students	Number accelerated students (%)	Estimated Number of schools
2001	5311	756 (14.2%)	342
2002	5403	810 (15.0%)	345
2003	5442	882 (16.2%)	340
2004	5209	867 (16.6%)	337
Total	21365	5209 (15.5%)	374
Government Schools	10228	42 (8.2%)	203
Catholic Schools	4256	749 (17.6%)	80
Independent Schools	6881	1724 (25.1%)	91
Single-sex setting	5561	1696 (30.5%)	156
Co-educational setting	15804	1619 (10.2%)	591
Boys	12897	1988 (15.4%)	Na
Girls	8468	1327 (15.7%)	Na

As shown in Table 12, the number of students in the data set reached a peak in 2003, however the percentage of accelerated students in the data climbed from 14.2% in 2001 to 16.6% in 2004. The percentage of accelerated students varied significantly between school sectors with more than triple the acceleration rate for Independent schools as opposed to Government schools. Similarly the acceleration rate was three times higher for single-sex classes than for co-educational classes. Although the acceleration rates were similar for girls and boys, the number of boys in the data exceeded the number of girls by 50%.

As there were significant differences in the number of students being accelerated, based on school sectors and school class settings, tests were conducted to check independence of the acceleration and sector variables.

*Tests for Independence*

Chi-squared tests (see Table 13) rejected the hypothesis that sector and acceleration are independent ( $p < 0.0005$ ) and the existence of this relationship was also verified by the nominal directional measures (see Table 14).

For example the tau value of 0.043 indicates that the error rate has been reduced by 4.3% of the error rate in predicting whether a student is accelerated based on what sector they were from. Similar tests were conducted for school class setting and acceleration and similar findings were evident ( $p < 0.0005$ ). As independence cannot be assumed, conventional methods of analysis are not appropriate.

*Table 13:* Chi-squared tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	905.616 <sup>a</sup>	2	.000
Likelihood Ratio	915.274	2	.000
Linear-by-Linear Association	903.220	1	.000
N of Valid Cases	21365		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 660.36.

*Table 14:* Nominal directional measures

			Value	Asymp. Std. Error	Approx. T	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.059	.003	17.063	.000
		School Sector Dependent	.077	.004	17.063	.000
		Accelerated Dependent	.000	.000	.	.
	Goodman and Kruskal tau	Symmetric				
		School Sector Dependent	.027	.002		.000
		Accelerated Dependent	.043	.003		.000
	Uncertainty Coefficient	Symmetric	.029	.002	15.654	.000
		School Sector Dependent	.021	.001	15.654	.000
		Accelerated Dependent	.050	.003	15.654	.000



### *Continuous variables*

Assumptions often made about continuous data include normality, linearity and homoscedasticity. In the following section these assumptions are investigated for the continuous variables MM, SM and GATMST

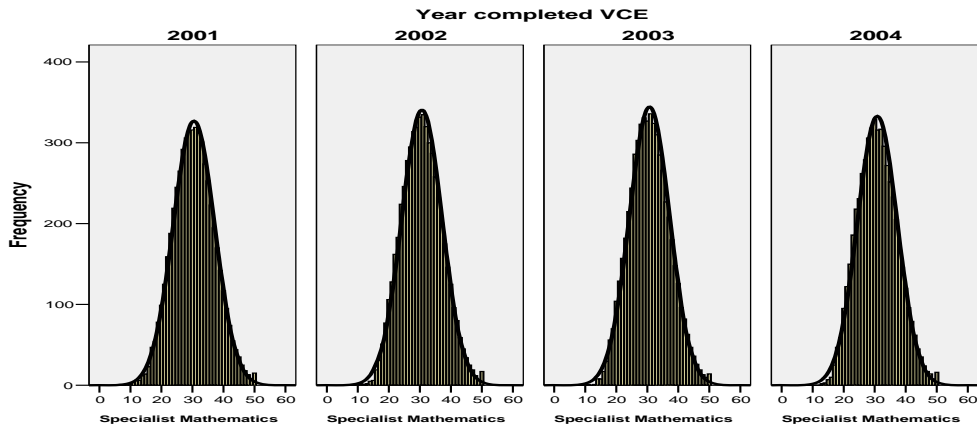
### *Normality*

Table 15 shows the mean values for MM, SM and GATMST for the students in the data. The GATMST and MM scores are higher than the average value of 30 because students who complete both MM and SM tend to have higher ability. The spread of values for MM and GATMST was also affected with MM having a standard deviation of 5.568 and GATMST a standard deviation of (6.4). As this data has a large sample size (200+), the slight skewness and kurtosis values shown will not affect the analysis and the assumption of normality can be assumed. Normality of the distribution for each of the variables MM, SM and GATMST is also evident from Graphs 1, 3 and 5.

*Table 15:* Descriptive statistics for continuous variables

	N	Min	Max	Mean	Std.	Skewness		Kurtosis	
							Std. Error		Std. Error
Mathematical Methods	21365	15	50	35.71	5.568	.020	.017	-.148	.034
Specialist Mathematics	21365	9	50	30.79	6.510	.163	.017	-.204	.034
General Achievement Test	21365	11	50	37.04	6.410	-.214	.017	-.203	.034
Valid N (listwise)	21365								

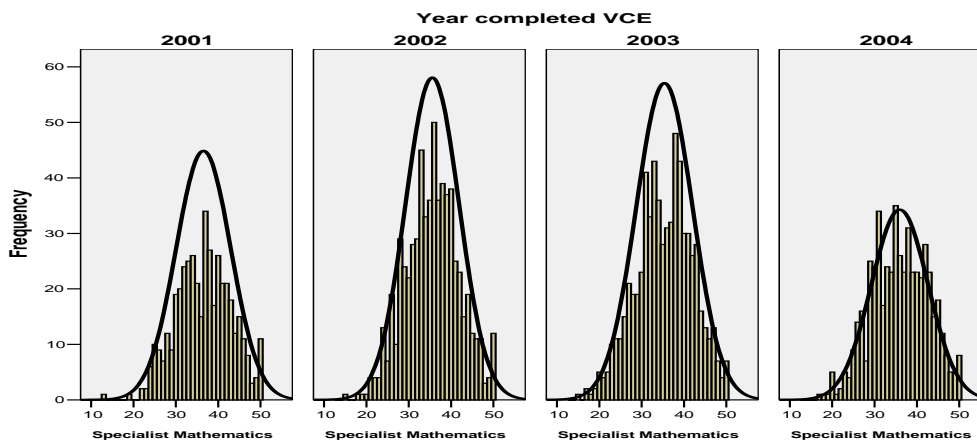
Graph 1: Normality of Specialist Mathematics scores



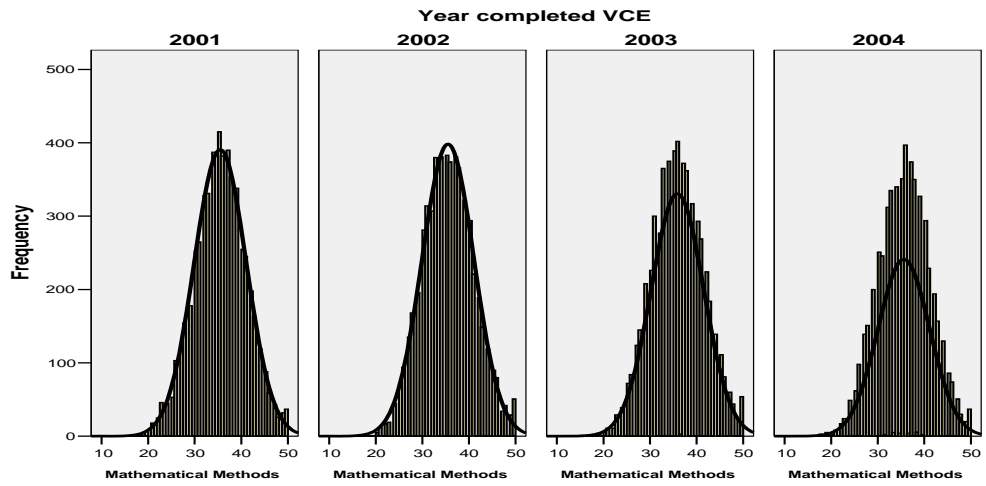
The GATMST and MM scores for accelerated students were obtained by averaging two scores. This is why there are values that are not whole numbers in the data. As such the graphs of the distribution of MM and GATMST do not look perfectly normal.

An analysis of the effects of acceleration will also be provided for students with a GATMST score above 45 (out of 50). These students would be regarded as exceptionally gifted as they are in the top 2% of students in the State of Victoria. Corresponding graphs of the distribution of students' scores for SM and MM, for students who obtained more than 45 for their GATMST score, also show normality for MM and SM (refer to Graphs 2 and 4).

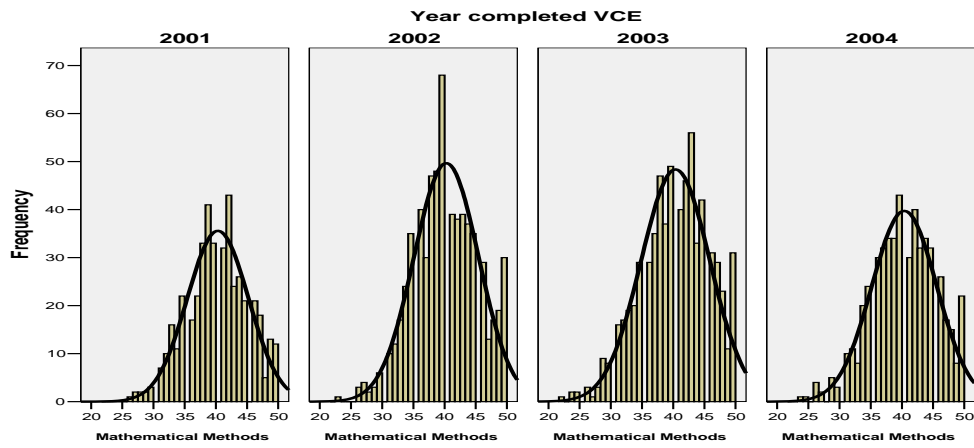
Graph 2: Normality of Specialist Mathematics scores based on GATMST above 45



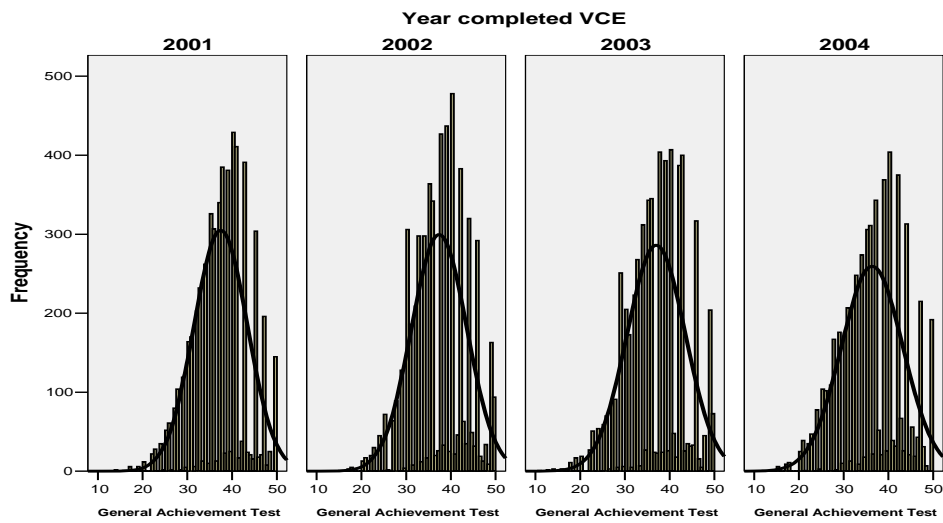
Graph 3: Normality of Mathematical Methods scores



Graph 4: Normality of Mathematical Methods scores based on GATMST above 45

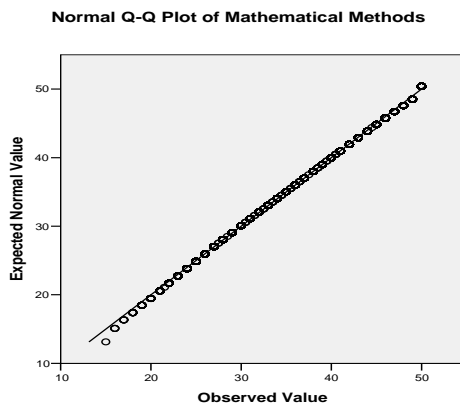


Graph 5: Normality of General Achievement Test (Mathematics/Science/Component) (GATMST)

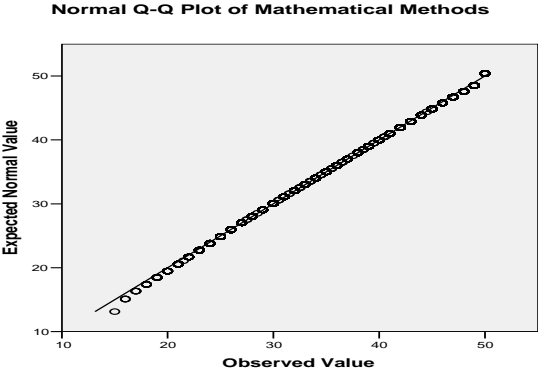


The normal Q-Q plots, which show the observed values for each score plotted against the expected value from the normal distribution for SM, MM and GATMST, are also provided in Graphs 6, 7 and 8. Since the lines are quite straight, it strongly suggests a normal distribution. As such the assumptions of normality are justified for the continuous variables MM, SM and GATMST.

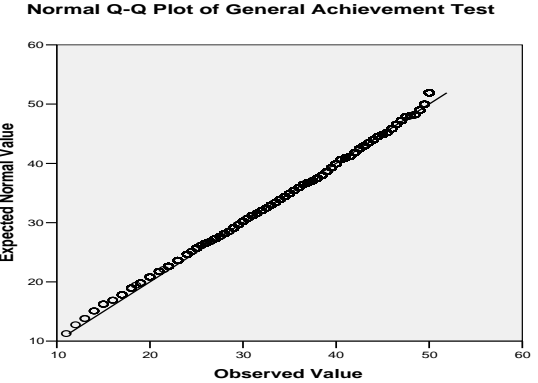
Graph 6: Normal Q-Q plot for the distribution of MM scores for the period 2001-2004



Graph 7: Normal Q-Q plot for the distribution of SM scores for the period 2001-2004

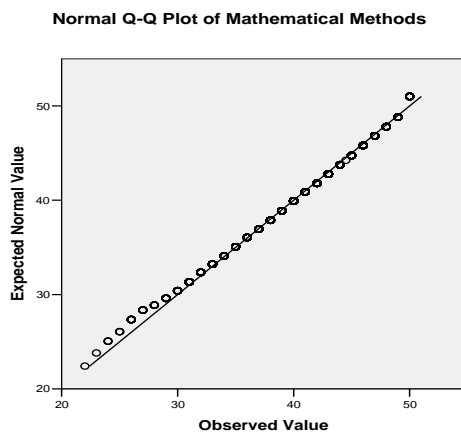


Graph 8: Normal Q-Q plot for the distribution of GATMST scores for the period 2001-2004

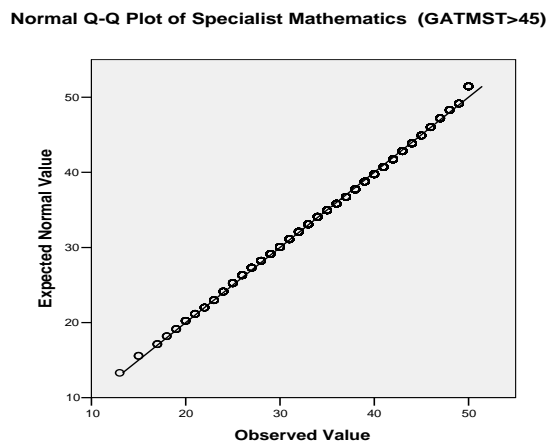


For students with GATMST above 45, Graphs 9 and 10 show that the distribution of MM and SM scores, are normally distributed.

Graph 9: Normal Q-Q plot for the distribution of MM scores (GATMST above 45) for the period 2001-2004



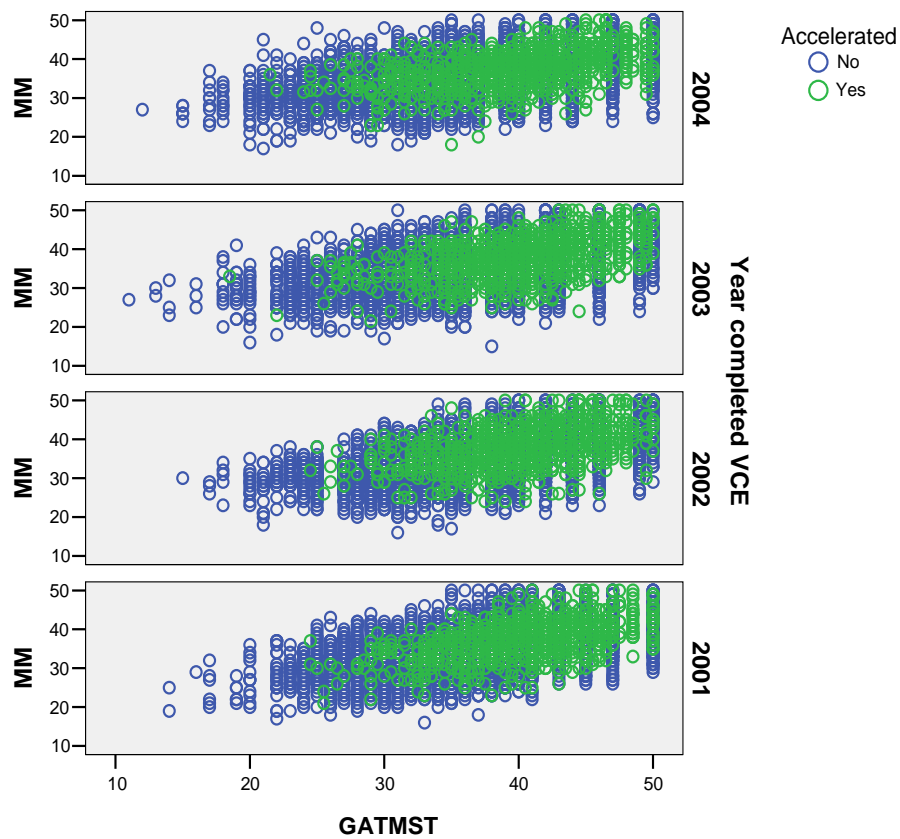
Graph 10: Normal Q-Q plot for the distribution of SM scores (GATMST above 45) for the period 2001-2004



### *Linearity and homoscedasticity*

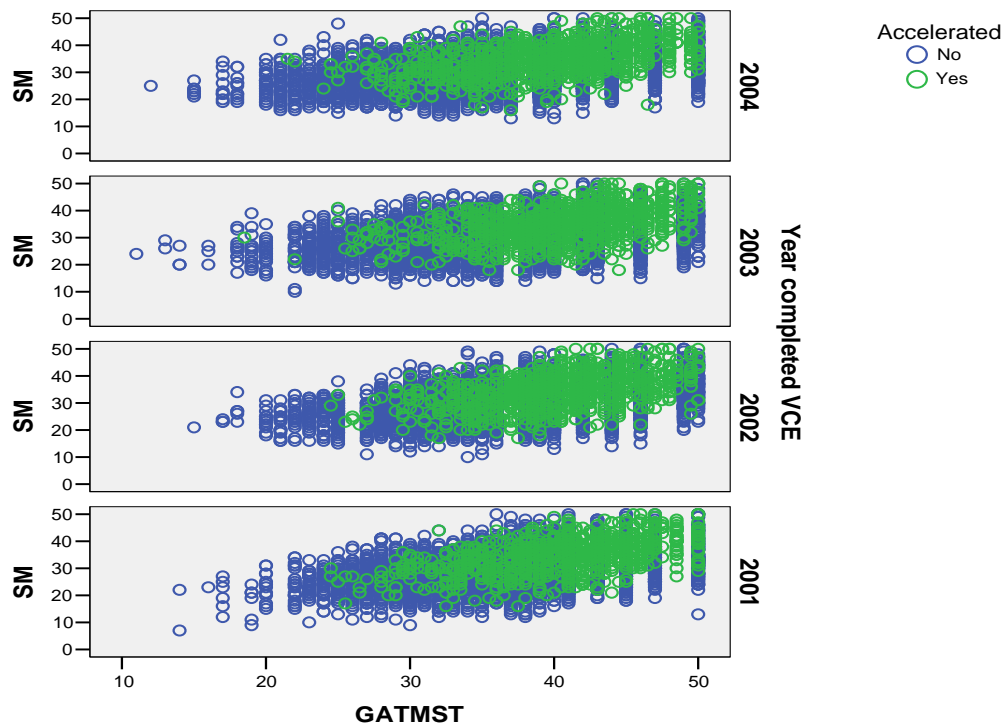
Scatterplots were constructed to observe the distribution of scores for accelerated students and the relationship between the continuous variables MM, SM and GATMST (refer to Graphs 11, 12 and 13). As is evident the scores are all positively and linearly related. High GATMST scoring students had high MM and SM scores and also tended to be accelerated students.

Graph 11: Scatterplots of the MM and GATMST variables for each of the years 2001-2004, based on acceleration



Graph 11 also indicates a substantial number of students with a slightly above average performance in the GATMST and who did very well at MM without being accelerated. These students could possibly be students who may be strong mathematically and may have less developed linguistic analytical skills that are normally suited for the GATMST, as might be the case for a number of Asian students.

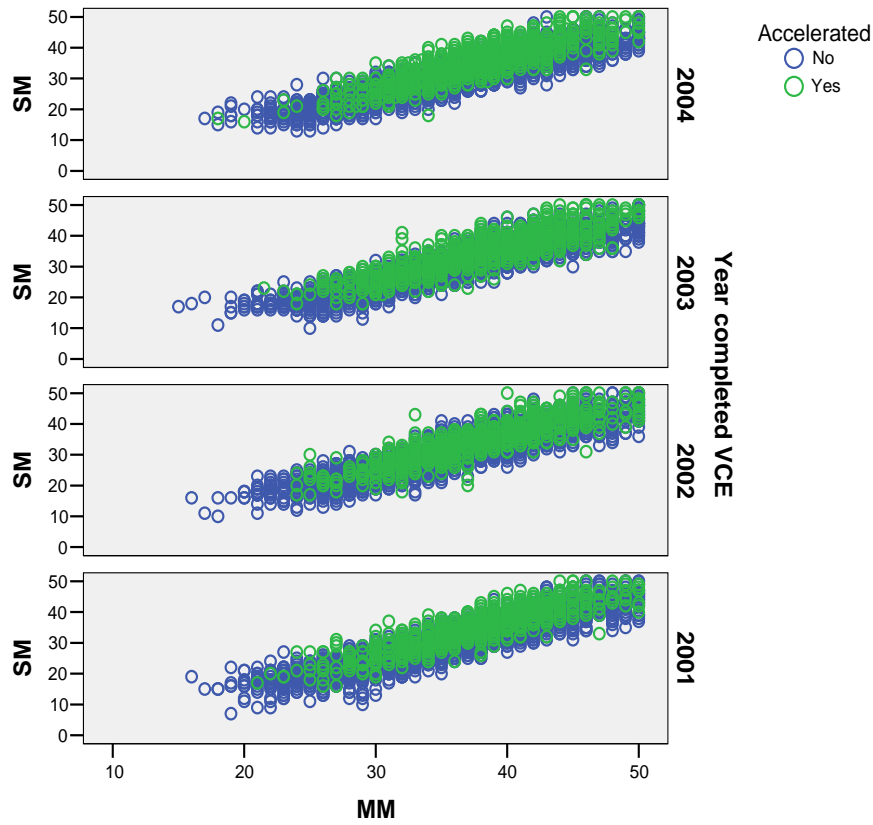
Graph 12: Scatterplots of the SM and GATMST variables for each of the years 2001-2004, based on acceleration



As MM is a pre-requisite study for SM, a scatterplot of the SM, MM and accelerated scores, was also constructed (see Graph 13). As is evident, MM and SM have a strong positive correlation and that accelerated students tend to have higher SM scores. The cluster of scores for all scatterplots is fairly even from one end to the other hence linearity and homoscedasticity can be assumed for the sample.



Graph 13: Scatterplots of the MM and SM and Accelerated scores for each of the years 2001-2004



As seen from the analyses, so far, no violation of the assumptions of normality, linearity and homoscedasticity have been made and appropriate statistical techniques can now be applied.

#### *Correlation analysis*

The SPSS statistical program was used to investigate the relationship between MM, SM and GATMST by finding the Pearson product-moment correlation coefficient (see Table 16).

Table 16: Correlations for MM, SM and GATMST

		<b>Correlations</b>		
		General Achievement Test	Mathematical Methods	Specialist Mathematics
General Achievement Test	Pearson Correlation	1	.494**	.429**
	Sig. (2-tailed)		.000	.000
	N	21365	21365	21365
Mathematical Methods	Pearson Correlation	.494**	1	.898**
	Sig. (2-tailed)	.000		.000
	N	21365	21365	21365
Specialist Mathematics	Pearson Correlation	.429**	.898**	1
	Sig. (2-tailed)	.000	.000	
	N	21365	21365	21365

\*\* . Correlation is significant at the 0.01 level (2-tailed).

As can be seen for the period 2001-2004 the relationship between all variables is positive and statistically significant, in particular the relationship between MM and SM is very strong (0.898), indicating that MM is a stronger predictor of SM than GATMST. This statistically significant positive relationship for the variables MM, SM and GATMST was consistently evident for each of the years:

- 2001 (n=5311, p<0.0005)
  - SM and MM (r=0.902)
  - SM and GATMST (r=0.468)
  - MM and GATMST (r=0.510)
  
- 2002 (n=5403, p<0.0005)
  - SM and MM (r=0.900)
  - SM and GATMST (r=0.451)
  - MM and GATMST (r=0.521)

- 2003 (n=5547,  $p<0.0005$ )  
SM and MM ( $r=0.903$ )  
SM and GATMST ( $r=0.404$ )  
MM and GATMST ( $r=0.478$ )
- 2004 (n= 5369,  $p<0.0005$ )  
SM and MM ( $r=0.889$ )  
SM and GATMST ( $r=0.412$ )  
MM and GATMST ( $r=0.482$ )

A correlation analysis for the period 2001-2004 was also carried out to compare the strength of the correlation coefficients for students who are accelerated and those who are not. Statistically significant correlations were found for MM, SM and GATMST with MM and SM having a very strong positive linear relationship.

- The MM and SM affect for students who are not accelerated was 0.905 ( $p<0.0005$ ), while for accelerated students it was slightly lower, 0.865 ( $p<0.0005$ ).
- The MM and GATMST affect for students who are not accelerated was 0.471 ( $p<0.0005$ ), while for accelerated students it was slightly higher, 0.496 ( $p<0.0005$ ).
- The SM and GATMST affect for students who are not accelerated was 0.381 ( $p<0.0005$ ), while for accelerated students it was higher, 0.488 ( $p<0.0005$ ).

The low significance levels that were reported provided a test for the null hypothesis that the correlation coefficient in the population is 0. In this case the null hypothesis is rejected.

Partial correlations were also used to explore the relationship between MM and SM controlling for GATMST. There was a statistically significant strong, positive partial correlation between MM and SM ( $r=0.874$ ,  $p<0.0005$ ) controlling for GATMST.

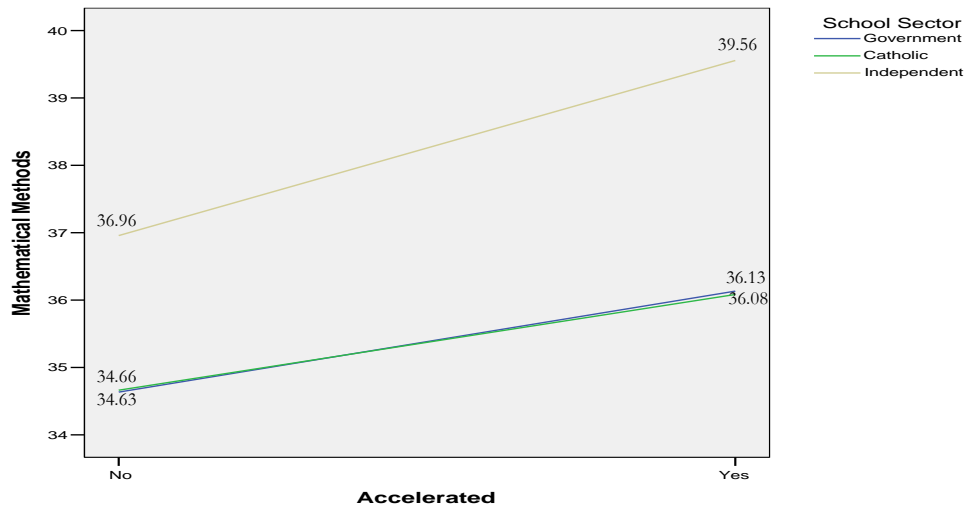
However, when exploring the relationship between SM and GATMST controlling for MM, there was a statistically significant weak negative partial correlation between SM and GATMST ( $r=-0.038$ ,  $p<0.0005$ ). This indicates that students with very high GATMST scores tend to have slightly lower SM scores. An inspection of the zero-order correlation for MM and SM controlling for GATMST ( $r=0.898$ ) suggests that controlling for GATMST had very little effect on the strength of the relationship between MM and SM. The zero-order correlation for SM and GATMST controlling for MM ( $r=0.427$ ) suggests that controlling for MM had a very big effect on the strength of the relationship between SM and GATMST. In regards to the correlation values found in this section it should also be noted that correlations may be over-estimated due to clustering with schools.

#### *A comparison of mean scores*

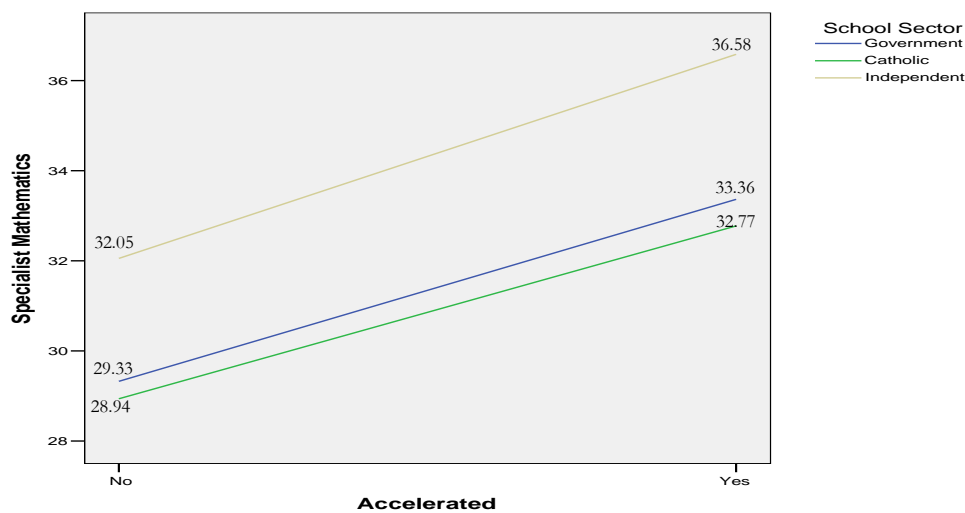
Line graphs were also drawn to inspect the average (mean) MM and SM scores across each sector and gender for the period 2001-2004. From Graphs 14 and 15, average MM and SM scores of students from Independent schools have higher means than students from Catholic and Government schools. In all sectors, for both MM and SM, accelerated students, on average, perform better than their equal ability age-peers. From Graph 14 average MM scores for students in Catholic and Government schools tend to be very

similar whereas the average SM scores as shown in Graph 15, students in Government schools tend to perform better, on average, than for students in Catholic schools.

Graph 14: Line graphs showing mean MM scores for each sector



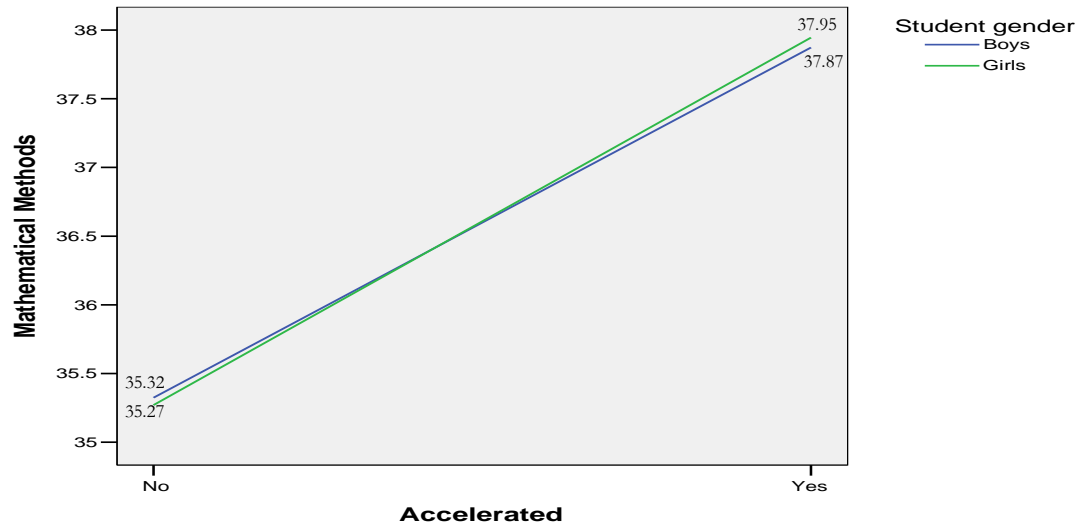
Graph 15: Line graphs showing mean SM scores for each sector



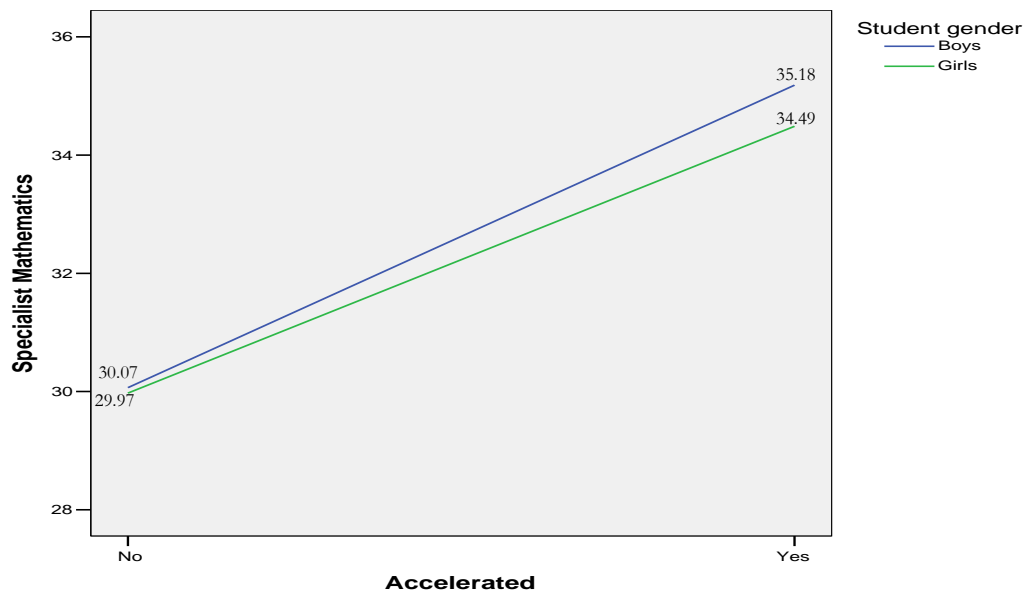
On inspection of the average (mean) MM and SM study scores across each gender (refer to Graphs 16 and 17), students who are accelerated perform better than students who are not. There seems to be no gender effect on average MM and SM scores for students who

are not accelerated. For students who are accelerated, boys perform better than girls on average for SM. The effect of gender for average MM study scores seems to be reversed with girls doing slightly better than boys when accelerated and boys doing slightly better than girls when not accelerated..

Graph 16: Line graphs showing mean MM scores for each gender



Graph 17: Line graphs showing mean SM scores for each gender



*A comparison of Like School Groups (LSG)*

Each Government and Catholic school is allocated a Like Schools Group (LSG) to represent information about the school's student profile. It provides information relating to the proportions of students from backgrounds of poverty, as measured by the Educational Maintenance Allowance (EMA) or Youth Allowance, and of students from non-English speaking backgrounds (NESB) (see Table 2, p9 for information about each of the categories (1-10) and their proportions). A summary of the measurement bases of the LSG variable is given in Table 17.

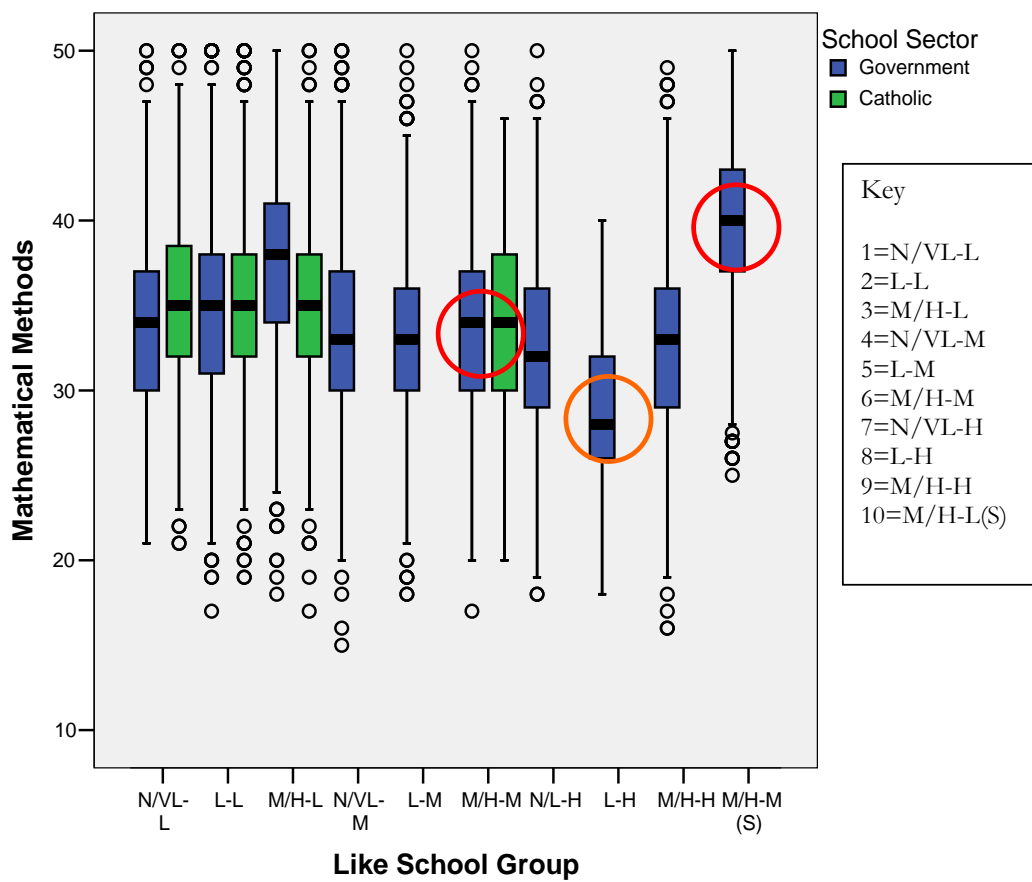
*Table 17: A summary of the measurement bases of the LSG variable*

Variable		Measure
Like School Group (LSG) (school's student profiles)	LSG	Assumes the following values 1=N/VL-L 2=L-L 3=M/H-L 4=N/VL-M 5=L-M 6=M/H-M 7=N/VL-H 8=L-H 9=M/H-H 10=M/H-L(S) the symbol (-) separates the proportion of LOTE speakers at home from the proportion of EMA or Youth Allowance recipients. N/VL means nil or very low L means low M means medium H means high M/H means medium to high

As previously mentioned LSG category 3S (referred to as LSG 10 in table 17) represents all select entry schools. These are Government secondary schools that provide a 'Select Entry Accelerated Learning Program' to address the learning needs of their gifted and high potential students who are capable of working at a significantly faster pace and in greater depth than their age peers (SOFWeb, 2004). They are the only Government

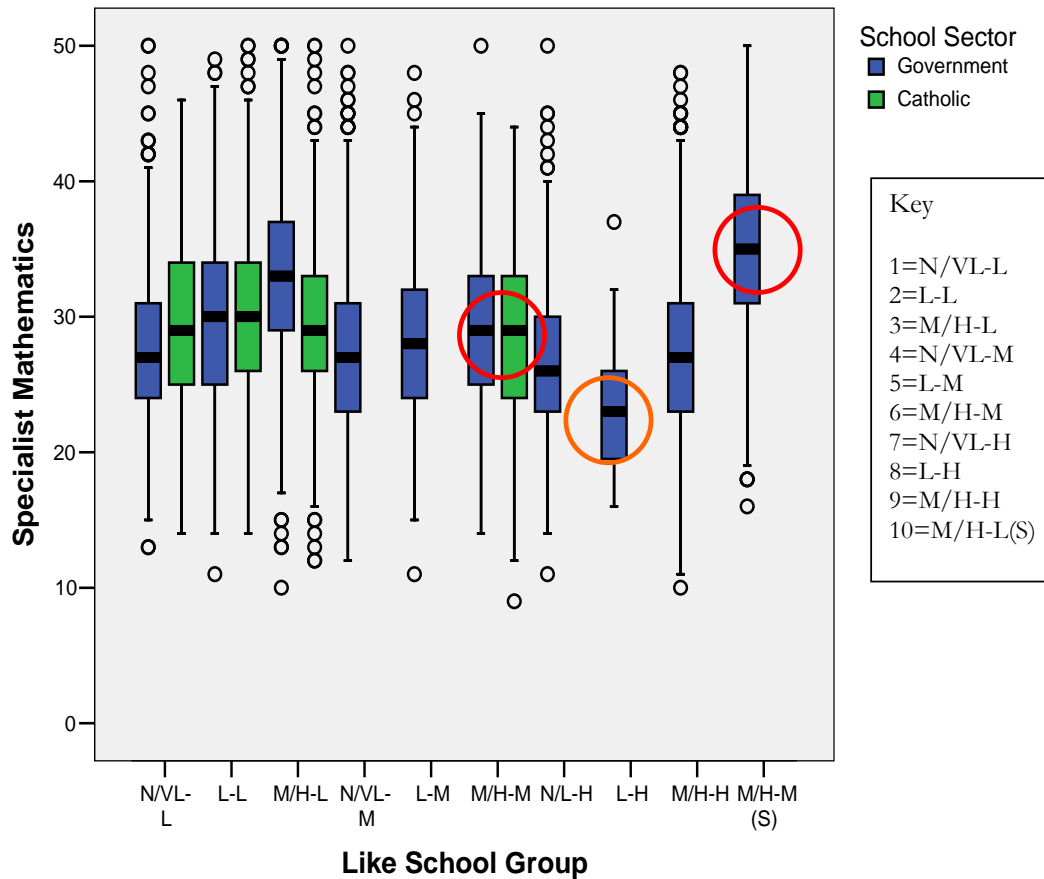
schools that offer acceleration programs. Boxplots showing the distribution of MM study scores (see Graph 18) and SM study scores (see Graph 19) were used to see if there were any differences in mathematics achievement amongst like school groups in particular LSG 10 (the select entry schools that offer acceleration programs) and LSG 3 (a group of schools with the same student profile (M/H-M) as LSG 10 but do not offer acceleration). The difference in achievement (see boxplots highlighted by the red circles) would be a consequence of either select entry, the use of acceleration or the interaction of both.

Graph 18: Boxplots showing the distribution of MM study scores amongst LSG schools





Graph 19: Boxplots showing the distribution of SM study scores amongst LSG schools



In comparing the two LSG groups with similar student profiles (M/H-M), both Graphs 18 and 19, show that Government schools that offer acceleration, namely LSG 10 (see also key) outperform Government and Catholic schools that do not offer acceleration programs (see location of boxplots highlighted by red circles). It must still be acknowledged that these schools recruit bright students through select entry and this may provide this more significant source of difference. Students attending schools that have a low proportion of students from NESB and a high proportion of students who receive a youth allowance, namely LSG 8, tend to have the lowest MM and SM study scores (see location of boxplot highlighted by orange circle).

With the exception of the LSG variable, which will not be used in the multi-level analysis, Table 18 summarises the frequencies of the data. The number of schools for the entire period is estimated as the average number of schools in the periods 2001-2002 and 2003-2004. This was necessary because different school identifiers were used in these periods.

*Table 18: Overall summary of student numbers*

	Number of students	Number accelerated students (%)	Estimated Number of schools
2001	5311	756 (14.2%)	342
2002	5403	810 (15.0%)	345
2003	5442	882 (16.2%)	340
2004	5209	867 (16.6%)	337
Total	21365	5209 (15.5%)	374
Government Schools	10228	42 (8.2%)	203
Catholic Schools	4256	749 (17.6%)	80
Independent Schools	6881	1724 (25.1%)	91
Single-sex setting	5561	1696 (30.5%)	156
Co-educational setting	15804	1619 (10.2%)	591
Boys	12897	1988 (15.4%)	na
Girls	8468	1327 (15.7%)	na

The percentage of accelerated students varied significantly between school sectors with more than triple the acceleration rate for Independent schools as opposed to Government schools. Similarly the acceleration rate was three times higher for single-sex classes than for co-educational classes. Although the acceleration rates were similar for boys and girls, the number of boys in the data exceeded the number of girls by 50%.

Table 19: Overall summary of mean scores

	GATMST	MM	SM
2001	37.48	35.57	30.59
2002	37.41	35.59	30.76
2003	37.01	35.96	30.84
2004	36.33	35.70	30.96
Total	37.04	35.71	30.79
Government Schools	36.53	34.76	29.66
Catholic Schools	36.83	34.91	29.61
Independent Schools	37.94	37.61	33.19
Single-sex setting	37.74	37.17	32.50
Co-educational setting	36.80	35.19	30.18
Boys	37.77	35.72	30.85
Girls	35.93	35.69	30.68

From Table 19, there appears to have been a slight decline in the GATMST scores over the four years, however, this has been matched by a steady increase in SM scores over the period. Independent schools outperform the other two sectors in all cases and single-sex classes outperform co-educational classes. Finally, boys appear to score higher than girls in all cases, but especially in the case of GATMST scores. The significance of the differences in Table 19 is not known. This can only be accurately established by fitting multi-level models to the data. In the following section a multi-level modelling analysis will be conducted that is organised according to two main research questions and sub-questions related to these.

## Multi-level Analysis

Multi-level analysis (as outlined in chapter 3) is a family of techniques that will be used to explore the relationship between students' study scores (outcomes) and acceleration taking into account a number of student and school factors (predictors). The following section will present the research questions with their corresponding hypotheses and analytical techniques.

The stated hypotheses will then be tested for six sets of data. That is, for all students who have:

1. completed their VCE studies in 2001;
2. completed their VCE studies in 2002;
3. completed their VCE studies in 2003;
4. completed their VCE studies in 2004;
5. General achievement test score for the mathematics, science and technology component (GATMST) above 45 (top 2%) and completed their VCE studies in the period 2001-2002;
6. GATMST score above 45 (top 2%) and completed their VCE studies in the period 2003-2004

Statistical analyses for each of the data sets will be carried out to answer the research questions, and a summary of findings will be provided for each of the years 2001, 2002, 2003 and 2004. To allow for the comparison of the estimated model coefficients over time, an overall summary, for the period 2001-2004, will be provided. The analysis of data for students with GATMST above 45 will be summarised for each of the periods 2001-2002 and 2003-2004. This was necessary because it ensured sufficient data and it

overcame the problem with school identifiers not being the same for each of the two year data sets. Furthermore a comparison of coefficients over time, for students with GATMST above 45, will also be provided. Multi-level models will then be fitted to the data using HLM version 6.

### *The Research Questions*

#### Question 1

What is the effect of *acceleration* on students' **MM** study scores based on prior knowledge, gender, school sector and school class setting?

#### Research Hypothesis 1

There is not a significant difference, on average, between the MM study scores of accelerated students compared to their equal ability age-peers who are not accelerated.

Sub-questions related to the MM study scores:

- a. What is the effect of *gender* on students' MM study scores based on acceleration, prior knowledge, sector and school class setting?
- b. What is the effect of the school factors, *sector* and *class setting* on students' MM study scores, based on prior knowledge, gender and acceleration?
- c. What is the effect of *prior knowledge* on students' MM study scores, based on acceleration, gender, sector and class setting?

Outcome variable: MM study scores

Predictor variables: ACCEL, GATMST, MM, Gender, Indpt, Govt and SETTING.

Analytic approach: The effects of these variables on MM study scores will be found by testing the following hypothesised multi-level model (see Figure 4) and allowing the

removal of any significant school parameters ( $p$  above 0.05). The coefficients are then interpreted with particular attention being paid to the coefficients for acceleration.

Figure 4: Model 1 - Proposed model to predict MM study scores

$$MM_{ij} = \beta_{0j} + \beta_{1j}GENDER_i + \beta_{2j}GATMST_i + \beta_{3j}ACCEL_i + e_{ij}$$

and

$$\beta_{0j} = \gamma_{00} + \gamma_{01}SETTING + \gamma_{02}INDPT + \gamma_{03}GOVT + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}SETTING + \gamma_{12}INDPT + \gamma_{13}GOVT + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}SETTING + \gamma_{22}INDPT + \gamma_{23}GOVT + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}SETTING + \gamma_{32}INDPT + \gamma_{33}GOVT + u_{3j}$$

where  $i = 1, 2, \dots, n$  ( $n$  = number of students)

$j = 1, 2, \dots, N$  ( $N$  = number of schools)

### Question 2

What is the effect of *acceleration* on students' **SM** study scores based on prior knowledge, gender, school sector and school class setting?

### Research Hypothesis 2

There is a significant difference, on average, between the SM study scores for accelerated students compared to equal ability age peers who were not accelerated.

Sub-questions related to the SM study scores:

- a. What is the effect of *gender* on students' SM study scores, based on acceleration, prior knowledge, sector and class setting?
- b. What is the effect of the school factors, *sector* and *class setting*, on students' SM study scores, based on prior knowledge, gender and acceleration?
- c. What is the effect of *prior knowledge* on students' SM study scores based on acceleration, gender, sector and class setting?

Outcome variable: SM study scores

Predictor variables: ACCEL, GATMST, MM, Gender, Indpt, Govt and SETTING.

Analytic approach: The effects of these variables on SM study scores will be found by testing the following hypothesised multi-level models (see Figures 5 and 6) and allowing the removal of any significant school parameters ( $p$  above 0.05). The coefficients are then interpreted with particular attention being paid to the coefficients for acceleration.

Figure 5: Model 2 - Proposed model to predict SM study scores

$$SM_{ij} = \beta_{0j} + \beta_{1j}GENDER_i + \beta_{2j}GATMST_i + \beta_{3j}ACCEL_i + e_{ij}$$

and

$$\beta_{0j} = \gamma_{00} + \gamma_{01}SETTING + \gamma_{02}INDPT + \gamma_{03}GOVT + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + \gamma_{11}SETTING + \gamma_{12}INDPT + \gamma_{13}GOVT + u_{1j}$$
$$\beta_{2j} = \gamma_{20} + \gamma_{21}SETTING + \gamma_{22}INDPT + \gamma_{23}GOVT + u_{2j}$$
$$\beta_{3j} = \gamma_{30} + \gamma_{31}SETTING + \gamma_{32}INDPT + \gamma_{33}GOVT + u_{3j}$$

where  $i = 1, 2, \dots, n$  ( $n$  = number of students )  
 $j = 1, 2, \dots, N$  ( $N$  = number of schools)

Figure 6: Model 3 - Proposed model to predict SM study scores (incl. MM as a predictor)

$$SM_{ij} = \beta_{0j} + \beta_{1j}GENDER_i + \beta_{2j}GATMST_i + \beta_{3j}MM_i + \beta_{4j}ACCEL_i + e_{ij}$$

and

$$\beta_{0j} = \gamma_{00} + \gamma_{01}SETTING + \gamma_{02}INDPT + \gamma_{03}GOVT + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + \gamma_{11}SETTING + \gamma_{12}INDPT + \gamma_{13}GOVT + u_{1j}$$
$$\beta_{2j} = \gamma_{20} + \gamma_{21}SETTING + \gamma_{22}INDPT + \gamma_{23}GOVT + u_{2j}$$
$$\beta_{3j} = \gamma_{30} + \gamma_{31}SETTING + \gamma_{32}INDPT + \gamma_{33}GOVT + u_{3j}$$
$$\beta_{4j} = \gamma_{40} + \gamma_{41}SETTING + \gamma_{42}INDPT + \gamma_{43}GOVT + u_{4j}$$

where  $i = 1, 2, \dots, n$  ( $n$  = number of students )  
 $j = 1, 2, \dots, N$  ( $N$  = number of schools)

### *Statistical Analysis (2001)*

To answer the research questions, the descriptives for level 1 (student) and level 2(school) variables are provided for each year. Following this, for each model, output produced using the HLM version 6 statistical program, is tabulated. These tables will show the final estimation of fixed effects of the predictor variables on the outcome variables.

### *Analysis for MM based on Model 1 (2001)*

Descriptives for 2001 showing student (LEVEL-1) and school (LEVEL-2) variables are provided in Table 20. As is evident from this table there were 5311 students, from 342 schools, who studied both MM and SM in 2001. There are three continuous variables, namely the outcome variable MM (mean=35.57, sd=5.56), SM (mean 30.59, sd=6.63) and predictor variable GATMST (mean=37.48, sd=5.96) where the GATMST is used as a measure of prior knowledge. There are also five dichotomous variables, namely ACCEL (accelerated(=1) or not(=0)), GENDER (girl (=1) or boy(=0)), SETTING (coeducational (=1) or single-sex (=0)), INDPT(Independent (=1) or Catholic(=0)) and GOVT(Government(=1) or Catholic(=0)) variables.



Table 20: Descriptives of level 1 and 2 variables for MM (2001)

LEVEL-1 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
GENDER	5311	0.40	0.49	0.00	1.00
GATMST	5311	37.48	5.96	14.00	50.00
MM	5311	35.57	5.56	16.00	50.00
SM	5311	30.59	6.63	9.00	50.00
ACCEL	5311	0.14	0.35	0.00	1.00
LEVEL-2 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
SETTING	342	0.79	0.41	0.00	1.00
INDPT	342	0.24	0.43	0.00	1.00
GOVT	342	0.55	0.50	0.00	1.00

Tables 21 and 22 show the fixed and random effects of the variables in the MM model.

Table 21: Final estimation of fixed effects for MM based on Model 1(2001)

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	19.934463	0.499162	39.936	339	0.000
SETTING, $\gamma_{01}$	-1.656454	0.288323	-5.745	339	0.000
INDPT, $\gamma_{02}$	1.986421	0.302814	6.560	339	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	0.710362	0.134209	5.293	341	0.000
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	0.406643	0.012016	33.841	341	0.000
For ACCEL slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	-0.020139	0.210035	-0.096	341	0.924

Table 22. Final estimation of variance and covariance components for MM (2001)

Random Effect	Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1, $u_0$	3.71723	13.81784	69	76.41844	0.252
GENDER slope, $u_1$	0.40870	0.16704	71	55.82051	above .500
GATMST slope, $u_2$	0.08495	0.00722	71	68.68243	above .500
ACCEL slope, $u_3$	0.57744	0.33344	71	66.55967	above .500
level-1, R	4.05897	16.4752			
Statistics for current covariance components model					
-----					
Deviance	= 30527.755924				
Number of estimated parameters = 11					

Tables 21 and 22 show all the variables needed in the model. Variables were left out of the model if their estimates were not significant, provided there were absolute t-values less than 2 and if further exploratory analysis involving t-tests like in Table 23, verified that they were not needed in the model.

Table 23: Exploratory Analysis to obtain estimated level-2 coefficients and their standard errors for MM (2001)

Level-1 Coefficient	Potential Level-2 Predictors		
	GOVT		
INTRCPT1, $\beta_0$			
Coefficient	-0.094		
Standard Error	0.233		
t value	-0.402		
	SETTING	INDPT	GOVT
GENDER, $\beta_1$			
Coefficient	0.000	-0.017	0.030
Standard Error	0.028	0.027	0.023
t value	0.009	-0.629	1.284
	SETTING	INDPT	GOVT
GATMST, $\beta_2$			
Coefficient	0.000	0.006	-0.003
Standard Error	0.005	0.004	0.004
t value	0.036	1.328	-0.678
	SETTING	INDPT	GOVT
ACCEL, $\beta_3$			
Coefficient	-0.021	0.037	-0.021
Standard Error	0.024	0.023	0.020
t value	-0.871	1.635	-1.069

For example, by using an exploratory analysis based on t-tests like in Table 23, the variables, for example SETTING, INDPT and GOVT, had no effect on the GATMST coefficient hence in the final model the regression equation for the regression coefficient of GATMST,  $\beta_2$ , is

$$\beta_{2j} = \gamma_{20} + u_{2j}, \text{ where } \gamma_{20} = 0.407 \text{ (see Table 21) and } u_{2j} = 0.085 \text{ (see Table 22)}$$

instead of what was proposed in Model 1, that is:

$$\beta_{2j} = \gamma_{20} + \gamma_{21} \text{SETTING} + \gamma_{22} \text{INDPT} + \gamma_{23} \text{GOVT} + u_{2j}. \text{ This reasoning can also be}$$

applied to the remaining coefficients  $\beta_{0j}$ ,  $\beta_{1j}$  and  $\beta_{3j}$

Hence the final model used to estimate the MM scores for 2001, based on the final estimation of fixed effects and estimation of variance and covariance components, is given in Figure 7.

Figure 7: Final model for estimating MM study scores based on Model 1 (2001)

$$MM_{ij} = \beta_{0j} + \beta_{1j}GENDER_i + \beta_{2j}GATMST_i + \beta_{3j}ACCEL_i + e_{ij}$$

and

$$\beta_{0j} = \gamma_{00} + \gamma_{01}SETTING + \gamma_{02}INDPT + \gamma_{03}GOVT + u_{0j}$$

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

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

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

where  $i = 1, 2, \dots, n$  ( $n$  = number of students )  
 $j = 1, 2, \dots, N$  ( $N$  = number of schools)

The estimates of the parameters in this model can be found in tables 21 and 22, as explained above. For the remaining sections of this chapter, only tables showing the descriptives of level 1 and level 2 variables for each year and the final estimation of fixed effects for each model will be provided.

*Summary for Question 1 based on Model 1(2001)*

As is evident from the Table 21, assuming all other variables of the model are constant, the following conclusions, in regards to Question 1 and its sub-questions, can be made:

- The acceleration effect on MM study scores is not significant (sig.=0.924).
- MM study scores are, on average, 0.71 points higher for girls than for boys but no moderation of this effect by school class setting or sector was evident.

- MM study scores are, on average, 1.99 points higher in Independent schools than that of Catholic schools
- In single-sex classes MM study scores are, on average, 1.66 points higher than in co-educational classes.
- For every 10 points increase in GATMST the MM study scores increase by about 4 points.
- Error variance ( $R^2$ ) = 16.47. This gives an indication of how well this model estimates the MM study scores. It is the variance of the error term,  $e_{ij}$ .

*Analysis for SM based on Model 2 (2001)*

Table 24 shows the fixed and random effects of the variables in the SM model for 2001.

Table 24: Final estimation of fixed effects for SM based on Model 2 (2001)

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	14.307510	0.614480	23.284	339	0.000
SETTING, $\gamma_{01}$	-1.729110	0.357053	-4.843	339	0.000
INDPT, $\gamma_{02}$	2.175859	0.378216	5.753	339	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	0.439613	0.164523	2.672	341	0.008
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	0.409433	0.014813	27.641	341	0.000
For ACCEL slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	2.590147	0.244189	10.607	341	0.000

*Summary for Question 2 based on Model 2 (2001)*

As is evident from Table 24, assuming all other variables of the model are constant, the following conclusions, in regards to Question 2 and its sub-questions, can be made:

- The acceleration effect on SM study scores is significant ( $p < 0.0005$ ). SM study scores tend to be on average 2.59 points higher for accelerated students than for their equal ability age-peers who are not accelerated. There is no moderation effect by sector or class setting.
- SM study scores, on average, are higher for girls (0.44) than for boys and again no moderation of this effect by school sector or school class setting.
- SM study scores are, on average, 2.18 points higher in Independent schools than that of Catholic schools. There was no significant difference between Government schools and Catholic Schools.
- SM study scores are, on average, 1.73 points higher in single-sex classes than in co-educational classes.
- For every 10 points increase in GATMST, the SM study scores increase by 4 points.
- Error variance ( $R^2$ ) = 23.77. This is much higher than Model 1 indicating that Model 1 is a better predictor of MM than Model 2 is in predicting SM scores.

*Analysis for SM based on Model 3 (2001)*

Table 25 shows the fixed and random effects of the variables in the SM model for 2001.

*Table 25: Final estimation of fixed effects for SM based on Model 3 (2001)*

Fixed Effect	Standard Coefficient	Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	-6.941969	0.424916	-16.337	339	0.000
INDPT, $\gamma_{01}$	0.438287	0.182268	2.405	339	0.017
GOVT, $\gamma_{02}$	0.508470	0.170080	2.990	339	0.003
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	-0.046027	0.135702	-0.339	340	0.734
GOVT, $\gamma_{11}$	-0.351274	0.177700	-1.977	340	0.048
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	-0.008281	0.008237	-1.005	341	0.316
For MM slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	1.038715	0.010974	94.650	341	0.000
For ACCEL slope, $\beta_4$					
INTRCPT2, $\gamma_{40}$	2.594398	0.154874	16.752	341	0.000

*Summary for Question 2 based on Model 3 (2001)*

As is evident from the Table 25, assuming all other variables of the model are constant, the following conclusions, in regards to Question 2 and its sub-questions, can be made:

- The acceleration effect on SM study scores is significant ( $p < 0.0005$ ). SM study scores are, on average, 2.59 points higher for accelerated students than for students who are not accelerated. The effect of acceleration is significant in all

schools and there is no moderation effect by school sector or school class setting.

- SM study scores are, on average, lower for girls than for boys in Government schools and there is no moderation of this effect by school sector or school class setting.
- SM study scores are higher in Independent schools than Catholic schools (less pronounced than for MM) but no significant difference between Government and Catholic schools.
- School class setting had no effect on SM study scores when taking students' MM scores into account.
- The effect of the GATMST variable was not significant ( $p=0.531$ )
- SM study scores, on average, increase in proportion to MM study scores.
- Error variance ( $R^2 = 6.14$ ) is much lower than previously, indicating that Model 3 is a more appropriate model, which includes the MM variable as one of the predictors of prior knowledge, for estimating the SM study scores.

### *Statistical Analysis (2002)*

#### *Analysis for MM based on Model 1 (2002)*

Descriptives of student (LEVEL-1) and school (LEVEL-2) variables are provided in Table 26. As is evident from this table there were 5403 students from 345 schools, who studied both MM and SM in 2002. There are three continuous variables, namely the outcome variable MM (mean=35.59, sd=5.55), SM (mean 30.76, sd=6.51) and predictor variable GATMST (mean=37.41, sd=6.19) where the GATMST is used as a measure of prior knowledge. There are also five dichotomous variables, namely ACCEL (accelerated (=1) or not (=0)), GENDER (girl (=1) or boy (=0)), SETTING (coeducational (=1) or



single-sex (=0)), INDPT (Independent (=1) or Catholic (=0)) and GOVT (Government (=1) or Catholic (=0)) variables.

Table 26: Descriptives of level 1 and 2 variables (2002)

LEVEL-1 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
GENDER	5403	0.40	0.49	0.00	1.00
GATMST	5403	37.41	6.19	15.00	50.00
MM	5403	35.59	5.55	16.00	50.00
SM	5403	30.76	6.51	10.00	50.00
ACCEL	5403	0.15	0.36	0.00	1.00
LEVEL-2 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
SETTING	345	0.78	0.41	0.00	1.00
INDPT	345	0.25	0.43	0.00	1.00
GOVT	345	0.53	0.50	0.00	1.00

Table 27 shows the fixed and random effects of the variables in the MM model.

Table 27: Final estimation of fixed effects for MM based on Model 1 (2002)

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	20.033229	0.525820	38.099	342	0.000
SETTING, $\gamma_{01}$	-1.717186	0.367995	-4.666	342	0.000
INDPT, $\gamma_{02}$	2.515210	0.332263	7.570	342	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	0.128434	0.416734	0.308	342	0.758
SETTING, $\gamma_{11}$	0.800412	0.428647	1.867	342	0.062
INDPT, $\gamma_{12}$	-0.654023	0.317774	-2.058	342	0.040
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	0.400390	0.011018	36.339	344	0.000
For ACCEL slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	1.087156	0.331733	3.277	343	0.002
SETTING, $\gamma_{31}$	-1.061521	0.446823	-2.376	343	0.018

*Summary for Question 1 based on Model 1 (2002)*

As is evident from Table 27, assuming all other variables of the model are constant, the following conclusions, in regards to Question 1 and its sub-questions, can be made:

- The acceleration effect on MM study scores in the case of single-sex classes is significant and, on average, it increases by 1.09 points for accelerated students than for students who are not accelerated.
- MM study scores are, on average, higher for girls (0.13) than for boys at non-Government schools.
- In single-sex classes MM study scores are, on average, 1.72 points higher than in co-educational classes.
- MM study scores are, on average, 2.52 marks higher for Independent schools.

- For every 10 points increase in GATMST, the MM study scores increase by 4 points.
- Error variance ( $R^2$ ) = 16.13. This is consistent with the error variance for this model for 2001 data.

*Analysis for SM based on Model 2 (2002)*

Table 28 shows the fixed and random effects of the variables in the SM model for 2002.

Table 28: Final estimation of fixed effects for SM based on Model 2 (2002)

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	15.400751	0.658453	23.389	342	0.000
SETTING, $\gamma_{01}$	-2.422469	0.450449	-5.378	342	0.000
INDPT, $\gamma_{02}$	2.534947	0.355683	7.127	342	0.00
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	-0.778274	0.507721	-1.533	343	0.126
SETTING, $\gamma_{11}$	1.514827	0.539787	2.806	343	0.006
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	0.397926	0.013391	29.715	344	0.000
For ACCEL slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	2.410637	0.266191	9.056	344	0.000

*Summary for Question 2 based on Model 2 (2002)*

As is evident from Table 28, assuming all other variables of the model are constant, the following conclusions, in regards to Question 2 and its sub-questions, can be made:

- The acceleration effect on SM study scores is significant ( $p < 0.0005$ ). SM study scores are, on average, 2.41 points higher for accelerated students than for students who are not accelerated.

- SM study scores for girls are, on average, 0.78 points lower than for boys in single-sex classes.
- SM study scores are, on average, 2.53 points higher for Independent schools.
- For every 10 points increase in GATMST, the SM study scores increase by 4 points.
- Error variance ( $R^2$ ) = 23.53. This is consistent with the error variance (23.77) for 2001.

*Analysis for SM based on Model 3 (2002)*

Table 29 shows the fixed and random effects of the variables in the SM model for 2002.

*Table 29: Final estimation of fixed effects for SM based on Model 3 (2002)*

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	-4.992388	0.384575	-12.982	342	0.000
SETTING, $\gamma_{01}$	-0.734146	0.188062	-3.904	342	0.000
INDEPEND, $\gamma_{02}$	0.315872	0.163985	1.926	342	0.054
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	-0.849051	0.242106	-3.507	343	0.001
SETTING, $\gamma_{11}$	0.856226	0.257371	3.327	343	0.001
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	-0.01511	0.007263	-2.081	344	0.038
For MM slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	1.023621	0.010671	95.926	344	0.000
For ACCEL slope, $\beta_4$					
INTRCPT2, $\gamma_{40}$	1.844213	0.159236	11.582	344	0.000

*Summary for Question 2 based on Model 3 (2002)*

As is evident from Table 29, assuming all other variables of the model are constant, the following conclusions, in regards to Question 2 and its sub-questions, can be made:

- The acceleration effect on SM study scores is significant ( $p < 0.0005$ ). SM study scores are, on average, 1.84 points higher for accelerated students than for students who are not accelerated.
- SM study scores of girls are, on average, 0.85 points lower than for boys in single-sex classes.
- SM study scores are, on average, 0.32 points higher for Independent schools.
- For every 100 points increase in GATMST the SM study scores, on average, decrease by 2 points.
- SM study scores, on average, increase in proportion to MM study scores.
- Error variance ( $R^2 = 6.49$ ) is much lower than previously, indicating that Model 3 is a more appropriate model for estimating the SM study scores. This is consistent with the error variances obtained in previous years for this model.

### *Statistical Analysis (2003)*

#### *Analysis for MM based on Model 1 (2003)*

Descriptives of student (LEVEL-1) and school (LEVEL-2) variables are provided in Table 30. As is evident from this table there were 5442(=n) students (level-1 units) from 340(=N) schools (level 2-units) who studied both MM and SM in 2001. There are three continuous variables, namely the outcome variable MM (mean=35.96, sd=5.61), SM (mean 30.84, sd=5.61) and predictor variable GATMST (mean=37.41, sd=6.19) where the GATMST is used as a measure of prior knowledge. There are also five dichotomous variables, namely ACCEL (accelerated (=1) or not (=0)), GENDER (girl (=1) or boy (=0)), SETTING (coeducational (=1) or single-sex (=0)), INDPT (Independent (=1) or Catholic (=0)) and GOVT (Government (=1) or Catholic (=0)) variables.

Table 30: Descriptives of level 1 and 2 variables (2003)

LEVEL-1 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
GENDER	5442	0.39	0.49	0.00	1.00
GATMST	5442	37.01	6.54	11.00	50.00
MM	5442	35.96	5.61	15.00	50.00
SM	5442	30.84	6.47	10.00	50.00
ACCEL	5442	0.16	0.37	0.00	1.00
LEVEL-2 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
SETTING	340	0.79	0.41	0.00	1.00
INDPT	340	0.26	0.44	0.00	1.00
GOVT	340	0.53	0.50	0.00	1.00

Table 31 shows the fixed and random effects of the variables in the MM model for 2003.

Table 31: Final estimation of fixed effects for MM based on Model 1 (2003)

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	21.417947	0.488111	43.879	338	0.000
SETTING, $\gamma_{01}$	-1.311982	0.264016	-4.969	338	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	0.893123	0.143285	6.233	339	0.000
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	0.363171	0.012540	28.961	338	0.000
INDPT, $\gamma_{21}$	0.059816	0.007487	7.989	338	0.000
For ACCEL slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	0.223015	0.227241	0.981	339	0.328

*Summary for Question 1 based on Model 1 (2003)*

As is evident from Table 31, assuming all other variables of the model are constant, the following conclusions, in regards to Question 1 and its sub-questions, can be made:

- The acceleration effect on MM study scores is not significant ( $p=0.328$ )
- MM study scores are, on average, 0.89 points higher for girls than for boys.
- In single-sex classes MM study scores are, on average, 1.31 points higher than in co-educational classes.
- For every 10 points increase in GATMST, the MM study scores increase by 4 points for Independent schools.
- Error variance ( $R^2$ ) =17.45. This is consistent with previous findings for this model.

Table 32 shows the fixed and random effects of the variables in the SM model for 2003.

*Table 32: Final estimation of fixed effects for SM based on Model 2 (2003)*

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	18.075452	0.630922	28.649	338	0.000
SETTING, $\gamma_{01}$	-2.290461	0.447373	-5.120	338	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	-0.791069	0.504665	-1.568	338	0.118
SETTING, $\gamma_{11}$	1.632719	0.536859	3.041	338	0.003
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	0.322154	0.014878	21.653	338	0.000
INDPT, $\gamma_{21}$	0.069359	0.009520	7.285	338	0.000
For ACCEL slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	2.610048	0.238702	10.934	339	0.000

*Summary for Question 2 based on Model 2 (2003)*

As is evident from the Table 32, assuming all other variables of the model are constant, the following conclusions, in regards to Question 2 and its sub-questions, can be made:

- The acceleration effect on SM study scores is significant ( $p < 0.0005$ ). SM study scores are, on average, 2.61 points higher for accelerated students than for students who are not accelerated.
- SM study scores of girls in single-sex classes are, on average, lower (0.79) than boys but in co-educational classes, SM study scores of girls are higher (0.84) than boys.
- For every 10 points increase in GATMST, the SM study scores increase by about 4 points for Independent schools.



- Error variance ( $R^2$ ) = 23.90. This is consistent with previous findings for this model.

*Analysis for SM based on Model 3 (2003)*

Table 33 shows the fixed and random effects of the variables in the SM model for 2003.

*Table 33: Final estimation of fixed effects for SM (2003)*

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	-4.531167	0.342876	-13.215	339	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	-0.149250	0.079882	-1.868	339	0.062
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	-0.048317	0.007301	-6.617	338	0.000
INDPT, $\gamma_{21}$	0.012347	0.004064	3.038	338	0.003
For MM slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	1.014613	0.009702	104.580	339	0.000
For ACCEL slope, $\beta_4$					
INTRCPT2, $\gamma_{40}$	2.774269	0.215428	12.878	338	0.000
INDPT, $\gamma_{41}$	-0.844830	0.307740	-2.745	338	0.007

*Summary for Question 2 based on Model 3 (2003)*

As is evident from the Table 33, assuming all other variables of the model are constant, the following conclusions, in regards to Question 2 and its sub-questions, can be made:

- The acceleration effect on SM study scores is significant. SM study scores are, on average, 2.77 points higher for accelerated students in Government and Catholic sectors and 1.93 higher in Independent schools.
- SM study scores of girls are, on average, lower than boys.

- For every 10 points increase in GATMST, the SM study scores increase by about 4 points for Independent schools.
- SM study scores, on average, increase in proportion to MM study scores.
- Error variance ( $R^2$ ) = 5.95. This is consistent with previous findings for this model.

*Statistical Analysis (2004)*

*Analysis for MM based on Model 1 (2004)*

Descriptives of student (LEVEL-1) and school (LEVEL-2) variables are provided in Table 34. As is evident from this table there were 5209 students from 337 schools, who studied both MM and SM in 2004. There are three continuous variables, namely the outcome variable MM (mean=35.71, sd=5.54), SM (mean 30.96, sd=6.43) and predictor variable GATMST (mean=36.37, sd=6.92). There are also five dichotomous variables, namely ACCEL (accelerated (=1) or not (=0)), GENDER (girl (=1) or boy (=0)), SETTING (coeducational (=1) or single-sex (=0)), INDPT (Independent (=1) or Catholic (=0)) and GOVT (Government (=1) or Catholic (=0)) variables.

Table 34: Descriptives of level 1 and 2 variables (2004)

LEVEL-1 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
GENDER	5209	0.41	0.49	0.00	1.00
GATMST	5209	36.37	6.92	12.00	50.00
MM	5209	35.71	5.54	17.00	50.00
SM	5209	30.96	6.43	13.00	50.00
ACCEL	5209	0.17	0.37	0.00	1.00

LEVEL-2 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MINIMUM	MAXIMUM
SETTING	337	0.78	0.42	0.00	1.00
INDPT	337	0.26	0.44	0.00	1.00
GOVT	337	0.51	0.50	0.00	1.00

Table 35 shows the fixed and random effects of the variables in the MM model for 2004.

Table 35: Final estimation of fixed effects for MM based on Model 1 (2004)

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	22.031864	0.447221	49.264	334	0.000
SETTING, $\gamma_{01}$	-1.587522	0.261673	-6.067	334	0.000
INDPT, $\gamma_{02}$	2.370107	0.287904	8.232	334	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	0.495369	0.158818	3.119	336	0.002
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	0.358808	0.010168	35.288	336	0.000
For ACCEL slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	0.034233	0.220409	0.155	336	0.877

*Summary for Question 1 based on Model 1 (2004)*

As is evident from the Table 35, assuming all other variables of the model are constant, the following conclusions, in regards to Question 1 and its sub-questions, can be made:

- The acceleration effect on MM study scores is not significant ( $p=0.877$ ).
- MM study scores are, on average, higher for girls (0.50) than for boys.
- In single-sex classes MM study scores are, on average, higher (1.59) than in co-educational classes.
- For every 10 points increase in GATMST the MM study scores increase by about 4 points.
- Error variance ( $R^2$ ) =17.45. This is also consistent with the error variances found for this model in previous years.

*Analysis for SM based on Model 2 (2004)*

Table 36 shows the fixed and random effects of the variables in the SM model for 2004.

*Table 36: Final estimation of fixed effects for SM based on Model 2 (2004)*

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	17.277173	0.530484	32.569	334	0.000
SETTING, $\gamma_{01}$	-1.661359	0.337073	-4.929	334	0.000
INDPT, $\gamma_{02}$	3.132571	0.349155	8.972	334	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	-0.208481	0.271307	-0.768	335	0.443
GOVT, $\gamma_{11}$	1.001881	0.348683	2.873	335	0.005
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	0.338102	0.011666	28.982	336	0.000
For ACCEL slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	2.755051	0.274280	10.045	336	0.000

*Summary for Question 2 based on Model 2 (2004)*

As is evident from the Table 36, assuming all other variables of the model are constant, the following conclusions, in regards to Question 2 and its sub-questions, can be made:

- The acceleration effect on SM study scores is significant ( $p < 0.0005$ ). SM study scores are, on average, 2.76 points higher for accelerated students than for students who are not accelerated.
- SM study scores of girls in Government schools are higher (0.8) than for boys in Government schools.
- For every 10 points increase in GATMST, the SM study scores increase by 3.4 points.
- Error variance ( $R^2$ ) = 23.82. This is consistent with the error variances for this model found in previous years.

*Analysis for SM based on Model 3 (2004)*

Table 37 shows the final estimation of fixed effects of the variables in the SM model for 2004.

*Table 37: Final estimation of fixed effects for SM based on Model 3 (2004)*

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	-4.493640	0.338573	-13.272	335	0.000
INDPT, $\gamma_{01}$	0.526904	0.154365	3.413	335	0.001
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	-0.313477	0.131133	-2.391	335	0.018
GOVT, $\gamma_{11}$	0.355502	0.163495	2.174	335	0.030
For GATMST slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	-0.023557	0.007341	-3.209	336	0.002
For MM slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	0.994396	0.009961	99.825	336	0.000
For ACCEL slope, $\beta_4$					
INTRCPT2, $\gamma_{40}$	2.858430	0.165995	17.220	336	0.000

*Summary for Question 2 based on Model 3 (2004)*

As is evident from the Table 37, assuming all other variables of the model are constant, the following conclusions, in regards to Question 2 and its sub-questions, can be made:

- The acceleration effect on SM study scores is significant ( $p < 0.0005$ ). SM study scores are, on average, 2.86 points higher for accelerated students than for students who are not accelerated.
- SM study scores for girls in Government schools being, on average, slightly higher (0.04) than boys
- SM study scores are higher in Independent schools.

- For every 100 points increase in GATMST, the SM study scores, on average, decreases by 2 points.
- SM study scores, on average, increase in proportion to MM study scores.
- Error variance ( $R^2$ ) = 6.49. This is consistent with the error variances for this model found in previous years.

*Summary of Multi-level Analysis (2001-2004)*

To establish the significance of the differences in study scores, multi-level models were fitted to the data. A summary of this analysis, outlined in previous sections, has been provided in Table 38, where only results which are significant at a significance level of 0.001 have been considered. The large number of tests performed makes it unwise to work at a higher significance level. The impact of the effects of student predictors (acceleration, gender and GATMST) and of school variables (sector and class setting), is summarised below.

Table 38: HLM Analysis Significant Coefficients (\*\*p ≤ 0.001, \* p ≤ 0.05)

Dependent variable	Independent variables	School Moderator	Parameter	Parameter Estimates			
				2001	2002	2003	2004
<b>MM Score</b>	Intercept		$\gamma_{00}$	19.93**	19.58**	21.42**	22/03**
		Setting	$\gamma_{01}$	-1.66**	-1.22**	-1.31**	-1.59**
		Independent	$\gamma_{02}$	1.99**	2.52**		2.37**
	Gender		$\gamma_{10}$	0.71**	0.87**	0.89**	0.50*
		Independent	$\gamma_{12}$		-0.68*		
	GATMST		$\gamma_{20}$	0.41**	0.40**	0.36**	0.36**
		Independent	$\gamma_{22}$			0.06**	
	<b>Acceleration</b>		$\gamma_{30}$	<b>-0.02</b>	<b>1.10**</b>	<b>0.22</b>	<b>0.03</b>
		Setting	$\gamma_{31}$		-1.07*		
<b>SM Score</b>	Intercept		$\gamma_{00}$	14.31**	15.40**	18.08**	17.28**
		Setting	$\gamma_{01}$	-1.73**	-2.42**	-2.29**	-1.66**
		Independent	$\gamma_{02}$	2.18**	2.53**		3.13**
		Government	$\gamma_{03}$		-0.78		
	Gender		$\gamma_{10}$	0.44*	1.51*	-0.79	-0.21
		Setting	$\gamma_{11}$			1.63*	
		Government	$\gamma_{13}$				1.00*
	GATMST		$\gamma_{20}$	0.41**	0.40**	0.32**	0.34**
		Independent	$\gamma_{22}$			0.07**	
	<b>Acceleration</b>		$\gamma_{30}$	<b>2.59**</b>	<b>2.41**</b>	<b>2.61**</b>	<b>2.76**</b>
<b>SM Score</b>	Intercept		$\gamma_{00}$	-6.94**	-4.99**	-4.53**	-4.49**
		Setting	$\gamma_{01}$		-0.73**		
		Independent	$\gamma_{02}$	0.44*	0.32*		0.53**
		Government	$\gamma_{03}$	0.51*	-0.85**		
	Gender		$\gamma_{10}$	-0.05	-0.85**	-0.15	-0.31*
		Setting	$\gamma_{11}$		0.86**		
		Government	$\gamma_{13}$	-0.35*			0.36*
	GAT		$\gamma_{20}$	-0.01	-0.02*	-0.05**	-0.02*
		Independent	$\gamma_{22}$			0.01*	
	<b>Acceleration</b>		$\gamma_{30}$	<b>2.59**</b>	<b>1.84**</b>	<b>2.77**</b>	<b>2.86**</b>
		Independent	$\gamma_{32}$			-0.84*	
	MM		$\gamma_{40}$	1.04**	1.02**	1.01**	0.99**



Considering the effect of acceleration we see an insignificant effect on MM scores in all but one of the years. In 2002 there was a significant acceleration effect but only for single-sex classes (SETTING=0). In the first SM model acceleration has a significant effect in all years with values ranging from 2.41 in 2002 to 2.76 in 2004. In the second SM model which controls for MM scores the acceleration is also significant. However, in 2003 the average acceleration affect is weaker for Independent schools (1.93) than for Catholic and Government schools (2.77). Girls show significantly better performance than for all years in the case of MM, except for Independent schools in 2002. SM scores are also significant higher for girls in 2001 and 2002 in the first SM model with much less convincing results in 2003 and 2004. However when we control for the effect of MM scores there is some indication of boys outperforming girls, particular in the case of single-sex classes in 2002. A GATMST mark 10 points higher appears to raise MM and SM marks by about 4 points, however, when we control for the effect of MM in the second SM model this effect seems to almost disappear.

The results in Table 38 also suggest a significant increase in MM scores of 1.22 to 1.66 points in the case of single-sex classes. MM marks were also 1.99 to 2.52 points higher on average for Independent schools in all years except 2003. Similarly the first SM model suggested higher scores for single-sex classes in all years and higher scores for Independent schools except in 2003. However, after controlling for MM scores single-sex classes significantly outperformed co-educational classes only in 2002, while the effects for Independent and Government schools also tended to be weaker. This analysis therefore seems to support the two hypotheses suggesting that although acceleration tends to improve performance in the case of SM scores this is not generally the case for MM scores. This implies that the MM scores will not be significantly different between accelerated students (who complete MM a year earlier) than their equal ability age-peers

who are not accelerated and complete MM a year later. The affect of acceleration was certainly stronger than the gender effect and was generally also higher than the sector or class setting effects, especially after controlling for MM scores.

#### *Data analysis with GATMST scores above 45*

A multi-level analysis was also conducted for students with GATMST scores above 45 (top 2%) using models 1, 2 and 3 with the GATMST variable removed. This enabled the school effect to be handled properly. The reason the MM and SM scores of students with more than 45 were chosen was to identify highly-gifted students and to see what the effects of acceleration are on their MM and SM study scores. Data for the 2-year periods 2001 to 2002 and 2003 to 2004 were used in this analysis. Preliminary checks were conducted to ensure that there were no violations of normality and linearity.

*Descriptive statistics*

The descriptive statistics of this sample for 2001-2002 is shown in Table 39.

*Table 39: Descriptives of level-1 and level-2 variables for 2001-2002*

LEVEL-1 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
GENDER	1058	0.27	0.45	0.00	1.00
MM	1058	40.37	5.04	23.00	50.00
SM	1058	36.05	6.39	13.00	50.00
ACCEL	1058	0.26	0.44	0.00	1.00
LEVEL-2 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
SETTING	265	0.76	0.43	0.00	1.00
GOVT	265	0.48	0.50	0.00	1.00
INDPT	265	0.29	0.45	0.00	1.00

For the period 2001-2002 there were 1058 students from 273 schools who studied both MM and SM and received a GATMST score above 45. There are two continuous variables, namely the outcome variables MM (mean=40.37, sd=5.04) and SM (mean=36.05, sd=6.39). There are five dichotomous variables, namely ACCEL (accelerated (=1) or not (=0)), GENDER (girl (=1) or boy (=0)), SETTING (coeducational (=1) or single-sex (=0)), INDPT (Independent (=1) or Catholic (=0)) and GOVT (Government (=1) or Catholic (=0)) variables. Table 40 shows that out of all the students who were in the top 2% of their GATMST, only 26% were accelerated with a balanced proportion of girls to boys.

Table 40: Students with GATMST above 45 based on gender and acceleration from 2001-2002 data

			Student Gender		Total
			Boys	Girls	
Accelerated	No	Count	570	213	783
		% within Student gender	74.2%	73.4%	74.0%
	Yes	Count	198	77	275
		% within Student gender	25.8%	26.6%	26.0%
Total		Count	768	290	1058
		% within Student gender	100.0%	100.0%	100.0%

Table 41 shows that for the period 2003-2004 there were 1157 students from 273 schools who studied both MM and SM in 2001 and attained a GATMST score above 45. There are two continuous variables, namely the outcome variable MM (mean=40.43, sd=5.38), SM (mean=35.71, sd=6.67). There are five dichotomous variables, namely ACCEL (accelerated (=1) or not (=0)), GENDER (girl (=1) or boy (=0)), SETTING (coeducational (=1) or single-sex (=0)), INDPT (Independent (=1) or Catholic (=0)) and GOVT (Government (=1) or Catholic (=0)) variables.

Table 41: Descriptives of level-1 and level-2 variables for 2003-2004

LEVEL-1 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
GENDER	1157	0.28	0.45	0.00	1.00
MM	1157	40.43	5.38	22.00	50.00
SM	1157	35.71	6.67	15.00	50.00
ACCEL	1157	0.26	0.44	0.00	1.00
LEVEL-2 DESCRIPTIVE STATISTICS					
VARIABLE NAME	N	MEAN	SD	MIN	MAX
SETTING	273	0.77	0.42	0.00	1.00
GOVT	273	0.50	0.50	0.00	1.00
INDPT	273	0.27	0.45	0.00	1.00

Table 42 shows that out of all the students who were in the top 2% of their GATMST, 26% were accelerated with a balanced proportion of girls to boys as was the case for the period 2001-2002.

*Table 42:* Students with GATMST above 45 based on gender and acceleration from 2003-2004 data

			Student Gender		Total
			Boys	Girls	
Accelerated	No	Count	619	236	855
		% within Student gender	73.9%	74.0%	73.9%
	Yes	Count	219	83	302
		% within Student gender	26.1%	26.0%	26.1%
Total		Count	838	319	1157
		% within Student gender	100.0%	100.0%	100.0%

*Summary of Multi-level Analysis (2001 – 2002 and 2003 – 2004)*

Tables 49 and 50, below, provide an overall summary (obtained from Tables 43 to 48 in Appendix D) for both data sets 2001 to 2002 and 2003 to 2004, based on final estimates of fixed effects.

Table 49: Summary of results for students with GATMST above 45 (2001-2002)

2001-2002	Model 1 MM	Model 2 SM	Model 3 SM (incl MM)
What is the effect of acceleration?	Acceleration effect for MM is not significant ( $p=0.077$ ).	Acceleration effect for SM is significant ( $p<0.005$ ). SM study scores of accelerated students are 4.17 points higher than students who are not accelerated.	Acceleration effect for SM is significant ( $p<0.005$ ). SM study scores of accelerated students are 3.31 points higher than students who are not accelerated.  (By including the MM factor in the model, the acceleration effect was removed from SM hence a lower difference in points)
What is the effect of gender?	MM study scores of girls are higher than boys.	The effect of gender on SM study scores is not significant ( $p=0.155$ )	The effect of gender on SM study scores is not significant ( $p=0.163$ )
What is the effect of school sector and school class setting?	MM study scores for single-sex classes are, on average, 1.64 points higher than co-educational classes. On average, MM study scores are 2.24 points higher for Independent schools.	SM study scores are, on average, 2.47 points higher for Independent schools.	School sector and school class setting had no effect on SM study scores taking students' MM scores into account.
What is the effect of prior knowledge (MM)?	Not applicable to this model.	Not applicable to this model.	SM study scores, on average, increase in proportion to MM study scores.
$R^2$	19.00	29.45	7.85

Note: The effect of each variable is considered while holding all other variables constant

Table 50: Summary of results for students with GATMST above 45 (2003-2004)

2003-2004	Model 1 MM	Model 2 SM	Model 3 SM (incl MM)
What is the effect of acceleration?	Acceleration effect for MM is significant ( $p < 0.0005$ ). MM study scores of accelerated students are, on average, 1.55 points higher.	Acceleration effect for SM is significant ( $p < 0.005$ ). SM study scores of accelerated students are, on average, 5.51 points higher.	Acceleration effect for SM is significant ( $p < 0.005$ ). SM study scores of accelerated students are, on average 3.83 points higher than students who are not accelerated.  (By including the MM factor in the model, the acceleration effect was removed from SM hence a lower difference in points)
What is the effect of gender?	MM study scores of girls are, on average, 0.57 of a point higher than boys.	The effect of gender on SM study scores is not significant ( $p = 0.373$ )	The gender effect is significant ( $p < 0.0005$ ). SM study scores of girls are, on average, lower (0.68) than boys.
What is the effect of school sector and school class setting?	MM study scores are, on average, 2.79 points higher for Independent schools.	SM study scores are, on average, 3.24 points higher for Independent schools.	SM study scores are, on average, 0.49 points higher for Independent schools.
What is the effect of prior knowledge (MM)?	Not applicable to this model.	Not applicable to this model.	SM study scores, on average, increase in proportion to MM study scores. For every 1 point increase in MM there is a 1 point increase in SM.
$R^2$	19.00	29.45	7.85

Note: The effect of each variable is considered while holding all other variables constant

*Summary of Multi-level Analysis (2001 – 2004)*

A summary of results combining both data sets 2001-2002 and 2003-2004, where HLM models are considered for only students with GATMST scores above 45, is provided below. It was not possible to combine the data for all four years because the method of school identification changed at the end of 2002. Table 51 presents the error variances for each of the models considered above. These are the estimated variances for the level one ( $e_{ij}$ ) errors. This table shows similar variances over the period 2001-2004. In the case of students with higher prior knowledge (GATMST over 45) there appears to be a higher error variance, suggesting that this group is not as homogeneous as might be expected.

*Table 51: Level One Error Variances*

Dependent Variable	Mathematical Methods (MM)	Specialist Mathematics (SM)	SM controlling for MM
2001 all students	16.48	23.77	6.14
2002 all students	16.15	23.53	6.49
2003 all students	17.45	23.90	5.95
2004 all students	17.17	23.82	6.49
GATMST over 45 2001-2002	19.00	29.45	7.85
GATMST over 45 2003-2004	20.27	28.66	8.41



Table 52: HLM Analysis Significant Coefficients for GATMST above 45  
 (\*\* p ≤ 0.001, \* p ≤ 0.01)

Dependent variable	Independent student variable	School Moderator	Parameter	Parameter Estimates	
				2001-2002	2003-2004
MM Score	Intercept		$\gamma_{00}$	39.62**	37.74**
		Setting	$\gamma_{01}$	-1.64**	
		Independent	$\gamma_{02}$	2.24**	2.79**
	Gender		$\gamma_{10}$	0.27	0.57
	Acceleration		$\gamma_{30}$	0.55	1.55**
SM Score	Intercept		$\gamma_{00}$	32.88**	32.10**
		Independent	$\gamma_{02}$	2.47**	3.24**
	Gender		$\gamma_{10}$	0.54	-0.34
	Acceleration		$\gamma_{30}$	4.17**	5.51**
	SM Score	Intercept		$\gamma_{00}$	-7.68**
		Independent	$\gamma_{02}$		0.49*
Gender			$\gamma_{10}$	-0.28	-0.68*
Acceleration			$\gamma_{30}$	3.31**	3.83**
MM			$\gamma_{40}$	1.06**	0.99**

Note: The effect of each variable is considered while holding all other variables constant

Table 52 suggests that in the first 2-year period the effect of acceleration, for MM scores, was not significant. However, this changed in the 2003-2004 period for MM scores where accelerated students scored an additional 1.55 points, on average, when other variables were controlled. The first model for SM scores showed a significant increase of 4.17 points, on average, for accelerated students in the first 2-year period increasing to

5.51 points in the second 2-year period. However, after controlling for the effect of acceleration on MM scores the second SM model showed an acceleration effect of only 3.31 in the first 2-year period and 3.83 in the second 2-year period. Gender effects were basically insignificant for this group of students and any GATMST effect was ignored due to the small range of GATMST values in this group.

In the case of MM scores, single-sex classes performed significantly better in the first 2-year period but not for the second 2-year period. Independent schools, however, achieved significantly better results, 2.24 to 2.79 points higher than Catholic or Government schools for both periods. After controlling for MM scores, school class setting and sector effects were minimal. It seems therefore that for students with higher prior knowledge the effect of acceleration is particularly beneficial.

### Reliability, validity and generalisability

Reliability, validity and generalisability for the data used in this study are considered in the following section.

#### *Reliability*

Reliability of a scale indicates how free it is from random error (Pallant, 2001). A good instrument must produce consistent results over time and across the sample population. The source of information for the data used in this study was provided by the Victorian Curriculum and Assessment Board (VCAA) which is managed by the Department of Education. Since the reporting format of the information from the VCAA is consistent across all students and schools, then the instrument used, from where the data were collected, was consistent over the years that VCE has been implemented, and across all students and schools. Therefore this ensures reliability of the data from VCAA.

### *Validity*

Validity of a scale refers to the degree to which it measures what it is supposed to measure (Pallant, 2000 p.6). Are the scores for MM and SM really measuring what we want measured (e.g. mathematical ability)? The VCAA's database from which the data was obtained is an accurate source for the data collected. Therefore this study accurately reflects the specific concepts that were measured.

### *Generalisability*

Generalisability is the extent to which research findings and conclusions from a study conducted on a sample population can be generalised to a larger population similar to the population from which the study sample was taken (Huck, 2000).

The results of this study may be generalised because the results are consistent across a four year period, suggesting that they have temporal integrity; secondly the sample is large and varied, encompassing all types of school within Victoria thus enhancing the generalisability of this study; and thirdly the statistical significance of the results indicates that the benefits of acceleration are real. In regards to cause-effect, since there are consistent significant and positive effects regarding acceleration, inferences about acceleration may be made from the results.

## Conclusion

This chapter presented a preliminary analysis of the data and appropriate analytical approaches to obtain results that were used to identify trends and findings as suggested by the data, in relation to the research questions of this study for each of the years 2001, 2002, 2003 and 2004. Hypotheses presented were accepted based on these findings.

Reliability, validity and generalisability were also considered. In the following and final chapter a summary of findings will be presented and the significance of the outcomes of this study will be given. Furthermore implications or recommendations indicated by the findings as well as the need for further research will also be provided.

## Chapter 5

### Summary, findings and implications

#### Summary

For over 20 years there have been a number of schools in Victoria that have implemented acceleration programs to meet the needs of their gifted learners. Yet even in these schools there is a concern amongst educators, administrators and even policy makers that, students who are accelerated will under-perform in their VCE Mathematical Methods study, because they take it a year earlier than their equal ability age-peers. If this were true, such accelerated students may be disadvantaged in terms of their ENTER scores (see Appendix B for information about the ENTER. VCAA, 2002). Having lower ENTER scores than their age-peers of equal ability who were not accelerated may also deny them the same options for course selection at tertiary level. Adding to this, league tables, on school performance, are becoming more accessible to the public domain and there are a number of schools in Victoria who are inclined to not offer acceleration programs so that their top students will perform better in Year 12. Despite the extensive research literature (see Chapter 2 of this thesis) on the positive effects of acceleration programs on student achievement, there is little specific quantitative confirmation of the benefits of these particular programs and there is no known experimental study that has researched the effects of acceleration on students' VCE Mathematics study scores.

This study has provided empirical grounds to address the concerns raised and to fill in the gaps of this research area. The design of the study was quasi-experimental with control groups at the student and school level and the study relied on pre-existing data analysis using the State of Victoria as its 'laboratory'. Experimental designs are difficult to

implement in education, but, when possible, they can be rigorous and provide compelling findings. Because a quasi-experimental design was possible the results of this study provide compelling evidence for significant difference between the performances of accelerated and non-accelerated students. The premises and procedures underlying this type of program are sufficiently straightforward such that the results of this study can be generalised to other states of Australia and world-wide where acceleration programs may be implemented for highly-talented students. A multilevel modelling approach was also adopted, a methodology that had not been used in past studies related to acceleration.

It is a source of significant satisfaction and interest that despite the use of a more appropriate method of data analysis, has produced results that overwhelming confirmed the positive effects of acceleration on students' performance reported in other studies, and the particular benefits of acceleration as studied in this research.

## Findings

The findings of this study, which aimed to determine the effects of acceleration on students' achievement in mathematics (based on their MM and SM study scores), taking a number of student and school factors into account addressed and answered two very specific questions.

Question 1. Is student performance in Specialist Mathematics improved by acceleration (compared with equal ability age-peers)?

Answer. Yes.

Question 2. Does studying Mathematical Methods a year early lead to reduced performance compared to equal ability age-peers taking this study in Year 12?

Answer. No.

These are very significant findings. In relation to question 1, accelerated students will, on average, out-perform their equal ability age-peers who were not accelerated. In particular for those students who are exceptionally bright (GATMST >45), their SM study scores were almost 5 points higher (on a 50-point scale). Based on these findings if we consider for example a student who is not accelerated and achieves a study score of 40 for SM, which places them in the top 7.5% of the students taking this particular study in the State, then another student of equal ability who has been accelerated may achieve a study score of 45, placing them in the top 1.5% of the students taking this study in the State. This is a significant difference in achievement in mathematics. As a consequence the student who was not accelerated and had obtained a study score of 40 for SM may have a lower ENTER score and hence be denied the same options for course selection at tertiary level as for the student who was accelerated. However the consequence for a student's overall ENTER score or the possible course selection that these students may or may not be excluded from is not the principle focus of this thesis.

In relation to question 2, on average, accelerated students will not under-perform in this study, as some people tend to believe. Consequently when schools are considering implementing acceleration programs they do not have to fear that ENTER scores will decline for accelerated students.

These findings are very significant as they provide answers to the concerns of educators, administrators and policy makers regarding the use of content acceleration for mathematics in Victorian schools and elsewhere in the world.

## Limitations

The study had several limitations. A complete analysis of all the possible effects of acceleration, such as attitude, social, emotional, or behavioural characteristics for students undertaking an acceleration program was not possible. This study focused only on the effects of acceleration on students' mathematics achievement at the VCE level and assumes that all students have the same experience of the curriculum content. In particular, students' mathematical experiences or involvement in other intervention programs are ignored in this study. For example the data does not identify students who have undertaken a university mathematics subject at Year 12. These students may or may not have been accelerated. Undertaking a university mathematics subject is likely to affect the study scores in both SM and MM.

There may also be bias in the data in that students who completed Mathematical Methods in Year 11 as part of an acceleration program and then decided not to continue with Specialist Mathematics in Year 12 were not considered in the sample. This bias would favour the acceleration option. Furthermore the study assumes that students have been correctly placed in or out of an acceleration program. Given the significant success of accelerated students, the study leaves unanswered the question of the ability cut-off for correct assignment of students to acceleration programs.

The use of pre-existing VCAA data, limits the variables that can be controlled for in this study. The impact of socio-economic backgrounds is particularly relevant but not available in this data, although measurement of prior knowledge may accommodate this source of variance to some extent. Another limitation for this study concerns the use of GATMST scores to identify students of equal ability in mathematics. In future research, the state-wide results of students' numeracy skills obtained when students are in years 5, 7 and 9 will provide a further indication of 'prior knowledge' and support more



thoroughly grounded assessments of student ability. The issue of correct assignment to the accelerated class requires further research.

Despite these limitations, this study remains one of the few and possibly the only study that has provided empirical grounds using a most appropriate methodology, to show the statistically significant positive effects of acceleration on student achievement in senior secondary mathematics.

### Implications for further research

This present study provides several opportunities for further research.

In regards to acceleration appropriate research studies could be undertaken to answer questions like:

- What are the effects of acceleration in other content areas?
- What are the effects of acceleration on students' attitude towards mathematics?
- What careers including further studies do accelerated students pursue?

With regard to mathematics achievement, appropriate research studies could be undertaken into methods of student assignment to accelerated classes and different approaches to instruction employed for these students.

These are just a few of the many questions that can be left to fellow researchers to build on this study with regard to acceleration and students' achievement in senior school mathematics.

In conclusion, the significant positive effects of acceleration on gifted students' academic achievement, should remove all doubts from educators, administrators and policy makers

about the benefits of acceleration programs in relation to students' academic achievement for the students that are currently accelerated the benefits are clear. Whether additional students may also be accelerated is a matter requiring further research. The researcher of this study does not claim that acceleration is the only program that should be implemented to support gifted students, but it should be one of the programs that schools need to consider in meeting the needs of their gifted learners. The researcher of this study finds it appropriate to conclude this thesis with a thought-provoking quote by Leta Stetter Hollingworth, a pioneer woman in the field of psychology.

In the ordinary . . . . . school situation children of 140 IQ waste half of their time. Those above 170 IQ waste nearly all of their time. With little to do, how can these children develop power of sustained effort, respect for the task, or habits of steady work? – (Children Above 180 IQ Stanford-Binet: Origin and Development, Leta S. Hollingworth, 1942, p. 299).

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APPENDIX A.

AIMS AND STRUCTURE OF THE MATHEMATICS STUDIES

### *Aims of the Mathematics studies*

VCE mathematics units 1-4 are designed to enable students to:

- develop mathematical knowledge and skills;
- apply mathematical knowledge to analyse, investigate, model and solve problems in a variety of situations, ranging from well-defined and familiar situations to unfamiliar and open-ended situations;
- use technology as an effective support for mathematical activity. (VBOS, 1999 p.9)

### *Structure*

The mathematics study is made up of the following units:

#### *Foundation Mathematics Units 1&2*

These units are intended to provide students entering VCE who need mathematical skills to support their other VCE subjects including VET studies and who do not intend to undertake any further VCE mathematics studies. There is a strong emphasis on using mathematics in practical contexts relating to everyday life, personal work and study (VBOS 1999 p.16)

#### *General Mathematics Units 1&2 (GM1&2)*

These units are intended for a diverse group of students and may be implemented in a number of ways. They may be undertaken alone or with Mathematical Methods 1&2. It contains assumed knowledge for related material in Further Mathematics 3&4. It is strongly recommended, in addition to Mathematical Methods Units 1&2 as preparation for Specialist Mathematics Units 3&4.

The areas of study for GM (1&2) are ‘Statistics and probability’, ‘Arithmetic’, ‘Functions and graphs’, ‘Algebra’, ‘Geometry’, and ‘Trigonometry’. (VBOS 1999 p. 40)

*Mathematical Methods Units 1&2 (MM1&2)*

These units have a closely sequenced development of material, intended particularly for Mathematical Methods 3&4. They may be undertaken alone or with GM 1&2. (VBOS 1999 p.8) Although it is possible to prepare for Mathematical Methods Units 3 and 4 by studying only Mathematical Methods Units 1 and 2, a much firmer basis for further study is obtained by also studying General Mathematics Units 1 and 2. (VBOS, 1999, p.10)

The areas of study are ‘Functions and graphs’, ‘Algebra’, ‘Calculus’ and ‘Probability’. (VBOS 1999 p.68)

*Further Mathematics Units 3&4 (FM3&4)*

These units are intended to be widely accessible. They provide general preparation for employment and further study. The assumed knowledge for FM3&4 is drawn from GM1&2 and/or MM1&2. (VBOS 1999 p.8)

FM (3&4) consists of a compulsory area of study ‘Data Analysis’ and then a selection of three from five modules in the ‘Applications’ area of study. The five modules are:

Module 1. Number patterns and applications

Module 2. Geometry and trigonometry

Module 3. Graphs and relations

Module 4. Business related mathematics

Module 5. Networks and decision mathematics. (VBOS 1999 p.96)

*Mathematical Methods Units 3&4 (MM3&4)*

These units are intended to provide an appropriate background for further study in, for example, science, economics or medicine. They may be taken alone or in conjunction with either Specialist Mathematics Units 3&4 or Further Mathematics Units 3&4. (p.8)

MM3&4 consists of the following areas of study: 'Coordinate geometry', 'Circular (trigonometric) functions', 'Calculus', 'Algebra' and 'Statistics and probability'. (VBOS 1999 p.126)

*Specialist Mathematics Units 3&4 (SM3&4)*

These units are intended for those students with strong interests in mathematics and those who wish to subsequently undertake further study in mathematics and related disciplines. They are normally taken in conjunction with MM3&4 and the areas of study extend and develop material from MM3&4. (VBOS 1999 p.8)

SM3&4 consists of the following areas of study: 'Coordinate Geometry', 'Circular (trigonometric) functions', 'Algebra', 'Calculus', 'Vectors in two and three dimensions' and 'Mechanics'. (VBOS 1999 p156)

APPENDIX B.

THE EQUIVALENT NATIONAL ENTRANCE RANK (ENTER)

The following extract has been taken from:

ENTER into Tertiary Study: A Guide to the Equivalent National Tertiary Entrance Rank (2002) The booklet is authorised by VTAC. Victorian Tertiary Admissions Centre. It can be found as a pdf file at:

<http://www.vtac.edu.au/pdf/publications/enterbook.pdf>

### **The Equivalent National Entrance Rank (ENTER)**

“The calculation of the ENTER for a student takes account of three facts.

First, apart from the English requirement, VCE students have no set studies to take at the level of Units 3 and 4. Comparing students using the ENTER involves comparing students who may have taken very different combinations of VCE studies.

Secondly, all studies count equally in determining the ENTER. Study scores however, only give the *ranking* of the students in each study. To compare rankings and study scores *fairly* from study to study requires that the *strength of competition* in each study is about the same.

Thirdly, students should be able to take the studies that they enjoy, that they need, and that they are good at. The ENTER should be calculated in such a way as to allow this to happen, and not to introduce any other factor which interferes with the student's choice of studies.



**Scaling** is a process which adjusts VCAA study scores to take account of these three facts before using the scores to calculate the ENTER. VCAA study scores are adjusted by VTAC to allow for any variation in the strength of competition between the cohorts of students taking the various studies that year. Thus students taking various combinations of studies can be compared, and students can choose their studies in a sound way without fear that they will be disadvantaged by the choice.

If a variation is required to reflect the strength of competition in that study that year, the scaling process adjusts VCAA study scores to become **ENTER subject scores**. The strength of competition in a study is judged by looking at the *total performance* of the cohort of students taking that study. That is, the performance of that group of students in all their VCE studies is compared with their performance in that study. This comparison is carried out for each VCE study. The scaling process leaves a top VCAA study score as a top ENTER subject score, and never lowers a top score of 50. Bottom scores of 0 are also unchanged. Scaling usually affects VCAA study scores most at the mean study score of 30. The score may stay the same, it may be adjusted up, or it may be adjusted down. After scaling, ENTER subject scores across studies can be fairly compared. A student taking a study where the competition was strong may have that competition reflected in a lower VCAA study score rank, but scaling will compensate for the strength of competition by giving a higher ENTER subject score. Another similar student taking a study where the competition was weaker may have achieved a higher VCAA study score rank, but scaling will bring the score close to the result for the other student. In the end a balance is achieved,

and similar students finish up with similar ENTER subject scores, no matter what studies they choose to do.

There are two complications to scaling.

First, the three mathematics studies are of graded difficulty and they are scaled to ensure comparability within the mathematics group.

Secondly, languages other than English (LOTEs) have an adjustment of 5 points upwards to their means after the initial but prior to the final scaling. This was introduced at the request of the Victorian Government to encourage the study of LOTEs.

### ***Determining the ENTER***

All students receiving an ENTER have been successful in that year's VCE class. There is no notion of pass or fail involved, as an ENTER is only awarded to successful students. Some students apply to study interstate and/or in different years to the one in which they complete Year 12. So, the ENTER needs to be comparable from year to year and from state to state as far as possible. In 1996 the states agreed on a method for achieving this comparability. The method takes into account the percentage of the age group that stays at school till Year 12, and where those who are not eligible for an ENTER might have come in the ranking. The percentage ranking amongst completing VCE students in a year is created first using the ENTER subject scores, and then an additional procedure works out the ENTERs by estimating where the ranking of the other people in the age group would have been.

The ENTER is determined in three steps. It is based on the ENTER study scores in the best English study [chosen from English, English (ESL), English Language and Literature] and at least three other studies in an allowable combination. The scores need not all be from the one year.

First, an **ENTER aggregate** is found by adding the ENTER study score for the best English study, the next best three ENTER subject (study) scores (of an allowable combination), and 10% of any fifth and sixth ENTER subject score that is available.... The increment for the sixth study may be replaced with the appropriate increment for an approved university study as part of the VCE extension study program. At most six results contribute directly to the ENTER aggregate. Where more than six results are available the six legitimate results yielding the highest ENTER aggregate are used....  
...The ENTER aggregate is a number between 0 and a little over 210.

Secondly, all eligible students are ranked in order of their ENTER aggregate, and a percentage rank is then assigned with (as far as possible) an even distribution amongst the students who have received an ENTER aggregate that year. All students with a particular ENTER aggregate receive the same percentage rank. If a number of students are tied on a particular aggregate the number that receives the corresponding percentage rank may increase.

Thirdly, the percentage rank is converted to an ENTER, which is the estimate of where the student came in the relevant age group, taking account of the students

who have successfully completed VCE as well as those who moved or left school before Year 12. This is achieved using a method agreed to by all states.

The ENTER is a number between 0 and 99.95 in intervals of 0.05.”

APPENDIX C.

A QUESTIONNAIRE ON ACCELERATION IN MATHEMATICS

## QUESTIONNAIRE ON ACCELERATION IN MATHEMATICS

**For how many years did/has your school offered an acceleration program?**

1, 2, 4, 5+, 6, 6, 6, 6+, 6+, 7, 7+, 9, 10, 10, 10+, 11, 15

**At what year level does your acceleration program begin?**

Yr 3	1
Yr 7	1
Yr 8	1 informally
Yr 9	13
Yr 10	3

For what reason/s was the acceleration program implemented?

To cater for bright students, Marketing purposes, Open VCE choices

Some students were itching to get on with maths and ready to tackle both the year 9 and year 10 components of each topic as it was introduced in year 9 e.g. factorisation, trigonometry, mensuration, algebra etc

For students who have a need for at least double maths at Yr 11 and 12 this allows them to have more subject choice by finishing a Unit 3/4 only. Enables school to offer extension to bright Yr 9 and 10 students without developing new courses. It ensures that able students are truly extended which may not happen in normal mixed ability classes.

To cater for the very capable students and open up the pathways through VCE

Because some of our brighter students were wanting more and the idea of doing Maths 3/4 was appealing to them.

Cater for students of exceptional mathematical ability, allow access to 3/4 studies in Yr 11, parental expectation, normal Yr 10 course too easy

Extending better Maths students, preparation for Specialist Maths (+MUPHAS)

Allowing access to Units 3 & 4 in Yr 11, therefore possible +MUPHAS at Yr 12

Plenty of parental support

To challenge mathematically able students who would be otherwise bored in the mainstream program. To enable mathematically able students to do in Methods 3&4 in Y11 and give them the option of doing MUPHAS mathematics in Y12.

Directive from the Principal, the Maths department was not given a choice. Probably motivated by marketing forces and parental pressure in light of what other schools were doing.

Exceptional students identified at Yr 7 & 8 could skip a level

Year 9 students in mixed groups doing integrated studies needed more advanced algebra.

We accelerate into Gen/Further rather than MM 1/2 at Yr 10. Further at Yr 11 means a good result can be used in case of a poor result in SPM. Cut teeth on SAC's at Yr 11, helps with boredom if doing GM 1/2 with weaker students

To give gifted students the opportunity to do Uni Maths at Yr 12

Not sure exactly. At the primary level, it's likely because it was easier to cater for bright students this way. A fair degree mathematical competence is needed to enrich students sideways and resources need to be gathered. Primary teachers do not always feel they have the necessary skills to do this (or the time). At the senior level it commenced soon after VCE came in when universities started offering their courses to school students.

Exceptional Yr 9 group coming through, parental pressure and perceived need.

To cater for students who have demonstrated exceptional mathematics ability. It was felt amongst College staff that Yr 9 students should not have to wait 1–2-years to enter senior school & undertake more intensive VCE studies.

**In your opinion, was/is the acceleration program a success?**

**Yes/No**

Yes	No
8	2
Too early to tell	
With reservations	
Yes, but not successful enough. Strong reservations	
Yes & No	



**Pros:**

Students like it, some teachers like teaching an accelerated class

Allows brighter students to access harder, more challenging work, extends and challenges students, Allows flexibility of subject choice i.e.: students do not have to continue accelerated into Yr 11.

Provides a challenge for brighter students and more choice in Yr 12

Students generally do well, less parental complaints about lack of extension, revitalise some students' interest in education, It heightens the profile of very bright students but makes it very everyday when they are mixed with students of a higher year level. Opens up the opportunity to do Uni maths.

Students who have been selected for the accelerated program have, with only a few exceptions, been motivated to succeed. There has been some healthy competition. They are better equipped to do Specialist Mathematics in Year 12.

Good preparation for SPM/MUPHAS, keeps kids interested/ motivated and pushed to their limits, greater choice for VCE nits 3/4.

MUPHAS option, real challenges at Yr 9 & 10, more 3&4 subject options at 11 and 12

Satisfies the wants of the client, gives students more choice in Yr 12, more students go on to SPM

Student success

Parents feel this is great, benefit of doing a Yr 12 subject in Yr 11

Easy to implement, parents think it's good because their child is seen as bright and in need of extra challenge, have to keep up with other schools that are doing this.

Excellent for able students

Keeps exceptional students challenged and motivated, Does not hold back their progression in the subject, allows VCE studies in Yr 10 (normally not encouraged)

It opens up the VCE options for students and allows students to give greater attention to SPM, one less subject to worry about at Yr 12. Good for the exceptional students who would achieve very highly regardless of when they do MM 3/4.

Students are challenged; it gives them a carrot on a stick because at the end of year 9 there are VCE options that they may qualify for. It enables those that are not being accelerated to be in mixed ability classes with a greater homogeneity.

Enables them to do SM3&4 with greater insight and deeper background (especially the calculus related content) and reduces the stress on them learning and using items that they have just been introduced to in MM3&4

Enables them to do a non-maths/science subject in Year 12 even if they are the traditional MM/SM/Chem/Phys student – many are quite capable of and in fact wish to do a LOTE or Media or Politics etc as a subject they are interested in

Enables them to do Enhancement Maths (we still follow Monash's original requirement, even though Monash itself has relaxed it since, that a student cannot do Enhancement Maths unless they have already completed MM3&4)

**Cons:**

Only a few students in each class, classroom management, keeping them focussed when they encounter difficulties, rostering support classes out of hours to assist these students.

Some insist on being accelerated to mediocrity!

It does remove many of the better students from the mainstream program with the disadvantage of lowering the bar in these classes.

In a small school it's hard to staff in Yr 10

Extraction of accelerated class lowers the performance of the middle band, selection or exclusion is fraught with danger, some do not do as well as they would have completing the course in the normal time frame

Disadvantaged in their 3/4 study score in Yr 11, stressful for some students, fast tracking has meant that skills are not always developed in depth. This results in

shallow coverage. Students tend to focus on learning rules rather than be given the opportunity to investigate concepts on their own.

Students who are capable at Yr 7 & 8 can begin to flounder with harder work at Yr 9 and 10 and begin to doubt their expertise. Some don't go onto SPM, so one wonders why do MM 3/4 in Yr 11?

Mixed in with older students, haven't achieved as highly as they could have had they done enrichment instead.

Prevents genuine enrichment maths being delivered from Yr 9 onwards, it might be the case that girls don't achieved as highly as they could have had they done enrichment instead.

Often too content based, little room for lateral movement in topics

Too much pushing from parents, kids not mature enough for MM 3/4 in Yr 11.

I can't think of any!

Too many students being accelerated, results are not as good as they could be, it seems to take the place of enrichment.

Results at MM 3/4 are not to the standard they should be. These are talented students who lack maturity and an ability to cope with pressure. They have no other option but acceleration. Doing SPM at the same time as MM makes MM easier. There isn't time

in an accelerated setting to focus on enough concept development, through investigation, and consolidation. Lateral extension and problem solving skills are not explored enough.

Most of our Year 11's doing MM3&4 would probably do better if they tackled it in Year 12

**Do you have any statistical evidence that you can provide here as to the success or otherwise of the program? (For example, VCE Mathematical Methods Units 3 & 4 study score results for students in Year 11)?**

I have collected some results. I don't think these students have done significantly better than the others

Not really

Better cohort of grades for those kids

Yes the Yr 11 boys usually achieve the bet results in  $\frac{3}{4}$ .

At our school there are 40 out of 135 girls doing SPM. In part I think this is a success born out of the current accelerated program.

**The great majority of accelerated students doing MM 3&4 in Year 11 have achieved unscaled study scores of 40 or above. (eg In 2002, 22 of the 23 achieved study scores of 40 or more, highest 2 on 48, the one who missed**

scored 39.) Invariably these students are usually the highest ranked in Specialist Mathematics.

We no longer offer this.

Yr 11 FM scores are always excellent & much higher than concurrent yr 12's. Several 50's, some SPM kids drop out after Sem1 as they have their 50 to fall back on.

No evidence. However under old "CATS" accelerated students would have done better. Under present VCE, no difference.

Not successful. Most students have done well in Yr 11, but it is difficult/impossible to compare this to a study score that has been calculated from the whole cohort by VCAA

No, no control group. Yr 11 students usually finish at top of MM  $\frac{3}{4}$  group – but so they should.

No hard statistical evidence.

Students really enjoy maths at year 9 when they are in the Extension (acceleration) classes. Many students take up the option of doing a VCE 3&4 in Year 11 once they have qualified over our hurdles even though there is no compulsion to do it (or in fact any Maths in VCE) and despite the fact that we do not hide the evidence that indicates that they might do MM3&4 better in Year 12 rather than Year 11

There is plenty of enrichment material available for students to extend themselves with the skills they already have. Learning maths is not finite and the extra year of enrichment would give students a broader and more mature understanding of the subject. I can't imagine a student not being better at problem solving after having another year's experience.

Our students who gain the highest scores in MM  $\frac{3}{4}$  are usually the Yr 11's. One can't help but think what they would have achieved had they left their study of MM  $\frac{3}{4}$  until Yr 12.

**What, if any, anecdotal evidence do you have as to the success or otherwise of the program?**

When I was home with kids and tutoring, I had a number of students from a girls' school that had been accelerated and they had lost a lot of confidence in their ability and were being pushed too far too fast. I sense that the school involved just put a particular number from the top of the year group into the acceleration class with no regard to whether it was really appropriate.

Students are inclined to dedicate more time and energy to their  $\frac{3}{4}$  Maths when it is completed a year early. As a group they do obtain outstanding results. The middle band would probably have performed better if they had not accelerated.

Plenty of anecdotal evidence based on discussions at the end of Yr 12. Many have said they regret doing it. The results were clearly not what they should have been in many cases. The real high flyers were pleased to have had the opportunity.

**Most students have been satisfied with their performance and achievement in the program. (feedback from students.)**

Most students are happy that they undertook the course.

If the accelerated students were grouped in one class, all benefit from the discussion amongst the class and all tend to lift their efforts, thus producing higher study scores. If one or two are in a non accelerated class they find it difficult to maintain their enthusiasm and consequently may underachieve. (Based on 3 years experience under both system)

**Does any article (or articles) that you have read stick in your mind as being very pertinent to argument for or against acceleration programs? Please list.**

*“Acceleration” as a needed strategy in Gifted Education. Anne Swinfield Vinculum March  
2003*

Have you attended any professional development sessions on acceleration in Mathematics and, if so, can you name them and the presenter/s?

**Additional comments:**

Acceleration can work if it is closely monitored and individual students are counselled by their mathematics teacher. Success at MM  $\frac{3}{4}$  depends on, not only the competency of the student in tackling routine problems, but also his or her experience and competency in tackling analytical questions under exam conditions.



APPENDIX D.

TABLES 43 - 48

Table 43: Final estimation of fixed effects for MM (2001-2002) with GATMST above 45-Model 1

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	39.620984	0.471604	84.013	262	0.000
SETTING, $\gamma_{01}$	-1.639788	0.442935	-3.702	262	0.000
INDPT, $\gamma_{02}$	2.242807	0.407726	5.501	262	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	0.268043	0.338340	0.792	264	0.429
For ACCEL slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	0.550840	0.310397	1.775	264	0.077

Table 44: Final estimation of fixed effects for SM based on Model 2 (2001-2002)

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	32.884853	0.368311	89.286	263	0.000
INDPT, $\gamma_{01}$	2.471393	0.498201	4.961	263	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	0.542917	0.380770	1.426	264	0.155
For ACCEL slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	4.172510	0.377793	11.044	264	0.000

Table 45: Final estimation of fixed effects for SM based on Mode 3 (2001-2002)

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	-7.678916	0.838846	-9.154	264	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	-0.275393	0.196672	-1.400	264	0.163
For MM slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	1.063177	0.021573	49.283	264	0.000
For ACCEL slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	3.313722	0.247548	13.386	264	0.000

Table 46: Final estimation of fixed effects for MM based on Model 1 (2003-2004)

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	37.741907	0.324384	116.349	271	0.000
INDEPEND, $\gamma_{01}$	2.794741	0.449801	6.213	271	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	0.572311	0.323351	1.770	272	0.077
For ACCEL slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	1.554143	0.353083	4.402	272	0.000

Table 47: Final estimation of fixed effects for SM based on Model 2 (2003-2004) with GATMST above 45

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	32.095226	0.356143	90.119	271	0.000
INDPT, $\gamma_{01}$	3.244524	0.479079	6.772	271	0.000
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	-0.339064	0.379982	-0.892	272	0.373
For ACCEL slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	5.510319	0.392940	14.023	272	0.000

Table 48: Final estimation of fixed effects for SM based on Model 3 (2003-2004) with GATMST above 45

Fixed Effect	Coefficient	Standard Error	T-ratio	d.f.	Approx. P-value
For INTRCPT1, $\beta_0$					
INTRCPT2, $\gamma_{00}$	-5.369365	0.716039	-7.499	271	0.000
INDPT, $\gamma_{01}$	0.489528	0.231503	2.115	271	0.035
For GENDER slope, $\beta_1$					
INTRCPT2, $\gamma_{10}$	-0.683985	0.224614	-3.045	272	0.003
For MM slope, $\beta_2$					
INTRCPT2, $\gamma_{20}$	0.990170	0.018778	52.729	272	0.000
For ACCEL slope, $\beta_3$					
INTRCPT2, $\gamma_{30}$	3.831039	0.235890	16.241	272	0.000





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