Attachment A

Participation in Physics and rigorous Mathematics and a consideration of educational, economic and political influences.

Thesis submitted by

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My thanks to all of my family, John and Julia Bell, Michael and Sue Ridd and Peter and Cheryl Ridd for their constant encouragement and, when required, valuable criticism. Most of all to my wife Elaine who, in addition to providing some candid but constructive comments endured six years with a husband who was even more irascible than usual.

Declaration

I declare that this thesis is my own work and has not been submitted in any form for any other degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Preface.

The work reported in this thesis was based on a number of separate but interconnected pieces of research that were performed during a six year Ph.D. candidature:

An initial and then on going examination of Mathematics and physical Science enrolments at Tertiary level in a number of countries including Australia. Evidence of both demand and supply side influences were noted.

An initial and then on going examination of Secondary enrolments in Physics, Chemistry and rigorous Mathematics, primarily in Australia and with a strong focus on Queensland.

Queensland state legislation pertaining to Statutory bodies involved in Secondary education and some consequences arising from that legislation were examined.

A major survey of opinions of Queensland Secondary Principals in respect of Mathematics and physical Science with emphasis on the condition of the lower Secondary level. That survey had a 70% response rate.

An examination of student outcomes at the end of Year 10 in both physical Science and Mathematics. That examination involved a consideration of the scant hard data in existence together with an inspection of popular text-books.

A survey of the opinions of all the Year 12 students in five schools who had just completed their study of Maths C.

A survey of approximately 300 Year 10 students in the five schools at the time they were making their subject selections for Years 11 and 12. The survey examined student motivation, attitudes and knowledge of the Year 11/12 subjects.

A detailed examination and analysis of the Overall Position (OP) implications of the concurrent study of Maths B, Maths C and Physics for the students in the five schools.

An examination of the OP effect of that concurrent study by gender-viewed in terms of comparative advantage.

The performance of females and males in a number of Year 12 subjects was examined. That examination was over the whole state and considered subject performance in comparison to a measure of general ability.

Publications.

Ridd, J. and Heron, M. (1998) Science in crisis?-Participation in Physics. *A.N.Z. Physicist.*35 pp. 255-260

Ridd, J. (2000). Year 9 and 10 structures in Queensland and possible implications for subsequent studies in Mathematics and Physics. *The Physicist.* 37(3). Pp94-98

Ridd, J. (2002) Attainment in Maths and Science to Year 10 in Queensland: a tragedy in one Act. Conference paper, ASERA July 2002.

Ridd, J. (2002) A Ricardian approach to subject selection. *Journal of Institutional Research,* Vol.11(2). Melbourne.

ABSTRACT

In this thesis the level of participation in Physics and the allied discipline of rigorous Mathematics at Tertiary and upper Secondary level is examined. Various possible supply side constraints are considered, in particular the condition of Maths and Physics in lower Secondary schools in Queensland. Some of the effects of weak Maths and Physics in that part of the education chain are examined indicating that there is a commonality of interest between many school students, especially males, and the disciplines per se.

Participation in Physics at Tertiary level is in decline in USA, Canada and Germany as well as in Australia. There are indications from both Germany and USA that those declines are not entirely explicable by a consideration of demand side influences, supply side factors must have some influence. Because it may be possible to manipulate supply side influences, the work reported here concentrates on those issues, in particular in Queensland.

Participation in Physics and especially rigorous Mathematics in the last two years of Secondary schooling has been in medium to long term decline across Australia. In Queensland that decline is mainly a decline in male participation. The student decisions not to study those subjects are made at the end of Year 10. Hence their educational experiences prior to that time are important. Clear evidence is presented from a large sample of school Principals in Queensland that there is a high degree of concern in the schools about the condition of both Mathematics and Science in Years 8,9 and 10.

An inappropriate structure of relevant Statutory Authorities in Queensland has led to there having been no collection for 15 years of data vis-à-vis student outcomes up to the end of year 10. The only exception being a single but excellent study for Mathematics that showed that outcomes are highly variable and frequently weak, particularly for algebra.

For physical Science there is no data but indications from textbooks are that very little numerical Science is studied. Hence there is a discontinuity at the Year10/11 interface.

It is known that participation in the physical Sciences is highly dependent on previous educational experiences. The discontinuity referred to will affect participation in Physics and Maths C, the most rigorous Mathematics in Queensland at the Year11/12 levels. An analysis of effects on student Overall Position (the equivalent of ENTER) consequent to the concurrent study of Maths B, Maths C and Physics shows that students are advantaged in OP terms by that concurrent study. Hence the decision by an increasing number of capable students not to take those subjects may have a deleterious effect on their final outcomes. A survey of students from five North Queensland schools confirms that students who are taking Maths B/Maths C/Physics are comfortable with it and recognise that it has been to their advantage. Another part of that survey demonstrates a degree of ignorance about both Physics and Maths C amongst the Year 10 students at the time that they are making their subject selections. It is noteworthy that the advantage gained by taking the combination Maths B, Maths C and Physics is at least as noticeable for males as for females. Consequently it is an area of comparative advantage for males. An examination of male/female performance in rigorous Mathematics and numerical Science across the whole state demonstrates that, contrary to received wisdom, females are not performing better than males of similar general ability or have relatively improved their performance over the last decade at least.

It is suggested that a major overhaul of both Mathematics and physical Sciences in lower Secondary schools in Queensland is required. Such an improvement would tend to raise participation levels in both Physics and rigorous Mathematics to the advantage of many students, particularly males and provide a larger pool of qualified students from which Tertiary physical Science and Engineering Departments could draw.

The condition of both Mathematics and physical Sciences in Years 8/9/10 is at best highly variable, at worst poor, to the detriment of many thousands of students and the related disciplines Mathematics and Physics. It is suggested that Parliament, the Statutory bodies, schools and Tertiary Education Faculties need to accept that a problem exists, accept a part of the responsibility for that problem and act decisively to rectify the situation.

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Acronyms and abbreviations

AIP	American Institute of Physics.
ASAT	Australian Scholastic Aptitude Test. Replaced by QCS. (qv).
CSP	Canada Scholarship Program.
DEETYA	Commonwealth Department of Employment, Education, Training and Youth.
DEST	Commonwealth Department of Education, Science and Training.
Edexcel	A major London based secondary school examinations authority
EFTSU	Equivalent Full Time Student Unit.
ENTER	Equivalent National Tertiary Entrance Rank.
E.U.	European Union.
FASTS	Federation of Australian Scientific and Technological Societies.
LSAYR	Longitudinal Survey of Australian Youth. There are over twenty of these, LSAYR 22 is the most frequently referred to in this thesis.
OP	Overall Position. The Queensland equivalent of ENTER. (qv). See Appendix 4.
QBSSSS	Queensland Board of Senior Secondary Studies. Now superseded by QSA (qv). QBSSSS was frequently referred to as BOSSSS. Responsible for all studies and assessment in Years 11 and 12 only.
QCS	Queensland Core Skills Test. A test used in the Scaling process leading to the OP. See Appendix 4.
QSA	Queensland Studies Authority. The present single studies authority. The successor to QBSSSS, TEPA and QSCC. (qv)
QSCC	Queensland Schools Curriculum Council. Responsible for curriculum in Years 1 to 10. No assessment responsibilities.
SAI	Subject Achievement Indicator. See Appendix 4.
SCAT	Secondary Catholic.
SGOV	Secondary Government.
SIND	Secondary Independent.
TEPA	Tertiary Entrance Procedures Authority.
TIMSS	Third International Maths and Science Study.
WT	Writing Task. A part of QCS. (qv).

CHAPTER 1

PARTICIPATION IN PHYSICS AND RIGOROUS MATHEMATICS

CHAPTER 1

Concern that participation in rigorous Maths and physical Science both in schools and undergraduate university programmes is declining is widespread. That concern was well summarised by the Australian Minister for Education who commented that '--concern remains that too few choose to continue with science--'. (Kemp, 2000).[1] It is difficult to overestimate the importance of both Physics and Mathematics. A grounding in Physics underlies engineering and much of modern technology. Mathematics, especially algebra is a basic prerequisite training for the solving of complex problems in a rigorous, sequential manner.

The primary objective of this chapter is to examine some trends in participation in Physics, Mathematics and Chemistry within tertiary departments and at secondary level. However there is not necessarily a one to one matching between the numbers involved in tertiary studies named 'Physics' and the health of the discipline of Physics itself. For example, fluid flow flow is around an object may legitimately be called 'Physics'. Does it cease to be Physics if the fluid over a metallic surface and is then called 'Aerodynamics'? The overwhelming majority of formally taught material studied in Engineering Faculties is either Applied Science or Applied Maths irrespective of the title of the course. Again, the formally taught material studied in Medical courses is overwhelmingly Applied Science.

Due to the smaller number of other 'subjects' which can involve Physics at secondary level, the numbers of Physics students there (and Chemistry and Mathematics) are a more precise measure of the health of the respective discipline in a wider sample of the community. Even at secondary level some other 'subjects' such as Multi Strand Science in Queensland do contain some Physics albeit at a somewhat more elementary level.

That there have historically been difficulties with the definition of knowledge into 'subjects' is illustrated by the citation for Rutherford's Nobel prize in 1908:- 'for his investigations into disintegration of the elements, and the chemistry of radioactive substances', Rutherford, that almost archetypal experimental Physicist, received the Chemistry prize. The inventor of the mass spectrograph, F.W. Aston was also awarded the Chemistry prize. In 1997, Boyer, Walker & Skou were awarded the prize for Chemistry for their work on the functions of adenosine tri phosphate within cells. The 'Economist' (1997) remarked that their work might ' ----- more properly belong in the category of medicine'.

These definitional problems, although providing interesting but perhaps pointless discussion, are apparently of no real importance, merely demonstrating the obvious continuum Maths-Physics-Chemistry-Biology. They do, however, illustrate the risks inherent in assuming that because the numbers involved in 'Physics' are lower, the discipline itself is weaker in the same proportion. Furthermore, if they lead, or tend to lead towards a public conviction that Maths/Physics/Chemistry are 'irrelevant' then the implications would be serious indeed for the scientific and technological fabric of the nation. This chapter examines Tertiary and Secondary enrolment data for Physics and, to lesser extent, the closely related subjects Mathematics and Chemistry. Firstly the situation in a small sample of overseas countries will be considered. Secondly the position in Australia will be examined in more detail, and finally the enrolment data for Queensland will be subjected to close scrutiny.

1.1 Overseas Tertiary enrolments.

It needs to be borne in mind that 'official' data is generally collected for reporting purposes, not for analysis, and that there is insufficient similarity between countries for any detailed comparative analysis. Furthermore even within a given country the data collection techniques change over time so limiting analysis. There is little purpose in examining the enrolment data in a large number of countries. A small number is sufficient to set the Australian data in a more global context. At the Tertiary level some data from USA, Canada and Germany will be presented.

1.1.1 Canada.

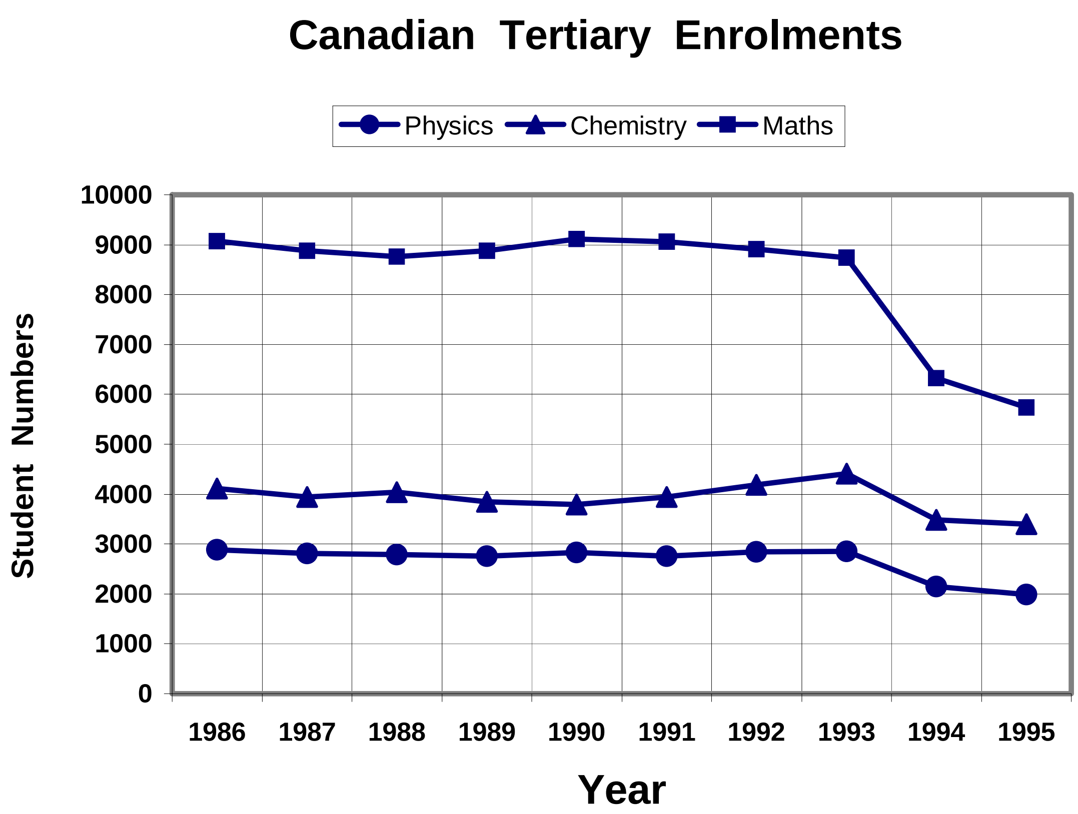
Physics has been under substantial pressure in Canada. Both Chemistry and Mathematics have been similarly affected. Table 1.1 and Figure 1.1 show the absolute numbers of undergraduates enrolled in Canadian universities for Physics, Chemistry and Mathematics for the period 1986 to 1995.

Table 1.1: Numbers enrolled at Canadian universities, 1986-1995.

Year	Physics	Chemistry	Mathematics
1986	2887	4113	9066
1987	2809	3947	8881
1988	2789	4042	8759
1989	2758	3848	8881
1990	2835	3796	9109
1991	2753	3938	9063
1992	2847	4187	8910
1993	2851	4413	8744
1994	2150	3483	6329
1995	1990	3401	5742

(Statistics Canada, 1997)

Figure 1.1: Numbers enrolled at Canadian universities, 1986-1995.



For all three subjects the enrolments changed little over the period 1986 to 1993, but subsequently a very steep decline occurred.

Over the same period 1986-1995, the total number of undergraduates increased. It is of interest to consider the enrolments as a percentage of the relevant total undergraduate enrolment and these are as shown in Table 1.2.

Table 1.2: Canadian enrolments as a percentage of total enrolments.

Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1996
Physics %	0.690	0.657	0.639	0.608	0.605	0.567	0.573	0.571	0.430	0.399
Chemistry %	0.983	0.923	0.926	0.849	0.811	0.811	0.842	0.883	0.696	0.683
Maths %	2.18	2.08	2.01	1.96	1.95	1.87	1.79	1.75	1.26	1.15

(Statistics Canada, 1997)

The number of Physics students as a percentage of total undergraduate population has declined 42%. Sixty percent of that reduction occurred in the last two years of the period. The number of Chemistry students as a percentage of total undergraduate population has declined by 30%. Two thirds of that reduction was in the final two years. Mathematics declined by 47% with 58% of that reduction in the final two years.

The Canadian experience - a period of relative stability followed by rapid decline-is of interest in that it shows the effects of a governmental attempt to influence participation rates. In 1988 the 'Canada Scholarship Program' was introduced to promote studies in Science and Engineering. The programme was 'sunsetted' as of February 1995.

Bernard Chabot, the Manager of the Canada Scholarship program stated that there were three reasons for the abandonment of the scheme: economic, policy and employment (Chabot 1997 pers.com.).

On the Economic reasons Chabot stated that "the C.S.P. was costing the government twenty three million dollars per annum in grants, and this, together with the subsequent Budget review, proved too much in the context of fiscal restraints".

On the Policy side, the intent of the Policy was "to encourage more top students, especially women, to enter Science, Engineering and Technology." However although the proportion of women in Science and Technology had risen substantially over the period of time between the introduction of the scheme and a Program review, "nevertheless, as in most programs, it was difficult to pinpoint a single cause, and the C.S.P. could not prove its effectiveness."

In 1988 it was anticipated that a shortage of graduates would occur in the relevant disciplines. 'but the recession of 1991, the re-engineering of large organisations in the Private sector and the streamlining of Government laboratories led to a surplus ---- in the selected disciplines". This surplus appears to be demonstrable since by May 1992 the percentage of ALL 1990 graduates in full time employment stood at 73%. For Physics it was 55% (61% for females). The same source gives unemployment rates "after graduation" in "all fields" as 34% (Bachelors), 23% (Masters), 16% (Doctorates). For Physics the rates were 41%, 21% and 23% for the same qualification levels. (National Graduation Survey (Canada), 1992).

It is reasonable to infer from the data set shown in Tables 1.1 and 1.2 that scholarship program had the effect of stopping or at least slowing the declines in enrolments, but that once the program ceased to operate the numbers declined drastically. It is almost as if the decline were 'pent up' by the program as a dam holds back water, but that once the dam was removed the speed of the decline increased rapidly. It may also be inferred that for Canada the weakness in demand for graduates in Mathematics, Physics and Chemistry had a far greater and more long lasting impact on enrolments than the governments attempt to manipulate supply side factors.

1.1.2 USA

Data quoted by the American Institute of Physics shows that the number of bachelor degrees conferred in Physics is in decline, having gone down by 15% from 1990 to 1995. The total number in the academic year 1994 - 95, at 4263 was the lowest since the 1950s. The decline continued in the later part of the 1990s reaching only 3646 in 1999.

At graduate level, first year Physics enrolments declined by 26% in the period 1992 to 1995. However in 2000 there was an increase of 4% in graduate enrolments, the first rise in almost a decade. Nevertheless, the fact that over half of those enrolments were for students categorised as 'foreign' may well present difficulties for Physics departments in the somewhat heated social atmosphere in the US consequent to the September 11 2001 terrorist attacks. The number of Physics Ph.D. awards fell in 1999 for the fifth consecutive year having declined by 15% since 1994. (Mulvey et al 1997, AIP 2000).

Hence the U.S. figures, showing a decline in Physics participation at all educational levels, suggest that the mid-term prospects for Physics Departments are poor. There is, however, a strong demand for 'Introductory Physics' (380,000 in 1994/95). The pre-requisite Mathematics requirements for these courses vary widely. Just less than 50% require calculus, nearly 40% require algebra only, whilst about 15% require neither algebra nor calculus. The increase in US participation in 'mathematically less intensive "conceptual"' physics courses is also noted in de Laeter and Dekkers (2001).

On a perhaps connected issue Zadeh (1997) states that "despite the rising demand for computer science graduates, the number of undergraduate degrees in computer science (U.S.) had dropped 43% from 42,000 in 1986 to 24,000 in 1994". Zadeh suggests fewer students are willing to do courses in which "hard work is required".

Zadeh's figures fit with the known decline in participation in the 'hard' subjects at Tertiary and Secondary level in Australia. In the vast majority of areas this decline has been predominantly due to a decline in male participation. At least two possible causes for the decline in male participation can be adduced. Firstly it may be that

Zadeh is correct, i.e. that an increasing percentage of young males lack both the self-discipline and the determination to stay at Secondary School and take subjects they think might actually require effort. Secondly it is possible that student experiences and outcomes up to and including middle secondary schooling are an inadequate preparation for later study and that such inadequate preparation affects males more than females. There is a clear difference in the Canadian experience, where demand side issues could be seen as an explanation of the enrolment declines, and the American experience as emphasised by Zadeh. For Computer studies the fall in enrolments cannot be explained in terms of demand side factors. The problem must be mainly supply side driven.

1.1.3 Germany

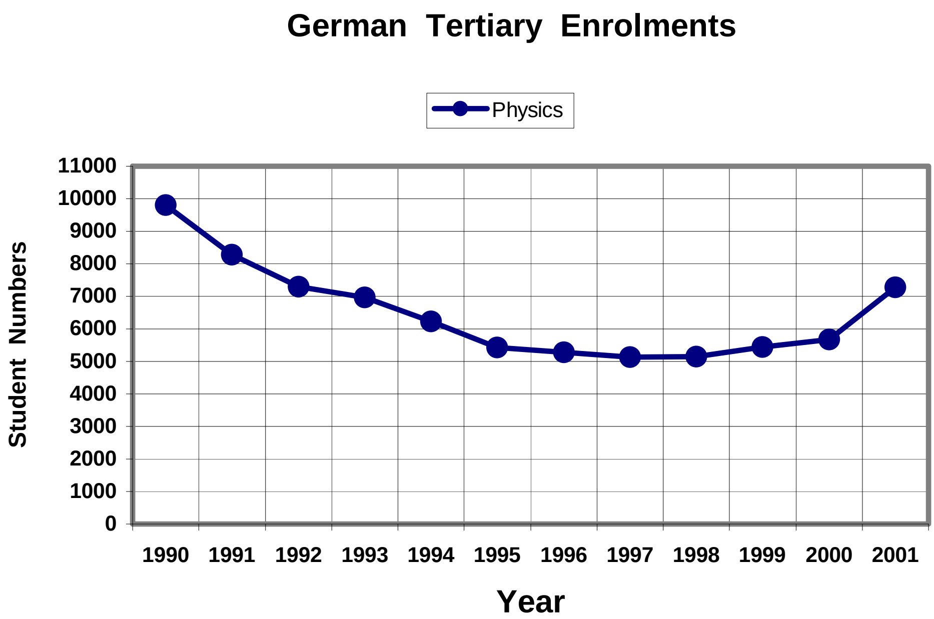
Whilst it may be necessary to approach the numbers from Germany with caution bearing in mind the relatively recent re-unification of West and East Germany, there can be little argument that a serious decline took place between 1990 and 2000 followed by a sharp increase in 2001. Table 1.3 and Figure 1.2 demonstrate that point.

Table 1.3: Number of new enrolments in first year Physics, Germany.

Year	1990/91	1991/92	1992/93	1993/94	1994/95	1995/1996
Number	9806	8278	7295	6965	6232	5432
Year	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02
Number	5276	5128	5147	5449	5680	7283

(Reineker 1995; German Bureau of Statistics 2002

Figure 1.2: Number of new enrolments in first year Physics, Germany.



The magnitude of the decline from 1990/91 to 1997/98 - 48% over seven years is partly compensated by a rise up to 2001/2002. The President of the German Bureau of Statistics, commenting on the data, stated that 'Increased employment opportunities due to an increased demand for scientists lead to an increase in first semester enrolments in (Physics and Chemistry) of ca. 30% since 1995. However the first semester enrolments are still below the 1990 level, therefore a continued increase in the lack of specialists is to be expected'. (Hahlen, 2001)

That this decline followed by a sharp rise is not limited to "minor' universities is demonstrated by the fact that the University of Heidelberg, which in the year 1994/95 had the largest number of Physics final exam candidates, shows a similar, albeit magnified pattern, as shown in Table 1.4.

Table 1.4. Number of first year students, first semester - Heidelberg.

Year	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
Number	191	158	174	175	140	149
Year	1997/98	1998/99	1999/00	2000/01	2001/2	
Number	176	153	167	194	290	

(Stieglitz 1997 pers.com, Bureau of Statistics, Germany, 2002)

The sudden drop 1994/5 to 1995/6 was severe. The 1991/1992 numbers are similar to those of a decade earlier, in 1980/81 the enrolment having been 185. The increases between 1998/99 and 2001/02, particular in the final year are quite extraordinary. Unless definitional change has occurred or additional courses offered that might distort the data, this is one Physics department that is in a very sound position.

Danielmeyer of Siemens AG, commenting on his perceptions in respect of Tertiary Education, contended that "qualitatively the global economic system and the education system at German Universities have diverged, what is required is a new set-up of university education ---"(Danielmeyer 1992).

Danielmeyer was to some extent referring to the fact that German students are older than others (within E.U.) at the time of graduation. However, his comments on the relationship between industry and Tertiary Education are of more universal application. He claims that Universities "prefer specialisation in classic disciplines" whereas what is required is "the ability to find solutions", and concludes with "that means, successful schools and department don't follow pure disciplines, but the practical needs".

Zadehs remarks quoted earlier in respect of poor enrolments for Computer Science in the US despite unmet demand are re-emphasised by Hahlen for the German experience. Firstly referring to IT he states that 'It is ours as well as the Federal Government's understanding that a significant demand for highly specialised IT experts can be expected and that the demand cannot be met solely by future graduates. That is the reason for the recent approval of a further 1000 residency permits for foreign IT specialists, so called greencards.' Secondly, with reference to Engineering, he comments that 'concerns that a lack of academically trained engineering specialists are definitely justified, in particular for the central disciplines mechanical and electrical engineering.' (Hahlen, 2001). As for the US it is evident that supply side problems exist, demand side considerations alone cannot explain the difficulties raised by Zadeh and Hahlen.

1.2 Enrolment trends - Australia - Tertiary

The evidence of changes in participation levels in Physics within Tertiary Physics Departments is strong and has been repeatedly demonstrated over many years. Jennings et al. (1996) showed a decline in numbers at third year level over the period 1991 - 96, a fluctuating situation in 4th year, and a decline in postgraduate numbers over the same period. A few years later de Laeter, Jennings and Putt (2000) showed that for the period 1997-1999 there were further declines in numbers in third year and fourth year and also in postgraduate studies.

The Federation of Australian Scientific and Technological Societies (Gascoigne1997 pers. com.) showed a marginal decline in first year enrolments from 1651 in 1995 to 1629 in 1996 but a far more severe decline, from 432 to 367 for second year. These figures indicate that only 22% of students studying Physics in First Year go on with the subject to second or later years.

In an examination of staffing numbers FASTS gave a decline in academic staff numbers in Australian Physics Departments from 282 in 1996 to 220 in 1997. They also state that restructuring/amalgamation were definite for James Cook, La Trobe, QUT, UNE, UWS, and Wollongong. FASTS also expresses concern for Flinders, Monash (serious 'downsizing'), Murdoch, Newcastle, Queensland (extreme staff reductions), Tasmania (pressure to amalgamate) and UTS (Physics major terminated).

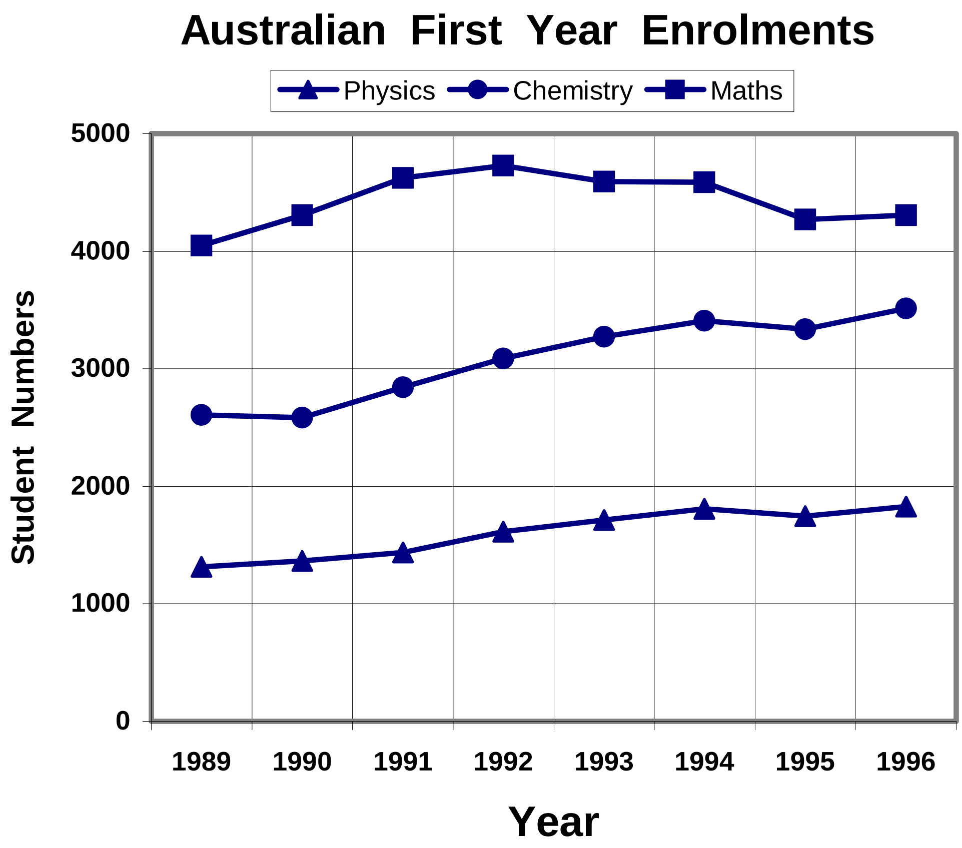
Tertiary figures for Australia are readily available from the Commonwealth Department of Education, Science and Training (DEST). However, interpretation of that data is not so readily achieved. Statistics obtained in 1996 from the Department of Employment, Education, Training and Youth (DEETYA), the predecessor of DEST, gave First Year enrolment as shown in Table 1.5, and as illustrated in Figure 1.3.

Table 1.5: Australian totals for First Year enrolments.

Year	1989	1990	1991	1992	1993	1994	1995	1996
Maths	4046	4306	4625	4728	4590	4586	4270	4305
Physics	1315	1365	1439	1613	1713	1810	1744	1827
Chemistry	2606	2586	2844	3088	3271	3407	3338	3511

(DEETYA, 1996)

Figure 1.3: Australian totals for First Year enrolments.



Such numbers appear to give little cause for concern, but they sit poorly with the known problems in the university Physics Departments. Confirmation of the departmental difficulties listed by FASTS earlier is contained in de Laeter, Jennings and Putt (2000). They list 'administrative changes' as having occurred at the following universities: James Cook, Central Queensland, New England, Western Sydney, Wollongong, Canberra, La Trobe, Victoria, Tasmania, Flinders, South

Australia, Murdoch and Queensland University of Technology. There is also anecdotal evidence that Physics, Mathematics and possibly Chemistry Departments are also being adversely affected by the loss of 'service teaching'. That can occur when another department, being in trouble itself, takes over the teaching of those disciplines so maintaining their own staff numbers but at the expense of the Physics, Maths and Chemistry departments.

However it is now evident that the figures shown in Table 1.5 were not for 'First Year' students. In 2002, the University Statistics section of DEST stated that; 'The figures (in Table 1.5) which you thought were for first year enrolments were in fact for total enrolments (both commencing and continuing students). Also the numbers for Maths included courses coded to 090401,090402,090403,090404 and 090499'. Those subjects, named Mathematics-General, Applied Mathematics, Pure Mathematics, Statistics and Operations Research and Mathematics-Other vary both in content and rigour. The full subject definitions, by numerical code, for the years up to and including 2000, are shown in Appendix 5.

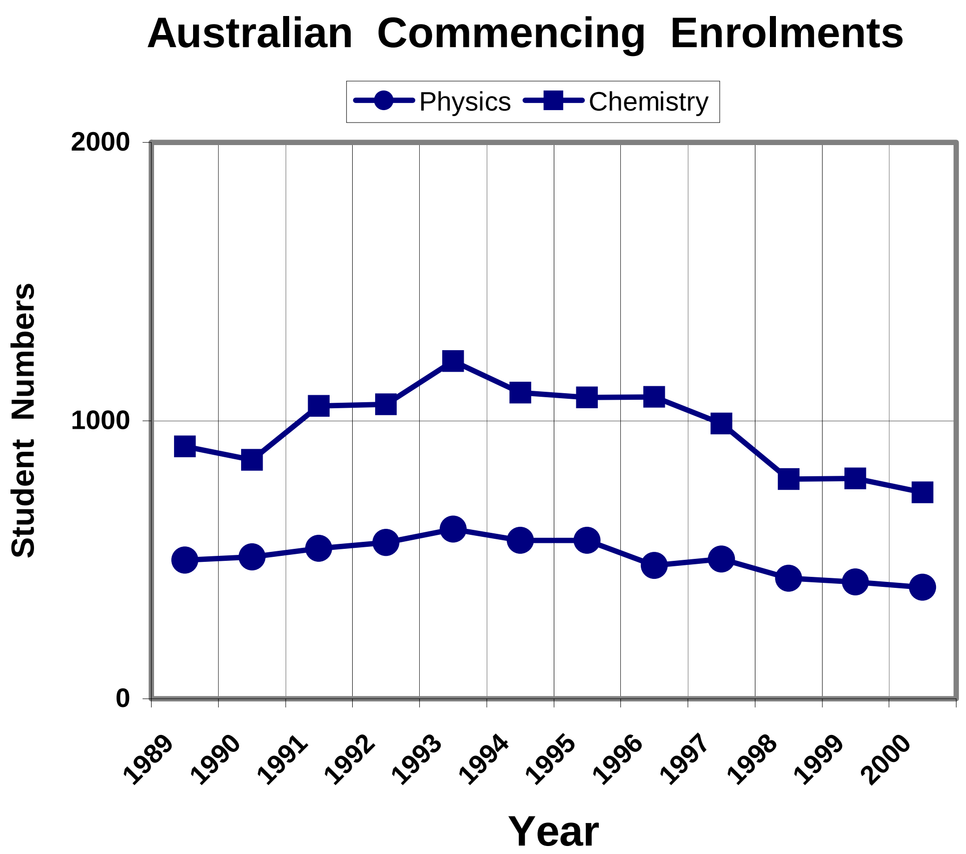
Table 1.6 and Figure 1.4 show 'commencing' enrolments for Physics and Chemistry for the years 1989 to 2000 inclusive. Note that there are no subject subdivisions for either subject for those years.

Table 1.6: Australian commencing enrolments, Physics and Chemistry 1989-2000

Field of Study	1989	1990	1991	1992	1993	1994
090502 Chemistry	907	860	1052	1059	1213	1100
090505 Physics	499	511	541	562	609	570
Field of study	1995	1996	1997	1998	1999	2000
090502 Chemistry	1084	1085	990	790	791	742
090505 Physics	569	479	503	433	419	401

(DEST, 2002)

Figure 1.4: Australian commencing enrolments, Physics and Chemistry, 1989-2000.



For Chemistry, the rise in enrolment observable in the period 1989 to 1993 is much more than offset by the decline from 1993 to 2000. For the whole period 1989 to 2000 enrolments declined by 18%, the decline from the 1993 peak to 2000 is 39%.

For Physics there was also a rise in enrolments between 1989 and 1993 followed by a marked decline from 1993 to 2000. The decline over the whole period was 20%. The drop from the 1993 peak to 2000 was 34%.

From 2001 the definitions for the various Physics, Chemistry and Mathematics 'subjects' used by DEST were altered. The definitions for 2001 are also given in full in Appendix 5.

Table 1.7 shows the commencing enrolments, based on the new subject definitions, for 2001. Note that Chemistry is now subdivided, Physics is not.

Table 1.7: Australian commencing enrolments in Physics and Chemistry 2001

Field of Study	2001
010500 Chemical Sciences	347
010501 Organic Chemistry	13
010503 Inorganic Chemistry	7
010599 Chemical Sciences not elsewhere classified	216
Total Chemistry	583
010301 Physics	346

(DEST, 2002)

If it is assumed that the Chemistry 'Total' can legitimately be compared with the single subject Chemistry for the earlier period, the enrolment decline continued. For the period 1993 to 2001 the decline was 36% and from the 1993 peak a remarkable 52%. The Physics (still a single subject) decline also continued. From 1989 to 2001 numbers fell by 31% and from the 1993 peak by 43%. The close association between Mathematics and the physical sciences makes an examination of Tertiary enrolments of interest. Table 1.8 shows those enrolments for the period 1989 to 2000.

Table 1.8: Australian commencing enrolments in Mathematics 1989-2000

Field of Study	1989	1990	1991	1992	1993	1994
090401 Maths-General	702	793	921	785	797	842
090402 Applied Maths	196	191	141	212	270	236
090403 Pure Maths	55	53	35	42	42	30
090404 Stats & Op. Res.	268	271	324	313	324	303
090499 Maths-Other	259	300	306	285	213	160
Total Maths	1480	1608	1727	1637	1646	1571
Field of Study	1995	1996	1997	1998	1999	2000
090401 Maths-General	668	577	643	552	556	595
090402 Applied Maths	231	268	241	174	148	132
090403 Pure Maths	46	26	36	29	21	21
090404 Stats & Op. Res	320	324	287	257	324	311
090499 Maths-Other	162	191	178	224	192	148
Total Maths	1427	1386	1385	1229	1241	1207

(DEST, 2002)

As for both Chemistry and Physics, total enrolments in Mathematics increased for a few years, reaching a peak in 1991, two years earlier than the peaks for Physics and Chemistry. From that peak there was a major decline in total enrolments. For the whole period 1989 to 2000 the decline was 18%; the decline from the 1991 peak to 2000 being 30%. Because of the multiple Maths 'types' for those years it is possible to examine the numbers in rather greater detail. Over the whole period 1989 to 2000 090401 Maths - General declined by 15%, 090402 Applied Maths by 33% and 090403 Pure Maths by 62%. Pure Maths started from a low base and by 2000 had become almost negligible. 090404 Statistics and Operations Research behaved abnormally, showing an increase of 16%. The catch-all definition 090499 Maths - Other declined by 43% but that decline was highly uneven as the figures for the years 1997, 1998, 1999 and 2000 show very clearly. Table 1.9 shows the enrolment data for 2001, i.e. subsequent to definitional changes.

Table 1.9: Australian commencing enrolments in Mathematics 2001

Field of Study	2001
010100 Mathematical Sciences	465
010101 Mathematics	224
010103 Statistics	171
010199 Mathematical Sciences not elsewhere classified	170
Total Mathematics	1027

(DEST, 2002)

The Physics data shown in Tables 1.6 and 1.7, when considered in conjunction with detailed Third year enrolment data by de Laeter (de Laeter et al 2000) are confusing. De Laeter examined Third Year enrolments in all Australian universities, confirming the data with each relevant Departmental Head. That data is tabulated against the DEST data in Table 1.10.

Table 1.10: Commencing and Third year Physics enrolments.

Date	1992	1993	1994	1995	1996	1997	1998	1999
Commencing	562	609	570	569	479	503		
Third Year			615	616	591	540	567	548

(DEST 2002. de Laeter et al 2000)

The interpretative difficulty is clear. In 1992 a total of 562 students 'commenced' Physics. It is assumed by DEST that most of those students would have been in First

Year; such an assumption is reasonable. Two years later, in 1994, when the 1992 entrants would have been in their third year at university there were 615 students studying 3rd Year Physics. That pattern, that the number of Third year students taking Physics is greater than the number who took (presumably) first year Physics two years earlier is evident in five out of the six years. That pattern is so counter intuitive as well as contrary to observation that it has to be assumed that a simple comparison of the data is inappropriate.

Information from the Planning and Statistics section of the Resources Office at James Cook University (Clark 2002 pers.com.) makes it clear that DEST aggregates data from the various Australian universities and that the data is given in EFTSU (equivalent full time student units). Hence, for example, for 1997, the 503 is not the number of students that were studying Physics in the First Year, but the sum of all the full time equivalents of all students who were studying any Physics in First Year.

The Third Year data however, is not in EFTSU units, but the number of students studying Physics at that level i.e. considered to be 'majoring' in Physics. Although it is difficult to estimate the EFTSU equivalent of the de Laeter et al.(2000) numbers such an estimate does enable a more valid comparison of First and Third Year data. If it is assumed that the 'Third Year' students are spending approximately one third to one half of their time on Physics, the EFTSU equivalent of 548 would be in the range 180-270. A change from 503 commencing student unit in 1997 to rather less than half that number of student units in 1999 at Third Year level is credible.

The data sets, because of the fact that they are based on consistent data collection systems over time, are a reliable indicator of trends that have occurred. What the data sets cannot do is indicate how many students are taking *any* Physics in First Year or the amount of Physics taught by Physics *Departments*. That total number must be very much larger than the EFTSU number. An examination of detailed data shows that 'mainstream' Physics subjects are normally rated as being 0.125 EFTSU, but some other non 'mainstream' Physics components within other subjects are rated as low as 0.03 EFTSU. The numbers enrolled in some of those low EFTSU rated subjects is often high, frequently much higher than the numbers enrolled in 'mainstream' subjects. Any attempt to estimate the number of students studying some Physics in their first year at university must inevitably have very large error bars, but there cannot be fewer than 4000 and it is probable that twice that number are involved to a greater or lesser extent.

Whilst there are obvious definitional problems in making judgements about 'standards', it is reasonable to suppose that a large percentage of students studying First Year Physics at Universities are studying only at a 'Foundation' or basic level. The consistent picture emerging from the Tertiary data is that Physics Department are providing a significant and essential exposure to Physics for students who are taking major studies in other areas.

1.3 Overseas Secondary

It is difficult to obtain meaningful statistics at secondary level outside Australia because: (a) in some countries some Physics is compulsory at all times, (b) some have a lack of available central data, and (c) most have changes to curriculum and syllabus structures which make comparisons over time effectively meaningless. However, some data from the U.K. is highly suggestive of a serious decline.

1.3.1 United Kingdom

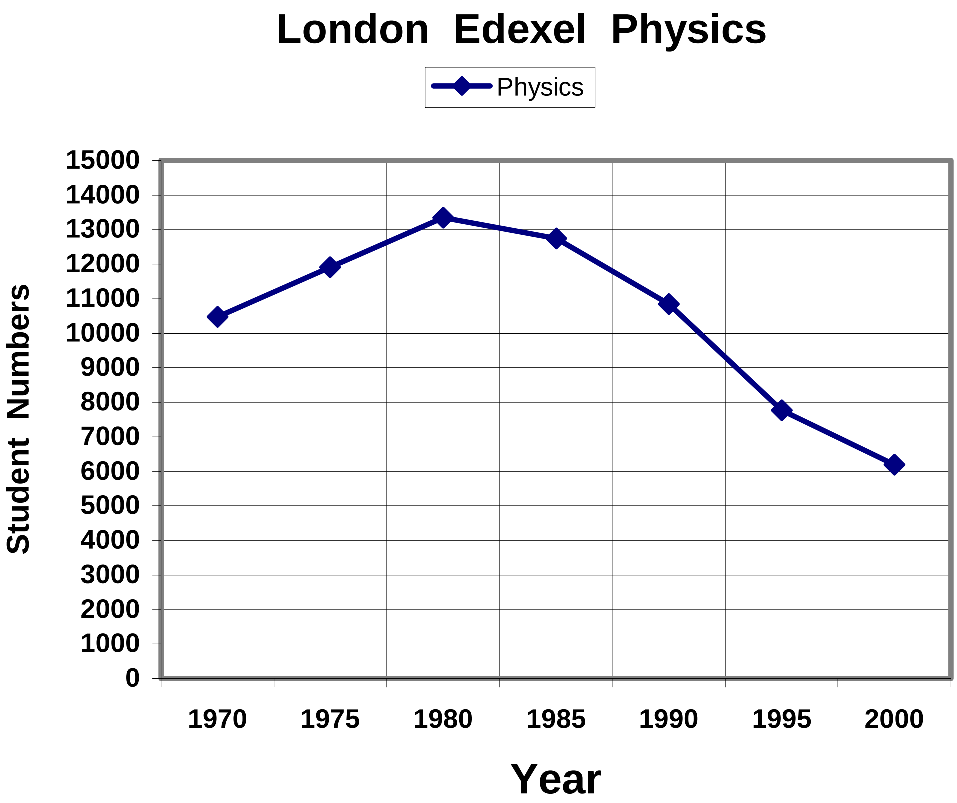
The University of London based examinations authority, Edexcel gives figures for Physics (combined 'Physics' and 'Physics Nuffield') over the past 25 years as shown in Table 1.11 and Figure 1.5.

Table 1.11: Edexcel Physics Numbers, London.

Year	1970	1980	1985	1990	1995	2000
Number	10468	13344	12743	10842	7773	6196

(Edexcel 1997, 2002)

Figure 1.5: Edexcel Physics numbers, London, 1970-2000



(Note, data for 1975 by interpolation)

The declines are very large over the twenty-year period 1980 to 2000. For the consecutive five-year periods between 1980 and 2000 the declines were: 4.5%, 15%, 28% and 20%. It is clear that the discipline is in serious trouble at the Secondary level. The consequences for Tertiary institutions are alarming - another example of a supply side problem.

Edexcel also holds excellent records in Mathematics, but changes to syllabi and curricula make them effectively impossible to use as a measure of change

M. Quinlan, Senior Technical Support Officer at Edexcel, comments that under traditional schemes a candidate sits for an exam and "receives a result for better or worse". However since the introduction in 1993 of modular syllabi a "candidate may decline to receive an award". Clearly such a system affects the apparent number of candidates. Quinlan also comments that "The rules governing the administration seem to change year on year". (Quinlan 1997 pers. com.)

It must be noted that the data from Edexcel is not the data for the whole of the United Kingdom, there being other examination authorities. Nevertheless the Physics enrolment trends shown in Table 1.11 and Figure 1.5 are a legitimate indication of the trends over the whole population.

1.4 Enrolment trends-Australia-Secondary.

Since University Departments are dependent on Upper Secondary Education in that the vast majority of First Year students come from that source, the numbers studying Physics in the last year of Secondary schooling are critical for the future at Tertiary level. De Laeter and Dekkers (1996) reported on the decline in Physics numbers in all states and ACT for the period 1992 - 95, as shown in Table 1.12.

Table 1.12: Australian enrolments, Physics/Chemistry. 1992-1995.

	1992			1993			1994			1995		
	M	F	TOT	M	F	TOT	M	F	TOT	M	F	TOT
Physics	28380	11302	39682	26131	10390	36526	23560	9222	32782	22208	8985	31193
Chemistry	24118	19574	43692	22378	18929	41307	20280	27833	38113	18930	17223	36153

(de Laeter and Dekkers, 1996)

After a period in which enrolments in both subjects had risen, the short period 1992 to 1995 saw significant declines. Total enrolments in Physics declined by 21.4 %. Male participation declined by 21.75%, Female by 20.5%. For the same period total enrolments in Chemistry declined by 17.3%. Male participation declined by 21.5%, Females by 12.0%

Dekkers and de Laeter (2000) examined Australian Secondary enrolments in the period 1980 to 1998. That analysis showed that '…..physics reached a peak in popularity in 1992, but then suffered a decline in enrolments until 1996. However, in the last three years (to 1998) enrolments…have increased, and it will be interesting to observe if this trend continues in the future'. As will be seen in Tables 1.14, 1.15 and 1.21 the improving trend did not continue.

Whilst not a problem in demonstrating trends in enrolment, the fact that there may be multiple definitions of a 'Physics student' is a difficulty in absolute terms. In Queensland, for example, figures (all valid) exist for:

- students who completed Secondary Education and did any Physics in the last two years,
- students who were doing Physics in last year at the time of school census taking (normally February),
- students who completed all four semesters of Physics.

The difference between the various numbers can be considerable, varying from 6455 to 5484 in 1996. It is reasonable to assume that only members of the last group are likely to be potential candidates for tertiary level Physics. Consequently the size of the cohort of students 'available to the embattled university departments may be even smaller than that indicated by de Laeter and Dekkers, or any other data set that may include students that have not studied a subject to the end of their final year at school.

Considering only those students who studied physics to the end of their final year at school, the changes on a State/Territory basis for the period 1992-1996 are as shown in Table 1.13.

Table 1.13: Participation change 1992-1996 as a percentage of 1992 numbers.

State/Territory	Change
New South Wales	Decrease 28%
Victoria	Decrease 18%
Queensland	Increase 1%
South Australia	Decrease 11%
Western Australia	Decrease 10%
Tasmania	Decrease 13%
ACT	Decrease 7%
Northern Territory	Variable, holding

(Boards of Study)

Over the last two years of the period a levelling out is observable. That levelling off is emphasised by Victorian data for the subsequent years 1997 to 2001, as shown in Table 1.14.

Table 1.14: Physics enrolments, Victoria, 1997 to 2001.

	1997	1998	1999	2000	2001
Male number	5717	5673	5731	5485	5558
Percent Male	73	74	73	74	74
Female number	2142	2036	2109	1934	1973
Percent Female	27	26	27	26	26
Total number	7859	7709	7840	7419	7531

(Victorian Curriculum and Assessment Authority, 2002)

Although a slight decline is evident, it is only 4% over the period. The Female/male participation ratio is effectively a constant over time. A similar pattern is observable in the data for NSW as shown in Table 1.15.

Table 1.15: Physics enrolments, New South Wales, 1997- 2001.

	1997	1998	1999	2000	2001
Male number	6742	6759	6689	6518	6580
Percent Male	74	73	73	71	74
Female number	2407	2551	2471	2603	2365
Percent Female	26	27	27	29	26
Total	9149	9310	9160	9121	8945

(NSW Board of Studies)

In their earlier (1996) analysis of Secondary participation, de Laeter and Deckers commented on the slight improvement in female participation in Physics (from 28.5 to 28.8%). However, as the brief analysis of the data shown in Table 1.12 showed, both male and female enrolments declined dramatically. The slight increase in female enrolments as a percentage of total enrolments is solely a consequence of the fact that the males' decline was even sharper than that for females.

In Chemistry the situation was rather different. Although female participation declined, the decline in male participation was much steeper. It is notable that by 1995 the participation rates of females nearly equalled that of the males.

An examination of the numbers for female/male participation rate changes for the slightly longer period 1992 to 1996 for those State/Territories where such data is available show some interesting trends as shown in Table 1.16.

Table 1.16: Physics Female/Male comparison, 1992-1996.

State	Qld.	W.A.	Tasmania	N.S.W.	A.C.T.	Victoria
Female	+9%	-9%	+1%	-32%	+9%	-20%
Male	-2.5%	-19%	-19%	-27%	-16%	-17%

(Boards of Study)

A broader view of the situation in the Natural Sciences is given by a consideration of the Physics data in conjunction with equivalent data for Chemistry, as shown in Table 1.17.

Table 1.17: Chemistry Female/Male comparison.

State	Qld.	W.A.	Tasmania	N.S.W.	A.C.T.	Victoria
Female	+16%	-5%	+10%	-25%	+1%	-10%
Male	-5%	-24%	-14%	-32%	-7%	-19%

(Boards of Study)

Of the 12 female/male comparisons the female trends are relatively higher in 10. Although the fact that the Physics female numbers are from a low base may be used as an extenuating argument for the relatively poor male enrolment trends in Physics, the same cannot be said for Chemistry. In all regions the female participation in Chemistry is comparable to male and in some regions it predominates. A clear example of that predominance is evident in the data for Victorian enrolments for the years 2000 and 2001. In 2001, 3570 males and 4513 females took Chemistry, i.e. 44% males, 56% females. In 2000, 3706 males enrolled and 4384 females, i.e.46% males, 54% females. That such female predominance is not consistent across Australia is illustrated by recent enrolments in Chemistry in New South Wales. In 2000, 5303 males and 4898 females were enrolled i.e. 52% male, 48% female. In 2001 the enrolments were 4740 males and 4277 females i.e. 53% males and 47% females. The 10% decline in participation in Chemistry affected both males and females.

It is perhaps noteworthy that in Queensland at least female Physics students are 'cleverer' than their male counterparts. The system in Queensland that produces the 'Overall Position' (OP) the Queensland version of the 'Equivalent National Tertiary Entrance Rank (ENTER) ranking system requires all students to sit for a standardising test (also under a variety of names over the years). Invariably the cohort of girls taking Physics score more highly than the cohort of boys taking Physics in the same year. A similar pattern is observable in the ACT. Some implications of the relative strengths of the female/male cohorts are analysed in Chapter 5.

Because the physical sciences and Engineering depend on a sound background of Mathematics, any examination of participation rates in the physical sciences needs to be supported by an examination of participation in rigorous Mathematics. The link between Mathematical skills and Engineering and problems consequent to weak Mathematics was examined by a Hearne Scientific Software report (2000) that stated that '52% of Australian Engineering lecturers feel that mathematics skills in engineering undergraduates have worsened over the last ten years'. The report also claimed that 'the level of mathematics and science taught in high school has deteriorated significantly'.

It is therefore noteworthy that contemporaneously with the decline in Secondary Physics enrolments noted by de Laeter and Dekkers (1996), by Dekkers and de Laeter (2001) and in this chapter, there has been a significant decline in the number taking the most rigorous Mathematics. Although the exact situation is somewhat murky due to syllabus variations in some States, the following examples shown in Table 1.18 are accurate enough to be both highly significant and of concern.

Table 1.18: Changes in participation in the most rigorous Mathematics.

State/Territory	Change
New South Wales	Decrease 49%
Queensland	Decrease 24%
Tasmania	Decrease 26%
South Australia	Decrease 10%
Northern Territory	Decrease 26%
Western Australia	Decrease 19%

(Boards of Study)

The decline in participation in rigorous Maths is examined in Dekkers and Malone (2000). That examination showed that when the Maths subjects in the various States were sub divided into 'High' 'Intermediate' and 'Low' levels of difficulty the enrolments in 'High' difficulty Maths declined from nearly 40000 to marginally over 30000 from 1990 to 1999.

For Queensland, Dekkers and Malone put the subject Maths C in the 'High' group. Maths C is described as the 'most rigorous' in this thesis. As will be seen in Table 1.23, Maths C enrolments in Queensland continued to decline after 1999.

It seems reasonable to suppose that the decreases in Physics and Mathematics may be interconnected both being, at least in part, results of common factors.

Secondary schools, like their Tertiary counterparts can in reality only keep a course going if the numbers justify its continuation. An examination of group sizes for Maths C, the most rigorous Mathematics in Queensland, shows a large number of schools with very small class sizes. An obvious risk is of a type of positive feedback: few students --- eventual dropping of the subject from a school --- even fewer students.

That type of feedback also occurs in the inter relation between Secondary and Tertiary level. University departments in Physical Science or Engineering, desperate for students, remove a subject as a pre-requisite. The Secondary students, knowing that fact, become less likely to take the subject. Why would they bother?

The consequence of abandoning pre-requisites for Engineering is addressed by Algie (1998) in a discussion about the maintenance of the professional standards in The Institute of Engineers Australia. He observes that standards of graduates in Engineering are almost certain to vary between universities under practices being adopted in the nineties. If the basics of Physics, Chemistry and Mathematics are not prescribed at Secondary level, then the Tertiary sector needs to be particularly alert to scientific and technological standards. Algie observes that it is increasingly being suggested that professionally oriented engineering should become an essentially postgraduate course, as is the case with Medicine.

1.5 Queensland.

This thesis focuses primarily on Queensland, 'the Smart State' (Beattie 2001). Hence it is necessary to examine participation in Physics, Chemistry and Mathematics in that State in more detail.

1.5.1 Tertiary.

Enrolments in Third Year Physics in Queensland were examined in de Laeter, Jennings and Putt (2000) as a part of an overall consideration of Physics in Australasia as a whole. Third Year Physics enrolments in Queensland for the period 1994 to1999 were as shown in Table 1.19.

Table 1.19: Third Year Physics enrolments in Queensland, 1994-1999.

1994			1995			1996		
Male	Female	Total	Male	Female	Total	Male	Female	Total
58	16	74	57	16	73	45	15	60

1997			1998			1999		
Male	Female	Total	Male	Female	Total	Male	Female	Total
40	20	60	47	12	59	47	14	61

(de Laeter et al 2000)

1.5.2 Secondary.

Analysis of available data for enrolments in Secondary Physics is made somewhat more difficult by the fact the enrolment numbers available for the years 1981 to 1994 are of information 'supplied by schools to the Board in March'. Very precise data giving the numbers of students who completed all

four semesters is available for the period 1992 to 2001. Both data sets are consistent internally and are hence suitable for showing trends, but they are not mutually consistent. There is an overlap of three years during which period both sets of data are available. Table 1.20 shows the total number of students (female and male) for the period 1981 to 1994 inclusive. Also shown are the numbers of schools offering Physics and the mean number of students in the schools.

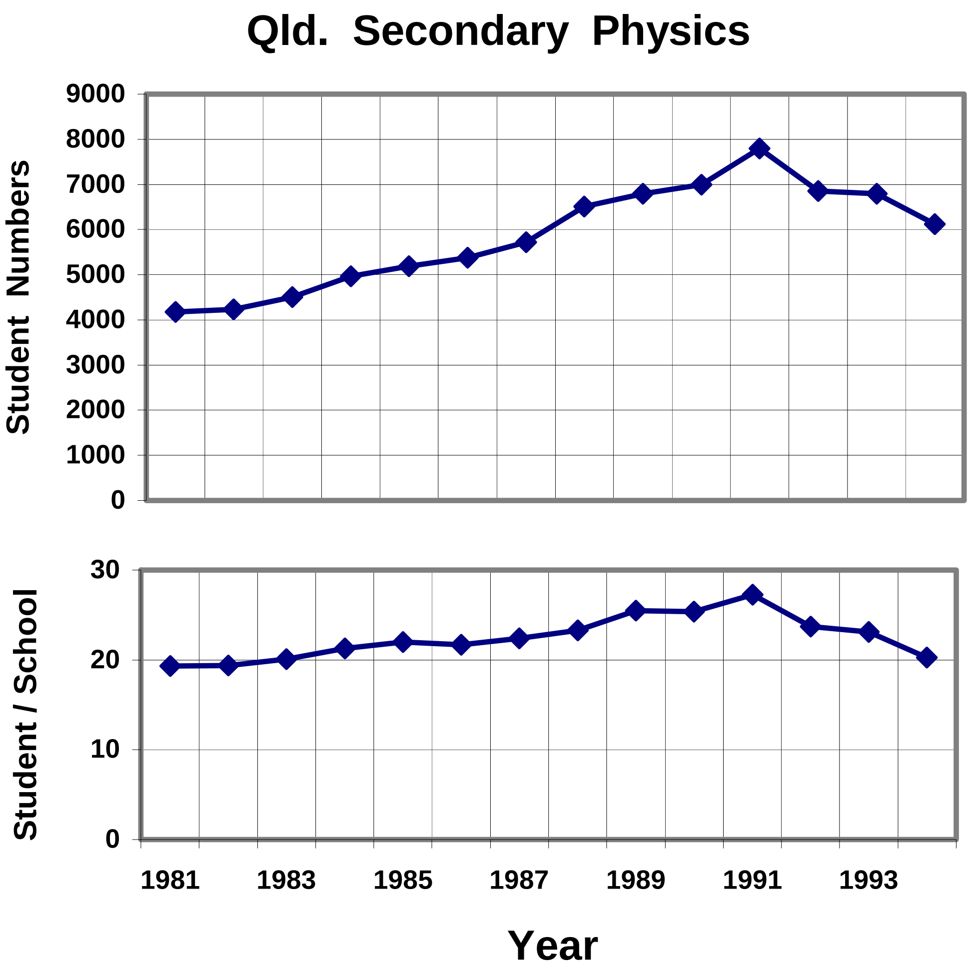
Table 1.20: Physics enrolments, number of schools and mean enrolment per school. Queensland 1981-1994.

	1981	1982	1983	1984	1985	1986	1987
Student number	4177	4234	4508	4971	5188	5374	5722
School number	216	218	224	233	236	248	255
Students/school	19.3	19.4	20.1	21.3	22.0	21.7	22.4
	1988	1989	1990	1991	1992	1993	1994
Student number	6512	6789	6998	7793	6850	6800	6118
School number	280	267	276	285	290	294	302
Students/school	23.3	25.5	25.4	27.3	23.7	23.1	20.3

(QBSSSS data)

The data trends are illustrated for both student number and for number of students per school by a consideration of the charts in Figure 1.6

Figure 1.6: Physics enrolments and student number per school, Queensland, 1981-1994.



Three things are clear: firstly there was a large rise between 1981 and 1991, secondly a sharp decline in the short period 1991 to 1994 and thirdly the students numbers per school had reverted to the levels of the 1980s.

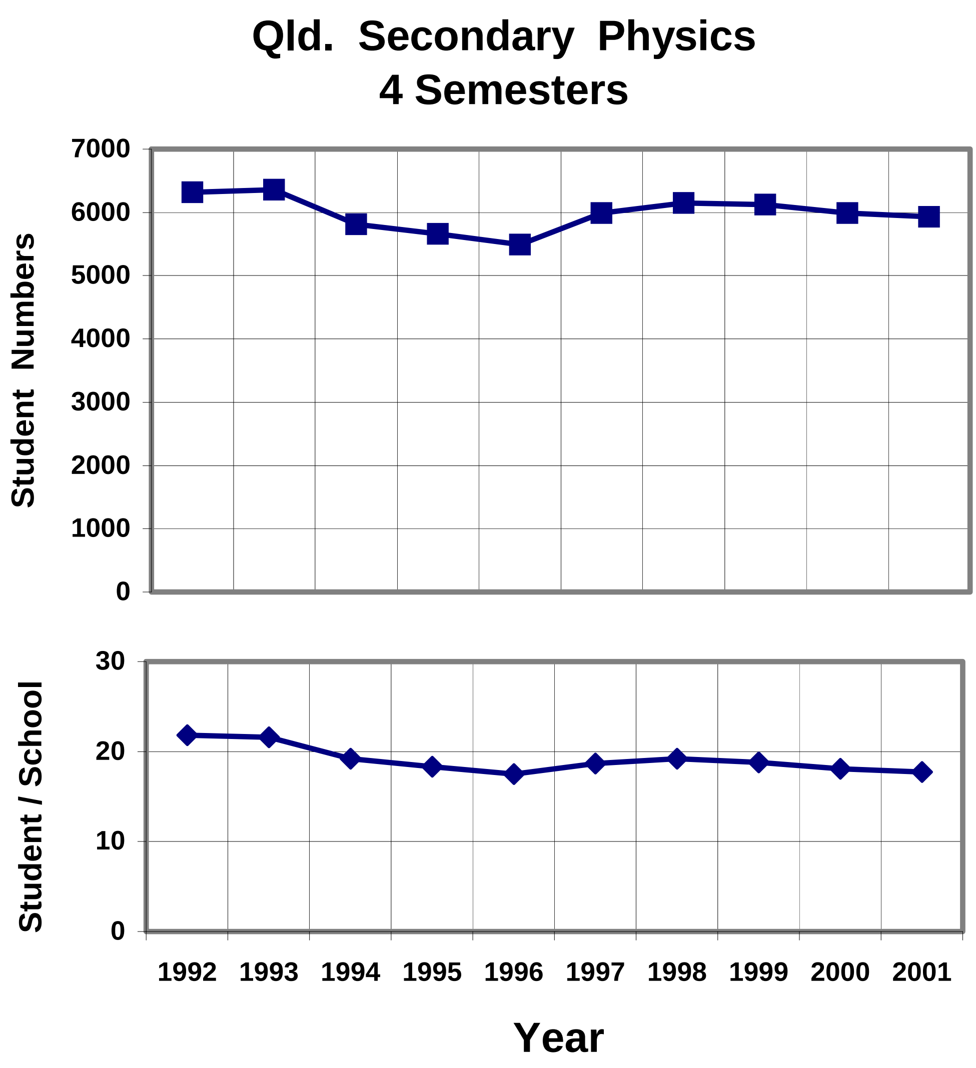
Table 1.21 and Figure 1.7 show the numbers of students who completed all four semesters of Physics. It is reasonable to suppose that only students who studied Physics up to the end of Year 12 are a part of any pool of students from which Tertiary Physics courses can draw.

Table 1.21: Physics student enrolments (4 semesters), number of schools and mean enrolment per school. Queensland, 1992-2001.

	1992	1993	1994	1995	1996
Student number	6317	6358	5813	5662	5489
School number	290	294	302	N/A	313
Students/School	21.8	21.6	19.2		17.5
	1997	1998	1999	2000	2001
Student number	5989	6153	6127	5987	5932
School number	320	320	326	331	336
Students/school	18.7	19.2	18.8	18.1	17.7

(QBSSSS data)

Figure 1.7: Physics student numbers (4 semesters) and number /school.



During the period 1992 to 2001 there is an evident uneven but substantial decline during 1992 to 1996(13%), followed by a period of some recovery between 1996 and 2001(8%). The two data sets shown in Tables 1.21 and 1.22 overlap for the years 1992 to 1995. Both show enrolment declines in that period, those declines being 11% and 8% respectively. Using data from both data sets it is reasonable to suppose that the decline from the 1991 peak to 2001 was approximately 15%.

The mean number of students per school is consistently below that pertaining twenty years earlier. During the whole twenty-year period the number of schools offering the subject has increased from 216 to 341. That rise has been caused by a number of factors. Firstly the rise in the total population. Secondly, in more rural areas, the desire of parents for the existence of a school to year 12 in every small town and thirdly an increase in the number of non-government schools even in areas that were adequately catered for by previously existing schools. A rise in the number of schools must inevitably result in the numbers per school in the 'minority' subjects decreasing. The mean number of Physics students declined to 17.4 by 2001. Consequently there must be a significant number of schools that struggle to maintain a Physics class at all.

Whilst the overall numbers do not indicate a threat to the study of the subject at Secondary level-although it may in individual schools-the poor numbers do constitute a problem for those sections of Tertiary institutions that depend on secondary Physics i.e. Physics and Engineering.

Physics is closely entwined with rigorous Mathematics. The most advanced Mathematics subject in Years 11 and 12 in Queensland is Maths C. As for Physics the data for the period 1981 to 2001 needs to be divided into the two periods 1981 to 1994 and 1992 to 2001. Tables 1.22 and 1.23 show the total number of students who completed Year 12 Maths C also for those periods. The tables also give the number of schools involved and the mean number of students per school. Figures 1.8 and 1.9 illustrate that data graphically.

Table 1.22: Maths C enrolments, number of schools and mean enrolment per school. Queensland 1981-1994.

	1981	1982	1983	1984	1985	1986	1987
Student number	3399	3576	3868	4179	4496	4637	4628
School number	210	217	220	219	234	247	256
Students/school	16.2	16.5	17.6	19.1	19.2	18.8	18.1
	1988	1989	1990	1991	1992	1993	1994
Student number	5243	5420	5221	5692	4492	4448	3956
School number	278	284	289	299	284	288	295
Students/school	18.9	19.1	18.1	19.0	15.8	15.4	13.4

(QBSSSS data)

Figure 1.8: Maths C student numbers and number per school, 1981-1994.

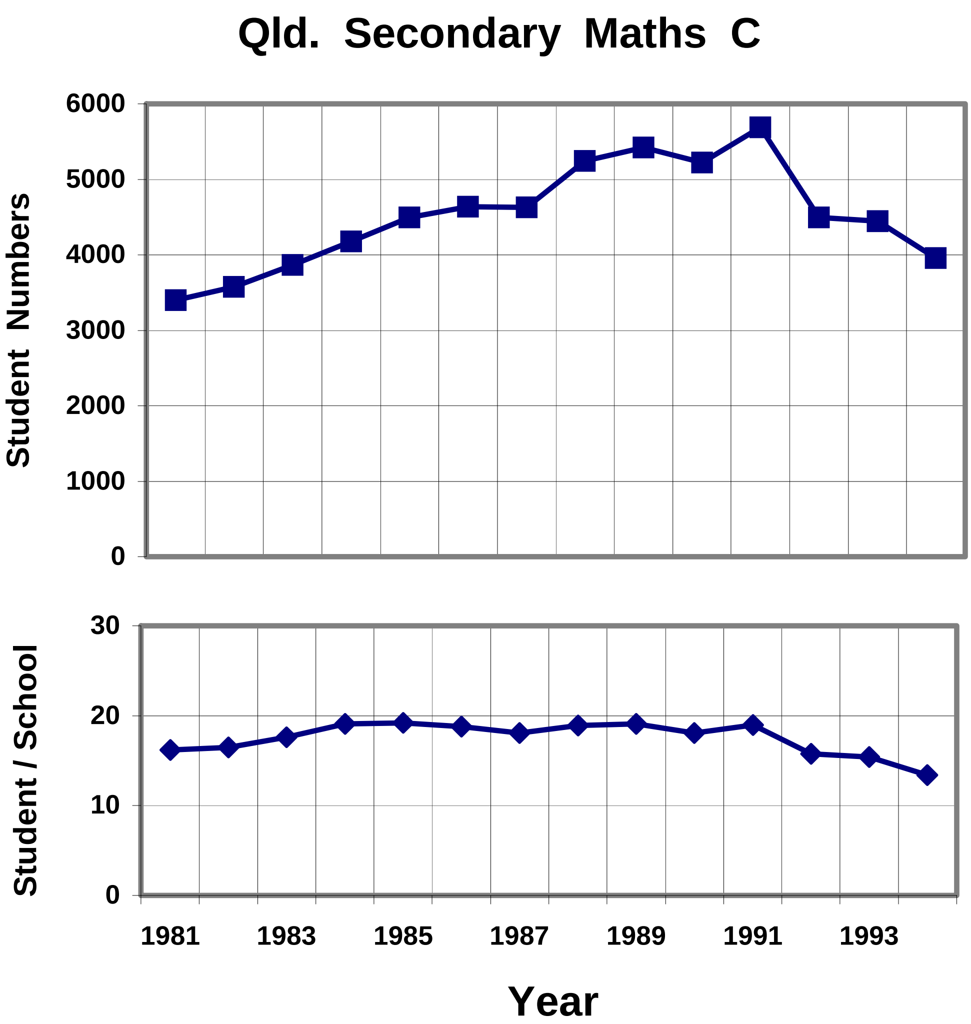
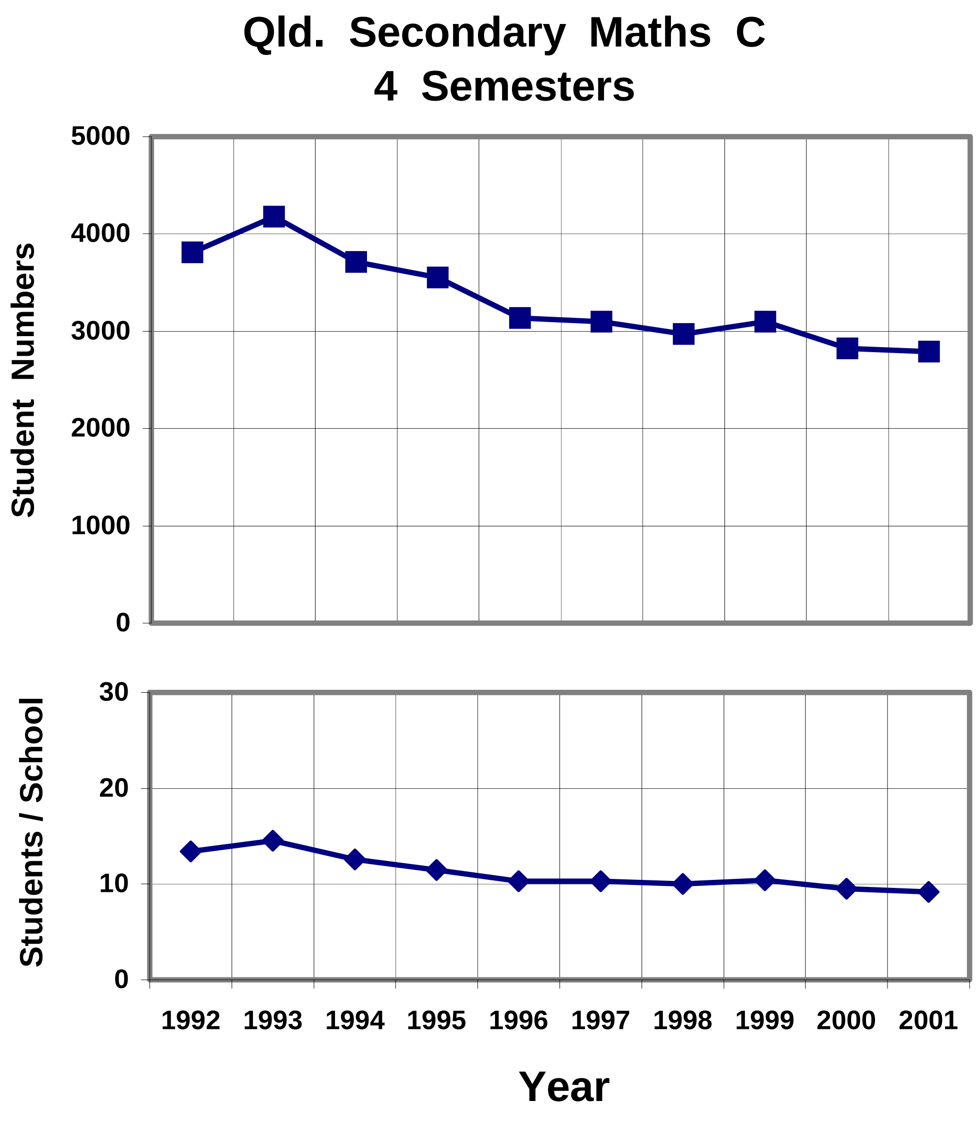


Table 1.23: Maths C student enrolments (4semesters), number of schools and mean enrolment per school. Queensland 1992-2001.

	1992	1993	1994	1995	1996
Student number	3813	4176	3712	3553	3134
School number	284	288	295	N/A	303
Students/school	13.4	14.5	12.6		10.3
	1997	1998	1999	2000	2001
Student number	3100	2971	3098	2824	2788
School number	301	297	299	298	302
Student/school	10.3	10.0	10.4	9.5	9.2

(QBSSSS data)

Figure 1.9: Maths C student numbers (4 semesters) and number/school,



The peak enrolment of 5692 occurred in 1991, the same year in which the Physics enrolment was also at it's highest level of 7793. That fact is perhaps an illustration of a relationship between Physics and rigorous Mathematics. In the period 1991 to 2001 Maths C enrolments declined by 51%, a reduction that, by itself, is probably sufficient to threaten the subject per se. Even more threatening to the survival of the subject is the fact that the mean student per school number is only 9.2. That decline has occurred because of two facts: firstly the number of students for the years 1997 to 2001 is down to a level below that in 1981, and secondly the 48% increase in the number of schools involved. It is very hard for a school, working within strict pupil/teacher ratios to continue to offer a subject for so few students. There is a very high risk that within a few years some, perhaps many, schools will stop offering the subject. The majority of such schools will be those with total enrolments that are themselves small. At that point a number of students are going to be prevented from taking the most rigorous form of Mathematics, a consequence that flies in the face of the ideal of providing a comprehensive education for all.

When the enrolment data is subdivided Female/ Male for the years 1997 to 2001 the outcome is as shown in Table 1.24.

Table 1.24: Physics enrolments by gender, Queensland 1997-2001.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Female number	1765	1878	1681	1718	1695	1865	1899	1736	1722	1708
Female %	28	30	29	30	31	31	31	28	29	29
Male number	4552	4480	4132	3944	3794	4124	4254	4391	4265	4224
Male %	72	70	71	70	69	69	69	72	71	71

(QBSSSS data)

Female participation as a percentage of total enrolments has shown very little change. The most important change, especially from a Tertiary entry viewpoint is the decline in male enrolment in absolute terms. Male participation has dropped by 328, female by 58. Hence the male decline is responsible for 85% of the overall decline.

A similar subdivision by gender for Maths C is shown in Table 1.25.

Table 1.25: Maths C enrolments by gender, Queensland 1981-2001.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Female number	1050	1216	1039	1036	941	928	875	943	882	803
Female %	28	29	28	29	30	30	29	30	31	29
Male number	2763	2960	2673	2517	2193	2172	2096	2155	1942	1985
Male %	72	71	72	71	70	70	71	70	69	71

(QBSSSS data)

Although the Female/Male participation ratio has remained almost constant, that fact has to be seen in the context of an overall decline. There is no indication that the decline is slowing much if at all. In absolute terms male decline was 778 (28%), female numbers dropped by 247 (24%). As was the case for Physics, male enrolment decline was by far the biggest contributor to total decline, being 76% of the total.

In Queensland, if a student takes Maths B, she/he is allowed to study Maths C concurrently. In that sense Maths B is a measure of the number of students in any given year that could have taken Maths C if they had so chosen. Table 1.26 and Figure 1.10 show the numbers taking Maths B, the numbers taking Maths C and the percentage of Maths B students taking Maths C for the years 1992 to 2001.

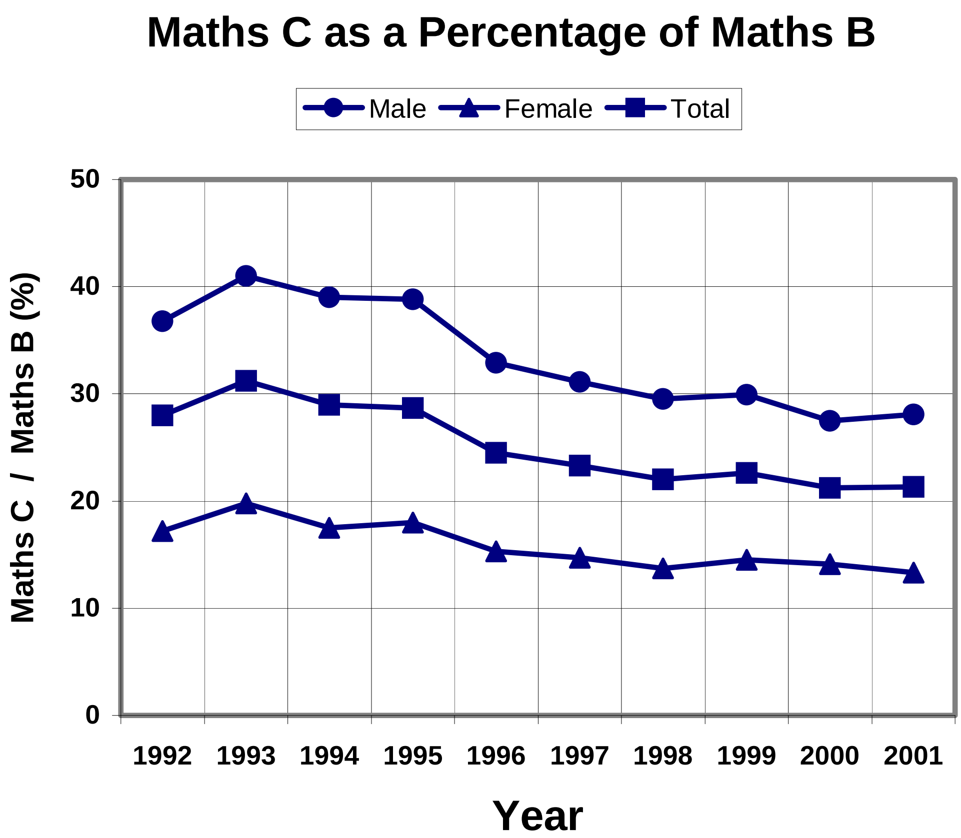
Table 1.26: Enrolments Maths B, Maths C; Maths C as a percentage of Maths B, Queensland, 1992-2001.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Male Maths B	7501	7222	6846	6580	6671	6995	7102	7200	7071	7072
Male Maths C	2763	2960	2673	2517	2193	2172	2096	2155	1942	1985
M.C as % M.B (Male)	36.8	41.0	39.0	38.3	32.9	31.1	29.5	29.9	27.5	28.1
Female Maths B	6120	6155	5936	5756	6142	6314	6393	6482	6254	6028
Female Maths C	1050	1216	1039	1036	941	928	875	943	882	803
M.C as % M.B (Fem)	17.2	19.8	17.5	18.0	15.3	14.7	13.7	14.5	14.1	13.3
M.C as % M.B (Total)	28.0	31.2	29.0	28.7	24.5	23.3	22.0	22.6	21.2	21.3

(QBSSSS data)

Figure 1.10: Participation numbers in Maths C as a percentage of numbers enrolled in

Maths B.



The percentage of Males who by, taking Maths B, were 'qualified' to take Maths C has declined by 24%. For Females that decline was 23%. In total the percentage of 'qualified' students who took Maths C has dropped by 24%.

Table 1.27 shows the historical enrolment data for Chemistry. Where the detailed female-male data is available, those numbers are included.

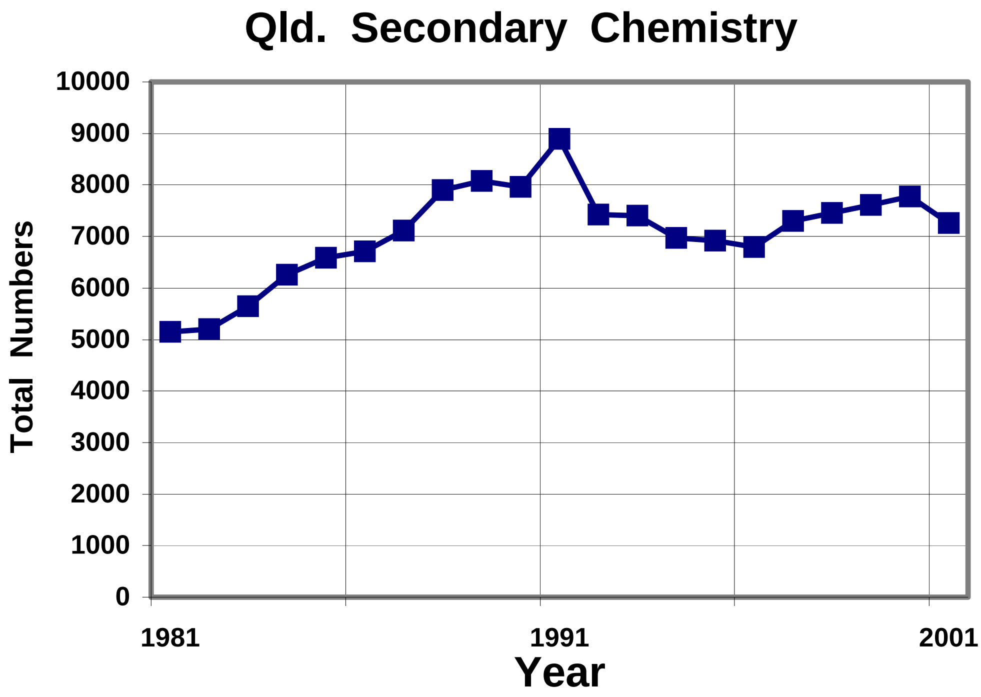
Table 1.27: Chemistry enrolments, Queensland, 1981-2001.

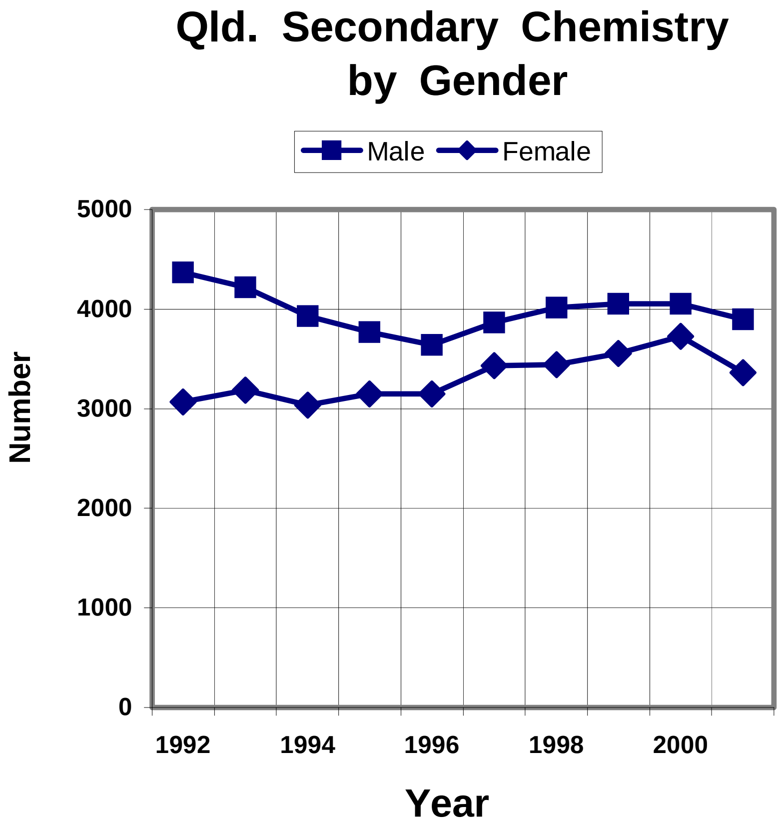
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Number-Male											
Number-Female											
Total	5147	5200	5645	6259	6588	6716	7117	7898	8080	7962	8892
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Number-Male	4358	4217	3932	3770	3640	3866	4015	4055	4053	3898	
Number-Female	3068	3183	3036	3148	3150	3430	3441	3552	3724	3362	
Total	7426	7400	6968	6918	6790	7296	7456	7607	7777	7260	

(QBSSSS data)

Figure 1.11 illustrates those total enrolment trends and sub-division by gender for the years for which that data is available.

Figure 1.11: Total and Female/Male participation trends in Chemistry





The data for Chemistry is very different from that for Physics, and different from that for Maths C. For the period 1992 to 2001 total enrolments are relatively stable. Those totals disguise a major change in Female/Male participation. Unlike Physics and Maths C where both Female and Male participation levels declined, for Chemistry only the Males declined. That decline was 11%. Over the same period Female participation increased by nearly 10%.

From all viewpoints except Male participation secondary school Chemistry is in good condition. The overall numbers provide a sound source of people who are suitable for entry into tertiary study in Chemistry or Chemical Engineering and the number of students per school is high enough to ensure that students from almost all schools have the opportunity to study the subject.

1.6 Enrolment discussion

Physics as a discipline has endured a major downturn in the last decade or so. That downturn has occurred in most if not all 'Western' countries at Tertiary level. There is evidence that the numbers studying Physics at Secondary level are also falling.

In Australia there is irrefutable evidence of a severe decline in Tertiary participation in Physics beyond First year, but an improvement at First Year albeit at a level that is probably superficial. Secondary enrolments have decreased throughout the nation.

In Queensland all University Physics Departments have enrolment numbers that are very low indeed. Secondary enrolments have declined, so providing a more restricted cohort of qualified students from which Tertiary Physics and Engineering departments can draw.

Concurrent with the falls in Physics enrolments has been a severe decline in participation in the 'hardest' Mathematics at Secondary level. That decline is evident throughout Australia. In Queensland the enrolments in Maths C - the 'hardest' Maths - have declined to the point where the existence of the subject is under real threat, especially in smaller schools.

Trends in Secondary enrolments are different for females and males. Because the greater part of the students enrolled in Physics and rigorous Mathematics has historically been male, the decline in male enrolment is especially damaging, in particular to relevant Tertiary departments. That problem does not exist in Chemistry where, in Queensland, for example, the rise in female participation almost compensates for the decline in male participation.

In the language of Economics there are two possible influences on enrolments in Physics and rigorous Maths: demand side and supply side. It is probable that a real and/or perceived lack of employment affects student decision-making. The enrolment data from Canada tends to support a thesis that demand side factors are highly significant. It is also probable that when students make decisions to take or not to take the subjects that they are affected by their previous experiences and developed attitudes. Both the American and German experiences tends to support that supply side issues can also be influential. The lack of qualified Statistics graduates in Australia-that is inadequate to meet the demand-also indicates that supply side factors are relevant. It is hard to envisage any actions that may be taken by and within governmental and educational institutions that will change the demand side of the equation. There may well be governmental and educational actions that might affect the supply side. Hence there is a greater likelihood that an examination of the supply side might produce results that could point the way towards useful actions that *could* be taken by governments and education institutions. Consequently the work reported in this thesis concentrates on supply side issues mainly in Queensland.

CHAPTER 2

THE IMPORTANCE OF LOWER SECONDARY SCHOOLING AND THE CONDITION OF MATHEMATICS AND PHYSICS IN QUEENSLAND

CHAPTER 2

2.1 Introduction.

The declines in participation levels in Physics and rigorous Maths in late secondary schooling and at tertiary institutions that were discussed in Chapter 1 will have multiple causes. Although many of the factors causing the changes will be from outside the formal education systems, there may be other factors that are within the systems themselves. This Chapter examines the condition of Years 8, 9, and 10 in schools in Queensland. The examination looks at three aspects. Firstly the importance of those years in terms of their long-term consequences. Secondly the legislative framework that has existed in the State, and thirdly the opinions of school Principals vis a vis the condition of Maths and Science in those years.

The critical decisions to 'drop' physics and rigorous mathematics are made by Secondary students two years prior to leaving school. Hence the reasons for their decisions must lie within the 14 – 16 year age group. It is probable that the reasons will be multiple, including difficulty, perceived irrelevance, inertia, the offering of attractive alternative subjects and previous experience. It is that previous experience that is examined in this chapter.

The intuitively reasonable proposition that educational experiences and outcomes at the lower secondary level influence upper secondary education is supported in the literature. Firstly there is evidence of an effect on the levels of participation in the various subjects. The influence of students' previous experience in Years 9 and 10 on subsequent participation in natural science was examined by Ainley (Ainley 1993). As a part of an Australian study into participation in science courses Ainley examined a number of factors which influence participation in physical science courses which were defined as conjoint study of physics and chemistry. Emphasising the importance of prior experience he concluded that '*As a generalisation, participation in a physical science course type is most strongly shaped by earlier achievement in numeracy, an interest in investigative activities and gender.*' Ainley also demonstrated that these general comments are susceptible to deeper and in the context of *fin de siecle* concern about male academic performance, more relevant analysis:- ‘Among males, the influence of earlier achievement on physical science participation is independent of, and much stronger than, socio- economic status.’

There is also evidence that lower secondary performance has an effect on outcomes at the end of secondary education. The most usual measure of the 'result' of secondary education is the Equivalent National Tertiary Entrance Rank (ENTER) result, the Queensland version of which is the Overall Position (OP). The Longitudinal Survey of Australian Youth (LSAYR 22, 2001) examined the correlation between various factors and ENTER scores as shown in Table 2.1.

Table 2.1: Correlation between ENTER score and various imput factors.

Factor	Correlation
Year 9 Lit/Num	0.5
Individual Schools	0.3
Socioeconomic	0.2
School Sector	0.15
Gender	<0.1
Region	< 0.1

(LSAYR 22. p.62)

It should be noted that each 'factor' was considered with all others held constant. Hence, in particular, the weak correlation between Gender and ENTER is to be seen in the context that all other variables, notably Year 9 Literacy/Numeracy have been 'eliminated. It is known that in Queensland male performance at OP is weaker than female performance in some parts of the distribution, notably near to, and somewhat above, the mean. (See Chapter 5). There is hence an apparent dichotomy: gender per se is not a major factor influencing OP when Year 9 Literacy/Numeracy is held constant, but males do perform somewhat more poorly than females as measured at Year 12 exit. It is a reasonable proposition that educational problems that may exist for males are to be found in their experiences prior to year 9 exit.

The relatively high correlation between ENTER score and Year 9 performance in numeracy and literacy is of prime importance. It emphasises the long-term implications of lower secondary schooling and, by implication, places a heavy responsibility on secondary schools to ensure that experiences in, and outcomes from, the lower secondary years receive a level of attention and commitment proportionate to that level of importance.

LSAYR 22 also disaggregates the Literacy/Numeracy effect on ENTER in two ways; by State and by sub-division into Numeracy alone and Literacy alone in addition to the combined effect of Literacy/Numeracy. The consequences of that disaggregation are as shown in Table 2.2.

Table 2.2: Correlation between ENTER and Year 9 Literacy/Numeracy by State.

State/Nationwide	NSW	Victoria	Qld	S.A.	Australia
Literacy	0.37	0.50	0.51	0.29	0.45
Numeracy	0.38	0.54	0.54	0.32	0.47
Literacy/Numeracy	0.47	0.62	0.62	0.38	0.56

(LSAYR 22. p.15)

The correlation between numeracy and ENTER score is higher than that between literacy and ENTER in all jurisdictions. LSAYR 22 speculated that this finding may be reflection of a '*greater weight applied to performances in Maths and Science'* (LSAYR 22 p.57) in the calculation of ENTER scores. The Queensland O.P. system makes no such 'weighting'. The alternative suggestion put forward is that '*numeracy skills are a better indicator of general analytical skills'*. (LSAYR 22 p.57)

Some of the correlations in Table 2.1 are lower than current conventional wisdom might have expected. LSAYR 22 emphasises the relatively low effects of some inputs on ENTER scores:

'Overall, gender differences in tertiary entrance performance are small compared to socieconomic sector, school sector and especially literacy and numeracy achievement. ---while female students in NSW scored significantly higher than males, in other States the differences were smaller and not statistically significant'. (LSAYR 22 p.58)

'Socioeconomic background has only a moderate relationship with tertiary entrance performance. This is contrary to the view that educational systems are simply a mechanism that strongly reproduces socioeconomic inequality between generations.' (LSAYR 22 p.58)

LSAYR 22 considered the possibility that the Year 9 results themselves are strongly related to socioeconomic background, and concluded that:

'-----at most 9% of the variation in literacy and numeracy is attributable to socioeconomic background'. (LSAYR 22 p.92 note 33)

There is confirming evidence of the importance of earlier education from both UK and US. Alison Wolf, professor of Education at the University of London's Institute of Education, repeatedly emphasises the importance of Secondary Education (Wolf 2002[1]). One of the outcomes of a UK longitudinal study that followed students born in 1958 and 1970 demonstrated that when all other variables including formal education are controlled, basic skills showed up as vital determinants of a person's future life. '(The study) underscores the enormous importance, in modern societies, of basic academic skills. Poor literacy and poor numeracy - especially the latter - have a devastating effect on people's chances of well-paid and stable employment.' (Wolf 2002[1] p.34) Wolf also reports on another longitudinal survey in the US for students who were in their final year of high school in 1972 and 1980. It examined 'whether (language and maths) skills, as measured by these tests, affect future earnings over and above the effects of any formal qualifications ……. It seems that they do''. Furthermore 'it again seems to be mathematical skills which matter most'. (Wolf 2002[1] p. 36).

The influence of middle schooling on participation rates, on outcomes and on later life is therefore well documented. Consequently any analysis of the causes of decline in physics and rigorous maths participation in Years 11 & 12 and hence at tertiary level must include an examination of student experiences in Years 9 & 10. Those experiences are determined by a complexity of factors including curriculum, school programmes, oversight of programmes, internal school organisation, teaching methods and teacher competence. Overarching the structures is the legislative framework. Since each jurisdiction, in Australia or elsewhere, has its own structure of education it is not possible to examine previous experience globally. This chapter is an attempt to examine the current position in Queensland only. However where any degree of commonality exists between the structures in Queensland and another jurisdiction this study may have wider implications.

2.2 Assessment structures in Queensland.

The Queensland Board of Senior Secondary School Studies (QBSSSS) had oversight of all syllabi in all schools at the Years 11 & 12 level. It awarded levels of achievement for each 'Board' subject, maintaining a satisfactory level of 'comparability' of student outcomes using regular teacher panel meetings at district and state levels. In the context of assessment/moderation all schools, Government or non-Government, operated under the umbrella of, and were responsible to the BOSSSS. The 'Overall Position' (O.P.) used for Tertiary entry was obtained using a 'skills test' to calibrate the individual subject results. The situation in Years 11 & 12, overseen by the highly professional BOSSSS but teacher driven, was both transparent and adequate.

In addition to the intentional moderation/assessment outcomes of panel meetings there was an important unintentional in-service outcome. The spending of a number of days each year with peer teachers reviewing other schools' student work is an highly educational, albeit sometimes chastening, experience.

At its inception in the 1970s the Board of Secondary School Studies also had responsibility for Years 9 and 10. However since 1988 QBSSSS became effectively irrelevant to the critical middle years 9 & 10. It is evident that there was, and still is, a lack of knowledge, information or data with respect to Years 9 & 10. In response to a request for hard data to the Queensland Minister for Education, Senior Policy Advisor Eltham stated that:

"*Since 1987, there has been no legislative process to ensure schools complied with syllabus requirements. Technically, accredited school programmes are still being followed- -. The newly formed Queensland Schools Curriculum Council does not have accrediting responsibility ….. QSCC …. has determined that matters associated with implementation are the responsibility* of *schools and school systems.*

Schools and their systems will determine time allocations. Education Queensland is establishing a number of processes, including ' teacher outcomes' and processes associated with schools' annual reports that will contribute to comparability of education programs in state schools. Non government schools will retain their own independence." (Eltham 1998 pers.com.)

Evidently Education Queensland does not know what syllabuses are actually being followed, the time spent, school internal organisation or outcomes to year 10.

When, in 1988, the Queensland Parliament abolished the Board of Secondary School Studies that had oversight and responsibility for all secondary assessment and replaced it with the Board of Senior Secondary School Studies responsible for Years 11 and 12 only, the other organisation which might have held data at year 9/10 levels became irrelevant.

2.3 The legislation of 1988.

Introducing the Bill, Hon. B. Littleproud M.L.A. Condamine, Minister for Education, Youth and Sport (Qld Parliamentary Debates) stated that when the Board of Secondary Schools Studies came into existence in the early 1970's the Junior Certificate (at Year 10 exit) *'held relevance for the majority of students and employers, as Year 10 was the main exit point'*. Pointing out that by 1988 progression rates to Year 12 had increased to over 80% he asserted that Junior was not a major exit certificate and that hence little oversight was required. The new Board of Senior Secondary School Studies had little authority at the 8/9/10 level, the intention being that it would *'maintain a limited interim role in relation to the Junior Certificate'* (Parliamentary Debates, 1988) but with scant resources such a 'role' was nominal. A few years later the Junior Certificate was abolished. It had by then become virtually meaningless.

In the Parliamentary debate Braddy, M.L.A. Rockhampton, and Sherrin, M.L.A. Mansfield, mentioned valuable in-service aspects of the previous arrangements, suggesting the possibility that the new legislation might endanger teacher involvement in the assessment and moderation process with a consequent reduction of in-service training. (Parliamentary Debates 1988)

L.Shuntner, formerly President of the Queensland Teachers Union, a former acting school Principal and long time member of the Board of Secondary School Studies, then member for Mount Coot-tha, stated that "*major difficulties will occur at the levels* o*f Years 8, 9 & 10.*" He also suggested that even those who continued on to Years 11 and 12 might want "*a statement that has some status and a degree of moderation applied to it that does not apply, or is seen not to apply, to certificates awarded without the imprimatur* o*f the BOSSS.*" (Parliamentary Debates 1988) It should be noted that all parties gave general support to the bill. Neither in 1988 or since has the Board been the subject of simplistic party political dispute. No consideration was given in the debate to the potential for an incremental divergence between government and non-government schools. Apart from Shuntner's comment no consideration was given to students being provided with data that had validity in a state-wide context. Hence students and their parents were expected to make their Year 11 subject selections partly on the basis of data which may have had little validity as a predictor for success in the State wide BOSSSS standardised subjects in Year 11.

Since the BOSSSS is not involved in Years 9 & 10 and as Eltham's comments indicate that Education Queensland (the government department of Education) hold no real data, it became necessary to obtain data and opinion directly from the schools themselves. To that end a survey of Secondary school Principals was carried out. (see Appendices 1 and 2).

2.4 Method of survey.

For the survey of principals' opinions to have any validity, two issues had to be considered. Firstly, the sheer geographical size of the state (and hence the large number of education 'regions'); and secondly the fact that secondary schools are divided into Secondary Government (SGOV), Secondary Catholic (SCAT) and Secondary Independent (SIND). The response had to be greater than thirty and preferably substantially more than thirty if there was to be adequate coverage of region and school type. A further potential problem was an understandable fear by respondents to be critical of the system, in particular of their employers.

The approach taken was that one hundred Secondary school principals were selected at random. A minimum of two schools came from each education region from each of the groups secondary government (SGOV), secondary catholic (SCAT) and secondary independent (SIND). Hence although principals were to be asked in which region they were and their school 'type', it would still be impossible to know the exact source of information, thus ensuring anonymity. The survey (Appendix 1, part B q.v.) was supported by a covering letter (Appendix 1, part A. q.v.). That emphasised the fact that they, and only they, held useful information and opinion about the condition of Years 8/9 and 10 and the enrolment problems for rigorous Maths and Physics in Years 11 and 12. The principals were asked a small number of questions and given space for optional comments. The brevity of the survey and the guarantee of anonymity were intended to maximise the response and encourage candour. The seventy completed responses were from all geographical parts of the state, and in total constituted about 20% of secondary schools in Queensland. The quite remarkably high response rate, when considered in conjunction with the number and length of the 'comments', indicates a correspondingly high level of concern among the principals. It is evident from the comments (Appendix 2, part B. q.v.) that their concern was in respect of the situation in Years 8/9/10, enrolment numbers in Physics and rigorous Maths, and linkages between Years 10 and 11.

2.5 Responses from Principals.

2.5.1 Time allocations.

The actual time a student devotes to a subject is a result of a combination of time allocated and losses of some of that time due to other school activities.

The principals were asked to indicate the times allocated to both maths and science in Years 9 & 10. Those data were then individually converted to a percentage of the total programmed time. Approximately 14.2% of total time was allocated to maths with government schools somewhat higher at 14.6%; non-government schools averaged 13.6%. For science the overall mean was approximately 13.3% of total allocated time. Again government schools had a somewhat higher mean allocation at 13.8%. Non government schools averaged 12.6%. For both subjects and for both school types the allocated times varied in a 2:1 ratio. All times included in this data are for time allocated. In reality other school activities interfere with that allocation. The QBSSSS, through its science subject advisory committee revised the Senior Physics syllabus. In respect of time allocation the Board's physics sub committee states "*Time specified for Board subjects is 220 hours over four semesters but teachers report that time is lost to sports carnivals, excursions and other special events."*

In a wider context the problem of loss of allocated time has been recognised in Tasmania. *"In developing Year 9 & 10 courses from Tasmanian Certificate Of*

Education (TCE) Mathematics syllabuses schools will provide the design time required by the syllabus; that is, a 100 hours for 'B' syllabuses. To take account of the extra curricular activities which interrupt class time, schools should aim to provide at least 3 hours per 5 day week preferably with at least 4 separate sessions of teacher contact per week, but no less than three separate sessions." (Numeracy Policy, Tasmania 1998). Assuming a school year is approximately 40 weeks, then the detailed weekly figures build roughly 20% of 'fat' into the timetable. The policy has a similar structure for Years 11 and 12 also to allow for *" interruptions to classroom time"*. The allowance at this level is approximately 25%. However S. Napier, Minister for Education and Vocational Training, Tasmania stated that for science syllabi at Years 9 & 10 *"times are not specified"* (Napier, 1998 pers. com.).

A Ministerial Council on Education, Employment Training and Youth Affairs report shows a wide variation in the amount of time allocated to mathematics, stating SCAT schools in Queensland as having variations from 33 hours to 60 hours per semester. (The National Report on Schooling in Australia 1996)

The report also states that for science in Queensland there is a requirement of 180 hours over the three junior years. That figure, about 1.5 hours per week approximates to two periods per week. Unsurprisingly all the 70 responding schools exceed that remarkably low minimum for a practical subject by a factor of two at least. In view of the worrying indications that students' interest in science declines from upper Primary school to lower Secondary school it is imperative that the time available for, and used for, practical science is increased. However it has to be recognised that where a teacher feels insecure about the subject itself or in respect of the maintenance of class discipline there will be a tendency to avoid practical lessons.

Some principals commented on the increased load on schools:
"The problem is that the 'basics' have expanded over the past 25 years to include so many things (computer ed., drug & alcohol ed., AIDS ed., LOTE ed., human relationships ed., arts ed. etc) that now the curriculum is overcrowded. If we are to cover all of this adequately we need to extend the school day and school year, and this would require additional staff, resources etc." (SGOV Wide Bay)

" Too many things being squeezed into schools – less time for purely academic pursuits." (SCAT Wide Bay)

Again in a wider context, these comments match well with a report from Western Australia (Hickey and Brady 1994). That report gave as one of the three barriers to achieving desired goals in science, "*the effect of an increasingly crowded curriculum on the ability of secondary schools to cover science syllabuses effectively in the time available."*

2.5.2 Internal organisation

Internal school organisation may be a factor of significance to the more able students who are potentially capable of studying physics and rigorous mathematics in Years 11 & 12. In response to the question "Do you subdivide the Year 9 & 10 students into 'levels' according to maths 'ability?" The principals' responses indicated that 20/21 SIND schools, 9/9 SCAT and 37/40 SGOV subdivided the Year 9 & 10 cohorts in one way or another. They were also asked how they subdivided the cohort. The responses indicate a plethora of structures in various combinations of method and timing and are given in full in Appendix 2 Part A. It is difficult to summarise such a wide variety of organisational approaches but the lists below, when considered together indicate the complexity of the situation. They are given as 'Method' and 'Timing'. With the exception of Vertical Organisation any combination occurred: e.g. Advanced/Ordinary in Year 9 only, or Algebra only in one semester.

METHOD	TIMING
Advanced/Ordinary	Year 10 only
Core/extension	Year 9 only
For Algebra only	Years 8,9 and 10
Challenge Maths/Science	1 Semester only
Vertical Organisation	Years 9 and 10

At the time the Board of Secondary Schools Studies was replaced by the Board of Senior Secondary Schools Studies, a new Mathematics syllabus for Years 8, 9 and 10 was at the 'trial' stage of development. That process, by its very nature, lasts over a period of some years. Because the then new Board had no responsibility or authority to complete the trial, there was no system to bring the new syllabus into general operation. However the Government Department of Education could, and did, make the new syllabus compulsory in government schools. Hence for well over ten years SGOV schools have been compelled to use a single maths syllabus containing ‘core’ and ‘extension’. Non government schools may continue to use the previous system of three different but related syllabi Maths Advanced/Ordinary/General. This variation between what is allowed in non government schools but not in government schools was the subject of a number of comments by principals:

“Retaining Advanced Maths/Ordinary Maths at Years 9 & 10 has allowed appropriate preparation for students for the rigour of Years 11& 12 Mathematics” (SIND Brisbane North).

“The maths program is still a trial/pilot!” (SGOV Brisbane-Ipswich)

2.5.3 Perceptions of “standards”

The lack of any overall moderation system up to and including Year 10 may be producing variations in ‘standards’ between schools. Although ‘standards’ is an imprecise term it was hoped that principals, being at ‘the coal face’ would be willing to respond with an intuitive ‘feel’ based on hard experience. A small minority of principals did emphasise the definitional problem: *“We simply don’t know standards in other schools in the Junior area. What do ‘standards’ mean in* *this context, and does it matter?"* (SGOV Brisbane- Ipswich). Nevertheless most felt able to reply to the question "From your experience over the years do you think that there are differences in 'standards' between schools at Year 10 exit?" They responded as shown in Table 2.3.

Table 2.3: Differences in 'standards'-opinions of principals.

School 'Type'	YES	NO
Secondary Independent (SIND)	19	2
Secondary Catholic (SCAT)	9	0
Secondary Government (SGOV)	28	10

Two responses indicated that it was impossible to judge. Although all three school types show a high 'yes' opinion there is a clear difference between government 74% 'yes', and non government schools 93% 'yes'. However it is possible to recognise that differences exist but consider that it is not a matter of concern. Hence those principals who indicated that there were differences were asked to respond to the question; "To what extent are these differences of concern?" Their responses were as shown in Table 2.4.

Table 2.4: Standards differences: opinions as to level of concern.

	SERIOUS	SOME	NONE
SIND	6	12	1
SCAT	3	6	0
SGOV	5	23	0

A higher level of concern among non government principals is evident.

Comments from the principals indicates that a significant problem is perceived by many of them in respect of standards and implications for further study in Years 11 and 12:

“The abolition of the accreditation and monitoring process at Years 9 & 10 has increased the gap between Years 9/10 and 11 & 12” (SIND Mackay)

“Of greater concern is the apparent ‘jump’ from Year 10 Maths to Year 11 Maths A/B/C” (SGOV Sunshine Coast)

“Standards of work should be moderated at Years 6 or 7 and at Years 9/10 in at least English and Maths.”(SGOV Toowoomba)

“The erosion of standards in Years 9 & 10 has been an ongoing process – even in literacy/numeracy areas.” (SIND Peninsula)

“This is of concern for this school (i.e. comparability in Maths/Science) as we draw many students from another school for Years 11 & 12.” (SGOV Wide Bay)

Other principals, emphasising the current lack of need for any exit certificate at the Year 10 level took a contrary approach (*vide supra* Littleproud)

“Year 10 certificates are near worthless these days. The desirability of moderating Year 10 results is questionable and almost pointless. One area of concern is however the algebraic skills of Senior students, especially average learners. (SGOV Mackay)

“Why does there need to be monitoring or comparability at Year 10?” (SCAT South East)

Since the ‘consumer’ stakeholders involved in the educational outcomes of schools are students and parents, the principals were asked: “Do you think that parents (et al) can depend on comparability of ‘standards’ between schools in maths & science at Year 10 exit?” Responses were as shown in Table 2.5.

Table 2.5: Dependability of Maths/Science 'standards' at Year 10 exit.

	SIND	SCAT	SGOV
Totally	0	0	0
Significantly	6	1	22
Small extent	3	8	11
Not at all	3	0	7

As before, non government principals show somewhat less confidence

than government. In total more than half of the responding principals opined that parents and others should have little or no confidence in comparability of standards (manifested to parents on school reports/certificates) between schools. Consequently students and parents may be mislead as to the adequacy of their work. Relevant comments by principals were:

"The pendulum seems to have swung too far, and students may well have been disadvantaged by impoverished courses and false confidence in their achievement levels.".(SIND Brisbane South)

"Having an external motivator such as a State wide test and/or certificate would help enormously. Maybe the 'wheel' is turning again." (SIND Sunshine Coast)

"Please also highlight the lack of assessment continuity from 8/9/10 – 11/12 in Maths. Students would be better served if the same structure flowed from Junior – Senior." (SGOV South Coast)

2.5.4 Other related concerns.

Matters raised by principals without the stimulus of questions were teacher quality and interaction. Some comments were:

"Quality of teacher graduates a concern – do not have basic literacy and numeracy skills – especially primary teachers." (SGOV district unknown).This quotation is obviously from a 1-10 or 1-12 school.

"I believe that Maths teaching (and to a lesser extent, Science) is of less quality than it should be across the whole state." (SGOV Bris/Ipswich)

"Problem is largely one of teacher competence in the junior school." (SGOV Mount Gravatt)

"Often the quality of the programs and students' results is in direct proportion to the quality of the Head of Department in charge.". (SGOV Northern)

"Attracting and holding on to suitable Maths Science teachers should be of the highest priority by all employing authorities." (SGOV Toowoomba)

"While a consideration of the possibility of lack of comparability of standards at Year 10 is important, I suggest that the bigger issue is the lack of real teacher talk/dialogue at Years 8/9/10. No one gets to see what others are doing anymore, with the possible result that in –class teaching and learning at Years 9 & 10 is being professionally stultified." (SIND Brisbane South)

The Third International Mathematics and Science Survey (TIMSS), in addition to collecting data on 13 year old students, also surveyed teacher attitudes. One outcome was that *"approximately 50% of the country's maths and science teachers would change to another career if given the opportunity"*. (National Report on Schooling in Australia 1996)

The combination of some principals' comments and the attitudes shown by TIMSS (assuming Queensland teachers are not attitudinally atypical) is a matter of great concern. It is noteworthy that no principals raised the lack or otherwise of computers as a matter of concern to them. A lack of skilled, professional humans is not a problem that is amenable to a technological 'fix'.

The inter-relationship between secondary and tertiary education was mentioned frequently, in particular the effect on secondary participation when tertiary prerequisites are changed:

"The irony is, of course, that while we are attempting to provide our students with the necessary skills for Maths B/C, Tertiary pre-requisites are ----reducing the needs for these subjects." (SGOV Rockhampton)

"Tertiary Institutions declaring that Maths C and Physics are no longer pre-requisites is probably the cause of the problem. The situation is dynamic. Fewer students Maths C & Physics ------- fewer teachers qualified to teach Maths C & Physics in following generations ------- less capacity of organisations to teach Maths C and Physics --------Fewer students studying Maths C & Physics -------" (SGOV Brisbane-Ipswich)

Fundamental to success in Physics and rigorous Mathematics in Years 11/12 are valid physical science experiences in Years 8/9/10 and a firm, reliable foundation in Mathematics. In particular the ability and willingness to use algebra as a tool is essential. References to algebra, either explicitly or by implication are common in the comments made by the principals. A need to improve algebra is mentioned in terms of internal school organisation. (Appendix 2, part A: SGOV 11, SGOV 20. SGOV 29 and SGOV 40). Any reference to 'Maths Advanced' also implies an algebraic emphasis. (Appendix 2, part A: SIND 4, SIND 5, SIND 8, SIND 10, SIND 13, SIND 14, SIND 15, SIND 16, SCAT 1, SCAT 2, SCAT 7, SCAT 9; and in Appendix 2, part B: SIND 5). The inevitable divergence between public and private schools caused by inappropriate governmental legislation is very clear: all references to Maths Advanced are from private schools; all references to algebra from the public sector.

It is clear that secondary principals in Queensland recognise the importance of student experiences in Maths and Science, notably algebra, in Years 8/9/10. Chapter 3 examines some of those experiences.

CHAPTER 3

ALGEBRA, THE ESSENTIAL TOOL

CHAPTER 3

3.1 Introduction.

In the sense that a tool is 'a thing (concrete or abstract) with which some operation is performed; a means of effecting something; an instrument' (OED, 1998) algebra may legitimately be viewed as a tool that is available for use in both Mathematics and the physical Sciences.

The literature for algebra generally is vast but for its use, applicability, far less. MERGA (2000), as a part of a review of research in Mathematics education in Australia, contains a sub section dealing with the 'context and Application of Algebraic concepts'. The amount of research listed is small. Prominent, however, is the work of MacGregor and Stacey. A valuable example of their work is in MacGregor and Stacey (1999) that in part deals with the use of algebra to solve 'problems'. Stacey and MacGregor (1999) emphasise the significance of algebra both as a language and as a method of solving problems.

There is almost no literature that deals with algebra as a tool in the Queensland context. Allen (2000) in a detailed examination of the condition of Mathematics at the end of Year 10 in Queensland, considers the general area 'Applying Techniques'. Much of that consideration pertains to the application of algebraic techniques.

In 1925 the physicist Werner Heisenberg, attempting to make some coherent sense of early sub atomic problems, rapidly realised that his mathematical techniques were inadequate for the task. In isolation he cobbled together a strange form of Algebra which could be used to explain the known measured phenomena. In less than two weeks Heisenberg constructed the basic frame work of Quantum Mechanics. The Algebra he strung together was in fact matrix algebra of which, perhaps surprisingly, Heisenberg was unaware. (Rhodes 1986)

That anecdote illustrates a number of matters that are of current significance. Firstly the absolute centrality of mathematics as a set of tools. Secondly, the fact that the available mathematics must be relevant to the problem in hand. This chapter is considering mathematics as a set of tools; it is not considering the aesthetics of the discipline – its elegance and sheer beauty.

Heisenberg was exceptional; he was able to manufacture a form of mathematics that he perceived as being necessary for the job in hand. Such abilities are given to the few and the very few. It is reasonable to assume that all secondary students will need to be shown the mathematical tools needed and the circumstances in which those tools may be valuable. They need to be shown both how to use and when to use a given tool.

3.2 Algebra as a tool.

At the lower secondary school level algebra is the great new tool. '…….the special role of algebra as a gateway to higher mathematics. Algebra is the language of higher mathematics and is also a set of methods to solve problems…..' (Stacey and MacGregor 1999). '..a gatekeeper to educational opportunity….. (and) introduces students to mathematics as a style or method of thinking, involving modelling, abstraction, and the formalisation of patterns and functions' (Silver 1995). In particular the ability to form and solve algebraic equations is a tool with wide applications. This width of application not only emphasises the power of algebraic skill but also provides a plethora of question 'types' in middle schooling mathematics that reinforce that skill. Crucially algebra needs to be seen as an integral part of elementary mathematics, not as a separate and rather pointless technical skill.

The total skill involved in the use of algebraic equations may be broken into inter linked parts. (a) The solution of equations; linear, quadratic and simultaneous. (b) Substitution into formulae. (c) The translation of simple word problems into algebraic sentences. (d) Logical sequencing of a mathematical explanation using appropriate terminology, layout and symbols. (e) Testing the validity of proposed solutions. (Junior maths syllabus, Qld). Of these parts the mechanical solving of equations will eventually be performed on more advanced calculators when they are generally available. All other parts (b) to (e) will remain the responsibility of the student. They are all, however, techniques which can be taught to the majority of students if they already have a suitable set of knowledge, skill and understanding. That set includes both verbal skills as well as mathematical skills and understanding in, for example, number, fraction, percentage, mensuration etc.

A student who is able to use algebra is advantaged in a number of ways. Firstly, it becomes possible to solve problems that are otherwise insoluble. Secondly, even for problems that can be solved otherwise, the student has a choice of techniques available. Thirdly, and most importantly, a problem in essence ceases to be a problem at all, becoming a matter of translation into algebra with subsequent application of known technical skills.

Consider the following two elementary questions:

A dealer buys a refrigerator for $350 and sells it to make a profit of 20%. What is the selling price?

A non-algebraically literate student can proceed:

Profit = 20% of $350 = $70

So selling price = $350 + $70 = $420

An algebraically literate person has the additional option to proceed:

S.P. = (100 + 20)% of C.P.

S.P. = 120% x C.P.

I’m told C.P. is $350; so substitute for C.P.

So S.P. = 120% x $350

S.P. = $420

For this type of question where cost price is given the algebraically literate student has an extra option.

For the question: I buy an article and then sell it for $90, making a profit of 25%. Find the cost price. The non-algebraically student cannot answer at all (short of guessing, almost certainly producing $67.50 as the answer). However the algebraically literate student can proceed:

S.P. = (100 + 25)% of C.P.

S.P. = 125% x C.P.

This time I’m told S.P. is $90; so substitute for S.P.
So 90 = 125% x C.P.
and then mechanically solve to obtain C.P. = $72.

For this type of question, where cost price is not given, the algebraically literate can respond successfully, and furthermore can use the same approach as for the first type. Here the consequence of algebraic literacy is that not only are all questions involving cost price, selling price and percentage profit or loss all possible, but they can all be solved by the same approach: form an equation, substitute the information and solve. Because that general approach is applicable to an enormous variety of situations, the implications of algebraic literacy are so large as to become a fundamental change in a student’s approach to mathematics, in particular to 'problem solving'.

In that context the finding that for Victorian schools ‘subtle reductions in goals and isolation of topics in the curriculum were disturbing trends,’ (Stacey and MacGregor 1999) is serious. Also, because the techniques/approach described above are within the grasp of most (though not all) students, the comment by a Queensland High School principal ‘ One matter of concern is, however, the algebraic skills of senior students, especially average learners’ (Quoted in Ridd, 2000) is worrying indeed.

However, just as algebraic literacy can help, even revolutionise later mathematics, so also does that wide usage emphasise the ‘usefulness’ of algebra. There is a repeated positive feedback to the consequent benefit of the students’ whole mathematical development. The variety and width of algebraic application in later elementary mathematics is large, but a few examples are illustrative.

At an elementary level, trigonometry of right-angled triangles results in equations of the form A = B/C where A is the sine, cosine, or tangent of an angle, and B and C are two side lengths. If a student is algebraically literate it makes little difference whether A, B or C is unknown. However, an algebraically illiterate student has little choice but to manufacture a set of ‘rules’ such as ‘if x is at the bottom I must divide; if it is at the top I must multiply’. The implications are significant. If the class can, and is willing to, handle equations then all the available time can be expended on the basic concepts of trigonometry because consequent calculations are trivial. If the class is not algebraically capable then in addition to the trigonometric concepts; time, effort and student worry are wasted on the final calculation.

Another piece of elementary mathematics that is affected by algebraic competency levels is ratio/proportion. The structure A/B = C/D is common. It follows that it is necessary for the students to be able to solve for any one of A,B,C or D given the other three. If a teacher determines to utilise the ideas of direct/inverse proportion, then the student will be confronted with equations of the form y = kx or y = k/x. Assuming an ordered pair is given (an important idea of itself) then k can be found by solving. Subsequently, knowing k either x or y can be determined given the other. Without algebraic skills albeit of a rudimentary nature, this work can become a jumble of disconnected bits all handled in different ways.

Student inability to solve simple equations is not a problem for mathematics alone. Aspects of early secondary science are also affected. Work on pressure, density, elementary electricity, force, velocity and acceleration all result in simple calculations. Taken seriatim we have Pressure = Force/Area; Density = Mass/Volume; V = IR; Wattage = Voltage x Current; Force = Mass x Acceleration; Speed = Distance/Time; Velocity = Displacement/Time; Acceleration = Change of Velocity/Time. The form of equations in much of this work is the same as for elementary trigonometry. The fundamental concepts involved in these pieces of work are not trivial. Taking Density = Mass/Volume as an example; the concept of density is not intuitively obvious. Time and practical work will be needed. Relevant units will also need careful consideration. The last thing the teacher or student wants is a needless difficulty with final calculations. Only a student who is algebraically literate is able to concentrate on the fundamental scientific ideas involved in the topic.
All the science examples above fall under the heading of physics up toYear10. However they are also basic concepts ultimately used in engineering. The algebraic forms also apply to later chemistry.

3.3 Some influences on algebraic outcomes.

Both the amount of time available for Mathematics and the quality of the teachers who are timetabled to teach the subject are causes for concern.

There is evidence that the amount of time apparently spent on mathematics and science is restricted and in decline, so reducing the opportunity to learn the discipline (Thomas[1], 2000). Those 'official' times give an over optimistic view of reality. Teachers are reporting that time is lost to sports carnivals, excursions, and other special events. (Ridd, 2000). In Tasmania the State Government has instructed schools to ' take account of the extra curricular activities which interrupt class time'. (Numeracy policy, Tasmania, 1998). That instruction, if followed, builds a buffer of between 20% and 25% of syllabus specified time into the timetable.

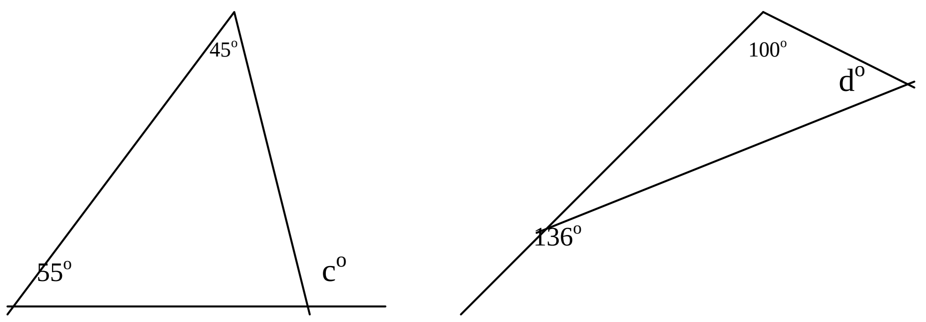
Under the present circumstances of restricted – and disjointed – time spent on mathematics, it behoves teachers, administrators and other education specialists to maximise the use of the time. It is a contention of this chapter that to view and teach junior mathematics in the absence of adequate algebraic literacy is, at best inefficient. The ability to solve (mainly linear) equations of clearly specified forms; to substitute into a formula and to translate simple word problems into algebra is central to a student's mathematical development. With that algebraic base in place, students are empowered to use algebra as a language and a tool in a vast number of situations that will arise in lower secondary school maths and physics. It would also enable the mathematics curriculum to be far more unified. This specified material needs to be handled in full in the first year of secondary schooling. The time expended on such material would be an investment of the scarce resource, time, which would reap a high return subsequently. A possible list of equation forms might be: (1) A = B x C. (2) A = B x C x D. (3) A = (B x C)/2. (4) A = B/C. (5) A = (B x C)/100. (6) A = BC + D. (7) $A^2 = B^2 + C^2$. In all cases solving for A, B, C or D given all other values. It is important to note that such a 'tool kit', simple as it is, would revolutionise the student's progress in later work. It is also noteworthy that the equation forms would, or should, be used so often within other 'parts' of mathematics and physics that the positive feedback referred to earlier would inevitably occur, and on an almost continuous basis. An alternative method of avoiding the problems in elementary science caused by algebraic illiteracy is to avoid numerical science altogether. As will be seen later, there are signs that such an approach is occurring in Years 8/9/10 in Queensland.

The shortage of secondary maths teachers is common throughout the western world. In Australia it is a nation wide problem. (Thomas, J.[1] 2000, National Report on

Schooling in Australia, 1996, Ridd, 2000). Many early secondary students are taught by reluctant teachers who possess restricted knowledge. They are often very aware of their limitations. Such teachers inevitably rely heavily on the textbooks being used in the school. This dependency has been recognised in the U.S.A. 'More and more students are taking algebra. Are schools giving them the best support with which to learn the subject? A recent review of algebra textbooks by the American Association for the Advancement of Science says probably not, if schools are relying solely on textbooks.' (AAAS, 2000.) None of the twelve textbooks reviewed rated 'highly'.

As a generalisation textbooks reflect the State's syllabus at the time of writing and the approach to the teaching of maths in vogue at that time.A text's view of the role of algebra as a tool is demonstrated, at least in part, by an examination of five aspects of the texts. (a) the questions given to the students, (b) worked examples, occasional comments within the general text material, (d) the order in which the mathematical topics are handled and (e) what material is considered to be difficult.

Secondary Maths for Queensland (SMQ) is a widely used series of texts. The Year 8 text book, handling geometric axioms and theorems gives the following worked examples.



Solution. $c = 100^{o}$, exterior angle of a triangle.

$d = 36^{o}$, exterior angle of a triangle.

and adds the note '(the exterior angle rule is used *backwards* to find an interior opposite like d. Subtraction is used)'. (S.M.Q. Year 8, 1988, p.238)

If the text were aimed at an algebraically literate student the second solution might read:

$136 = 100 + d,$ exterior angle of a triangle.

$136 - 100 = d$

giving $d = 36^o$.

The lack of algebraic literacy has compelled the text to lead the students to an additional 'rule'; 'if you want an interior angle, you must subtract'. The compulsory memorisation of an increased number of ' rules' is an inevitable result of algebraic illiteracy.

SMQ Year 8 (page 249) does use algebra in a worked example. The question involves a triangle in which the three angles are $3k^o$, 100^o and $2k^o$. The suggested solution is:

$3k + 2k + 100 = 180$

$5k + 100 = 180$

so $5k = 80$ (by subtracting)

so $k = 16$ (by dividing)

so $3k = 48^o$ and $2k = 32^o$

The value of this worked example is reduced by the fact that the text section dealing with the solution of equations is about 140 pages later.

The approach that algebra is not a tool but a problem, is further illustrated in the Year 9 text. Again in the context of elementary geometry and immediately prior to worked examples is the phrase ' some angle problems can even involve algebra'. (SMQ Year 9, 1990, p. 294). The implication of that comment appears to be that algebra makes a question more difficult. In Year 10, geometry questions in which the student is instructed to 'use algebra' are separated from others, and are marked with two stars, indicating that they are perceived as harder. (SMQ. Year 10, 1990, p. 134)

Another popular text book series, 'Future Maths', again when dealing with elementary geometry, gives very few worked examples prior to the various exercises. Such worked examples could have indicated a suggested approach for students to use. (Future Maths, Years 8/9/10, McGraw – Hill 1988,89,90)

A further indication that the solution of equations is viewed as a problem rather than a tool may be seen by an examination of when the solution of equations and their application is considered.

In SMQ Year 8, the solution of some simple forms of linear equations is in the last chapter of the text only. In the Year 9 text the solution of very simple quadratic equations appears in the last chapter; there are no ‘word problems’.

In all texts examined most questions requiring the use of a formula are posed in such a way as to require substitution only. Examples are to be found in Pythagoras’s theorem and elementary trigonometry. Where the required quantity is not the ‘subject of the formula’ hence requiring the solution of an equation, they are frequently dealt with as a separate ‘type’ and marked as more difficult. See for example Future Maths Year 10 page 244. The perception that a formula needs to be written so as to make the required variable the subject of the formula extends to Year 11. In one text the cosine rule is given in six different ways so as to make A, B, C, a^2, b^2, *and* c^2 *respectively the subject of the formula. (Q Maths 11b, 1993, pp266,267)*

3.4 Algebra at the end of Year 10.

As discussed in Chapter 2, the overarching legislative framework pertaining to education in Queensland has inevitably led to the situation where, for well over a decade, there has been no effective system of gauging student outcomes up to the end of year 10 for any subject. Hence there is almost no hard data across schools as to the standards achieved in mathematics. 'There is currently no ongoing collection of systematic data concerning the adequacy of mathematics programs at Years 9 and 10 in preparing students for entry to mathematics courses in Years 11 and 12'. *(Wells 1999 pers. com.). The fact that Mr Wells was at that time the Minister for Education adds to the significance and potency of his remark. The situation in mathematics has been made even more opaque by the fact that, as also discussed in Chapter 2, since the late 1980s, government schools are compelled to use a maths syllabus that is different in basic structure to that still used in non-government schools. There is a consequent divergence between maths in public and private schools. The magnitude of that divergence is unknown. For Years 11 and 12, the final two years of schooling, the position is transparent because for those years syllabus development and* *outcome assessment have been under the auspices of the highly competent Board of Senior Secondary School Studies.*

In a belated move to ascertain the current condition of Maths to Year 10, the Queensland Schools Curriculum Council in conjunction with the Board of Senior Secondary School Studies (BOSSSS) has completed a study ‘Year 10 Maths as a Foundation’ (Allen, 2001). The study had two phases. In phase 1, the perceptions of teachers of Year 11 Maths A, Maths B and Maths C inrespect of students on entry into Year 11 were obtained. Maths B is the normal prerequisite for entry into mathematically based courses at tertiary level. Students who take Maths B may also take Maths C that provides additional, wider, mathematical experiences. Maths A is an easier, more general subject.

School response to the BOSSSS request for information was at the 80% level for each of the school groupings: state, non-state non-Catholic and non-state Catholic. (Allen, 2001, p.4). In phase 2, schools were asked to provide the marked work of three students who were considered to be either High achievers or Very High achievers at Year 10 exit. Although school response to this request was lower than for Phase 1, being about 25% for each school group, a total of 547 folios of student work were forthcoming. Most importantly ‘eighty-eight schools provided at least one V.H.A. folio that contained all the assessment instruments’. (Allen, 2001, p.25.). As a consequence of the satisfactory response from the schools combined with the skills of the BOSSSS employees and associated teachers, the study is of the highest quality and should be seminal to educational thinking in Queensland.

Phase 1 obtained the teachers’ perceptions of their Year 11 classes familiarity with 80 well defined facets or items of maths. The 80 items were grouped under the three headings ‘basic concepts’, ‘extracting information’ and ‘applying techniques’. The teachers were asked for estimates of class familiarity with each item on a ten point scale from 10 – ‘nearly all’ down to 1 – ‘hardly any'. Hence 'an item where most responses are between 5 and 8 suggests…. That roughly half of the students can handle this aspect of maths' (Allen 2001).

For the purposes of this chapter, which is an examination of the use of algebra as a tool, the general area ‘applying techniques’ is the most directly relevant and significant. For that area the teacher responses indicate ‘ that there are *no* items showing perceptions of general widespread familiarity’ (Their emphasis) (Allen, 2001, p15). It follows that only in items scoring heavily at the 9/10 level is student knowledge, understanding and skill reliable.

Year 11 students who have opted for Maths B and/or Maths C or Physics or Chemistry are confronted with a wide selection of material requiring the use of algebra. Financial maths, trigonometry, projectile motion, connected bodies and physical chemistry are but a small sample of such topics. Prerequisite to the use of algebra as a tool is the ability to translate a word problem into an algebraic sentence. It follows that only Year 11 classes that can translate simple word problems into algebraic sentences with a very high degree of reliability are appropriately prepared for the rigours of Maths B or Maths C or Physics or Chemistry. Such a degree of reliability would be manifested in ‘Year 10 Maths as a Foundation’ by a score 9 or 10 for the specific topic ‘translate simple word problems into algebra’. It is therefore of concern that only 9% of the Year 11 groups are considered to be in categories 9 or 10, i.e. to have reliable abilities on this topic. Even for Maths B groups the percentage 9/10 is only about 15%. Only the Maths C groups, supposedly the most able, score more than 30% at the 9/10 level. (Allen, 2001, p.15)

Evidently a very large number of students entering Year 11 are highly unreliable at the fundamental skill ‘ translating simple word problems into algebra’. If that skill is not available then it follows that algebra cannot be used as a tool. Furthermore if a student cannot use one mathematical tool - algebra then the use of another tool - calculus is made more difficult because the basic idea that mathematical tools are useful, is missing.

Teacher perceptions for other items of relevance are shown in Table 3.1.

Table 3.1: Teacher perceptions of Year 11 maths classes' knowledge and ability to use various algebraic procedures. By item and by percentage of groups in three reliability levels.

ITEM	% by group		
	8	**9**	**10**
Logical sequencing of a mathematical explanation using appropriate terminology, layout and symbols.	9	6	2
Testing the validity of proposed solutions	7	3	1
Substitute into formulae	17	15	15
Determine whether values satisfy an equation	15	12	9

(Allen 2001, Appendix 2,pp 5,8)

For these items the group 8 level of class familiarity has been added to emphasise the magnitude of the problem as perceived by Year 11 teachers. The probability is that a Year 11 group, even one taking Maths B or C cannot reliably translate a word problem into Algebra, logically sequence their work or test the validity of their solutions. The implications of such a weak set of mathematical thinking patterns for later mathematics and physical science are large.

As noted earlier, the solution of equations tends to be in the last sections of the 8/9/10 text books. It is unsurprising therefore that the survey 'Year 10 as a Foundations' found that Algebra constituted 29% of the items in the assessment packages presented for Phase 2 of the survey. For packages entitled either 'Advanced Maths' or 'Extension Maths' the percentage of items which were algebraic rose to 40%. Because non State schools are able to use a syllabus which State schools are precluded from using, it is again unsurprising that 'Of the twenty-seven sets of folios shown as being from 'advanced' or 'extension' mathematics courses, only two were from State schools.'(Allen, 2001,p.25).

The combination of the two facts, that far more private schools showed 'advanced' or 'extension' work, and that there is a much greater amount of algebra in those folios means, incontrovertibly, that students in public schools are learning less algebra than students from private schools. The high emphasis on algebra in the last months of a three-year course is only explicable if it is assumed that algebra is not viewed as a tool that could have been useful in earlier mathematics, but as a chore.

In Phase two of the survey, ‘expert teachers’ were used to make pair-wise comparisons, judgements, of the student work folios presented by the schools. Those multiple pair-wise comparisons were then analysed to produce ‘well defined rank order information’ (Allen, 2001, p.29). The analysis showed a wide variability in the performance of students even though they had all been awarded the highest achievement levels. The report comments that standards variation noted by ‘the judges are much, much bigger than they would be if there were no clear differences amongst the folios’, and that there was ‘variability in the content, coverage and standards.’ (Allen, 2001, pp.31,32)

The size and nature of the variability was illustrated by the assessment instruments provided. ‘When a school’s assessment program does not include assessment of the higher order mathematical skills and processes it is likely that these are not being given much attention in teaching, to the probable impoverishment of the mathematical learning of the more highly achieving students. Lack of opportunity to demonstrate higher order mathematical skills dominated the written comments made by teachers comparing folios’. (Allen, 2001, p.31)

The survey contains illustrative samples of the work of ‘Very High Achievement’ students. Examples of questions and individual student responses that are relevant to this chapter are: (students responses transcribed):

(a) Question: A video costs $128 more than a bread maker. If the two of them cost $523, what is the cost of each item?

Answer:

V+B =$523	Bread maker=$197.50
B+B+$128=$523	Video=B+128
B+B+$128-$128=$523-$128	Video=$325.50
2B =$395	
2B/2 =$395/2	

B=$197.50

This simple question barely requires the use of algebraic techniques. The solution suggests poor thinking; no distinction is made between a ‘video’ and the number of videos, there is no definition of the variables used and initial letters are used as the unknowns, a known misleading practice. (MacGregor and Stacey, 1999).

(b) Question: A cylinder and a sphere have the same radius. The height of the cylinder is 2 metres. The surface area of the cylinder is 6π m^2 less than the surface area of the sphere. What is the volume of the sphere?
(Formulae for surface area of sphere and cylinder and the volume of a sphere are given. π not to be evaluated)

Student answer:

$2\pi r^2 + 2\pi r \text{ x } 2-6\pi = 4\pi r^2$

$2\pi(r^2+r \text{ x } 2-3) = 4\pi r^2$

$2\pi \qquad =4\pi r^2$

or

$r^2+r \text{ x } 2-3=4\pi r^2$

$r^2+r = \underline{4\pi r^2-3}$ (the r^2 on both sides is shown as cancelled)
2

r = 4.78

This student has the confidence to manipulate algebra. That confidence is misplaced. The technical errors are startling especially from a student who has been awarded the highest level of achievement.

(c) Question: A rectangular field has a total perimeter of 250 metres. Two of the sides are each 25 metres longer than the other sides. What are the dimensions of the field?

Student answer:

P = 250m.

Dimensions = 250-25-25

= $\frac{200}{4}$ =50

150 100 *(small numbers shown here*

= (50 +25x2) + (50x2) are as written by the student)

50 50 75 75

2x + 2x + 3x + 3x = 10x

$\frac{250}{10x}$ =25

x=25

2x = (50x2) + 3x = (75x2)

Length is 75m. Width is 50 m.

It is doubtful whether the student has used algebra at all. The thinking patterns and skill levels demonstrated are poor and make the prospects of success at later rigorous maths very slight.

On the other hand some student work is of a remarkably high standard. One student solves, without hesitation or amendment, a problem involving the interception of a missile following a given parabolic path with an antimissile assumed to have a given linear path.

The report comments on the relatively low response rate by the schools to the request for folios of student work (25% as opposed to 80% for Phase 1). ‘Schools provided samples of H.A. and V.H.A. work voluntarily. Accordingly, variation is likely not to have been overestimated (but may have been underestimated.)’ (Allen, 2001, p.25.).

That variability extended across ‘…content, coverage and standards. There are students finishing Year 10, and there are classes of students entering Year 11, who have followed rich, stimulating and diverse mathematical studies. There are others who have not – their courses may have lacked variety and stimulus or their learning may have been unsuccessful.’ (Allen, 2001, p.32.)

3.5 Discontinuity in mathematics at the Year 10/11 interface in Queensland.

Variable, frequently incompetent and low use of algebra as a tool to Year 10 is a consequence of syllabus/text book/teacher intentions. In contrast the Maths B syllabus for Years 11/12 heavily emphasises the use of mathematics as a tool. The ‘ focus’ of the section ‘Optimisation using derivatives’ states, in part, ‘---develop an understanding of the use of differentiation as a tool in situations---’ (Qld Senior Maths B syllabus, 2001 p 21). In the ‘focus’ of the section

‘Introduction to Functions’ the statement is made that ‘emphasis should be placed on the application of function to solve problems in a range of life – related situations’. (Qld Senior Maths B syllabus p.14) The emphasis on the applicability of mathematics to a variety of circumstances is a constantly occurring theme in both the Maths B and C syllabuses. It occurs in both ‘focus’ statements and in ‘suggested learning experiences’. For example ‘life related applications of sine and cosine functions’ (Qld Senior Maths C syllabus, 2001, p. 26), or ‘investigate life related situations where small changes in calculated quantities due to small errors in measurements can be approximated using derivatives’. (Qld Senior Maths C syllabus p.16).

There is an evident discontinuity in the thinking expected of the students as they move from year 10 to year 11. Most enter year 11 with little idea of the power of algebra as a tool. Such thinking patterns are a poor grounding for year 11 in which they are expected to use a variety of mathematical concepts and techniques as tools.

3.6 Use of algebra in early secondary science in Queensland.

The shortage of maths teachers referred to earlier extends to a lack of teachers who are competent to teach the numerical sciences, especially physics. Consequently the science text books used to Year 10 become significant. It is clear that at that level there has been a severe decline in the numerical sciences over the last few decades. Earlier texts required the students to be able to apply simple mathematical techniques to questions in dynamics. For example, at the Year 10 level:

‘A bullet is fired from a rifle whose barrel is 60 centimetres long. The bullet
leaves the barrel at a speed of 180m/s.

(a) What is its average speed in the barrel?

(b) How long is it in the barrel?

(c) What was its acceleration? (In Search of Science Book 3,1968, p.47)

At the Year 9 level, students, given the formula Q = mct were asked:

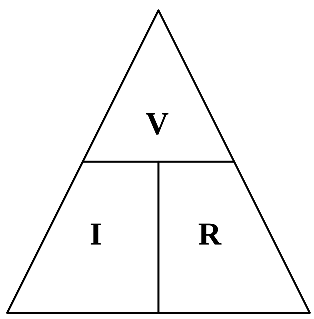
'A solid with a mass of 250 g is cooled from 120^{o} C to 80^{o} C. Measurements show that 3000J of heat energy have been removed. What is the specific heat of the solid? (Science Spectrum Book 2, 1988, p.310)

If students cannot solve simple equations then, unless numerical science is avoided altogether, simple physical laws have to be memorised in multiple forms so as to make each variable the 'subject of the formula'. Thus, from a currently used Year 9 textbook:

'Ohm's law can be used to solve electrical problems involving current, voltage and resistance. There are three different ways of writing the Ohm's law expression. These ways are as follows:

1. current = voltage/resistance or I = V/R
2. resistance = voltage/current or R = V/I
3. voltage = current x resistance or V = IR.'

(Science 9, 1984, p.181)



The text then provides a (literal) *rule of thumb.* The student is directed to place a thumb over the required variable and so read off the required form of Ohm's law: cover I and obtain I = V/R; cover V and obtain V = IR. cover R and obtain V/I.

The students are encouraged to use a similar system for the relationship between weight, mass and gravity; and for density, mass and volume (Science 9, 1984, pp.277,294)

A more recent series of science texts for Years 8/9/10, Jacaranda Science (Wiley 1999) places a near zero emphasis on the algebraic aspects of physics. Some use is made of elementary arithmetic in suggested experiments and in a very small number of subsequent questions:

'…calculate the value of $\frac{\text{energy fully used in heating water}}{\text{energy supplied to electric jug element}} \times \frac{100}{1}$

(Book 2 p.257)

3.7 Discontinuity in physics at the Year 10/11 interface.

Unfortunately there is no science equivalent to 'Year 10 Maths as a Foundation'. Hence there is no data whatsoever as to the actual situation of science in the schools to Year 10 exit. It is however hard to adduce reasons why numerical science should be much different from mathematics. The implications of this lack of data are commented on in the BOSSSS maths review. 'For P-10 syllabus developers, an implication of this study is the need to develop processes for regular review of both practices and standards in practice.---For Year 11-12 syllabus developers, the lack of systematic information about standards and practices in other areas of the curriculum means that they must rely on anecdote.' (Allen, 2001, p.33)

The reduction in the use of, and hence need for, algebraic thinking in current science text books to Year 10 exit ill prepares students for physics at the Year11/12 levels. The proposed new physics syllabus states 'At the very heart of physics practice is algebra – the manipulation of symbols representing physical quantities in order to analyse data and predict outcomes. (Draft Senior Syllabus in Physics. 2000. p.15). As is the case for rigorous mathematics there is a clear discontinuity in the thinking, attitudes and skills expected from the students at the interface Year 10 science/Year 11 physics.

Many students by the end of year 10 suffer from a weak Maths foundation. The weakness in algebra is particularly serious because of the implications in year 11/12 for both Maths and Physics. For Physics the weakness in algebra is compounded by the apparent very low emphasis give to the numerical aspects of Science during

Years 8,9 and 10. The consequent discontinuity at the year10/11 interface may have implications for both participation in, and success at, rigorous Maths and Physics in the last two years of Secondary schooling. Chapter 4 examines one possible consequence of the study of rigorous Maths and the physical sciences i.e. the final outcomes, the ENTER results obtained by students at the end of Secondary schooling.

CHAPTER 4

INFLUENCES OF SUBJECT SELECTION ON FINAL SECONDARY SCHOOL RESULTS (OVERALL POSITION) IN QUEENSLAND

CHAPTER 4

4.1 Introduction.

As noted in Chapter 1, many university Physics, Mathematics and Engineering departments in Australia and elsewhere have experienced major enrolment problems, notably at second year and later, for at least a decade, causing closure, amalgamation and serious loss of staff. Furthermore those declines bring into question the future of industries that are based on physical Science and mathematics. The student pool from which physical Science and Engineering departments can draw has declined because of the reduction in participation, especially male participation, in higher level Maths and Physics at secondary level. That reduction is a consequence of decisions made over two years before the student left secondary school.

Calderon et al (2000) examined some consequences of subject selection on Equivalent National Tertiary Entrance Rank (ENTER) outcomes. They demonstrated that students who studied Mathematics and Languages other than English (LOTE) 'tend to gain higher (tertiary entrance scores) than students taking other combinations of subjects'. However they added the caveat 'perhaps it is simply a matter of "bright" students undertaking those subjects'.

The Victorian ENTER scaling system is such that it is not easy to identify the 'bright' students or the 'bright' cohorts of students. Consequently it is not possible in that State to compare 'like with like'.

The system of scaling used in Queensland to ascertain a students' Overall Position (OP), the equivalent of ENTER, makes it possible to divide students and cohorts of students according to known achievement on core curriculum elements, i.e. according to demonstrated all round ability. Hence it is possible to compare 'like with like'. The aim of the work reported here is to examine the ENTER (or equivalent) consequences of the study of some subject combinations for groups of students that are known to have similar levels of demonstrated general ability.

4.2 The Queensland OP system: an analytical opportunity.

At the completion of secondary school in Queensland, a student is awarded a Senior Certificate that gives the students' 'Level of Achievement' for each of the subjects studied in Years 11 and 12. In addition the student receives an Overall Position (OP) which is a number between 1 and 25. The Overall Position (OP) is designed to be, and is used as, the major entry sieve for tertiary study. Overall Position (OP) is ENTER under a different name. (See Appendix 5 for diagrammatic representation of the OP system.)

The OP awarded to a student is a consequence of the sum of the student's subject results subsequent to scaling using the Queensland Core Skills Test (QCS). The rules laid down by the Queensland Board of Senior Secondary School Studies (QBSSSS) state that all year 12 students who wish to be awarded an OP '**must** sit for the (QCS) test'. The test is designed to measure achievement on the 'Common Curriculum Elements' that underpin the Board of Senior Secondary Schools Studies (QBSSSS) subjects. It is not subject specific and includes criteria such as 'comprehend and collect', 'structure and sequence', 'analyse, assess and conclude'. There is also a 'writing task.' The Queensland Core Skills Test (QCS) is hence a measure of all round ability; it provides a measure of the relative academic strength of the various cohorts of students. Recent QCS results for some selected subjects are shown in Table4.1.

Table 4.1: QCS results. Mean and standard deviation for all students, selected subject cohorts.

	All students	French	German	Maths C	Physics	Chemistry	Geography	Marine Studies
Mean	122.9	144.6	137.2	143.8	141.6	141.3	121.4	114.3
sd	28.7	26.1	26.8	27.6	26.0	25.4	25.9	24.0
n	30059	617	815	3337	6936	8465	5227	1121

Source: QBSSSS data. 1998

Note: Maths C is the highest level maths.

Noting that these numbers are for all students taking the subjects, not a sample, it is clear that in Queensland the student cohorts taking high level Maths, LOTE, Physics and Chemistry were much stronger than the average. Unless Victorian student behaviour in subject selection is radically different from that in Queensland, it would seem that the caveat in Calderon et al (2000) is justified. The generally higher ENTER scores obtained by students taking LOTE and Mathematics is a reflection of the 'brightness' of the students taking those subjects.

The availability of QCS results for Queensland students not only makes it possible to compare 'like with like' in terms of their all round ability, it makes any analysis that does not make such comparisons inadequate. Education Queensland, via its Equity Programs Unit put out a set of slides for general use and discussion. It showed that in 1996 a higher percentage of females than males taking, for example, Maths C (considered to be the most rigorous maths) and Physics obtained a High or Very High Level of Achievement, i.e. the females 'did better'. It did not mention the QCS results for those cohorts. The Maths C females scored a QCS mean of 152.0, sd 25.8; the males 146.2, sd 27.4. The Physics females scored a QCS mean of 149.9, sd 25.7; the males only 141.5, sd 27.1. Noting the large statistical samples, there can be no doubt that the female cohorts were of substantially greater general ability than the male. In the absence of the presentation and consideration of relevant QCS data it is inappropriate to draw, or ask others to draw, conclusions or even implications from the fact that females had a higher percentage of the upper Levels of Achievement than had the males. It would be worrying indeed if the demonstrably more able females had <u>not</u> out-performed the males.

In Queensland an individual subject result subsequent to calibration is the Scaled Subject Achievement Indicator (SAI). The sum of each student's five best SAIs is obtained. After all adjustments are made, all students in the State are placed in rank order. The highest results are awarded an Overall Position rank 1 (OP1), the next few percent of the results an OP2 etc. The direct link between Scaled Subject Achievement Indicators (SAIs) and Overall Position (OP) is crucial. A change in an SAI will produce a change in OP.

The Overall Position (OP) is not a score or a measure of student versus some standard. It is a number which indicates a given students' position in comparison to all other students in the State student cohort. There is a commonly held fallacy that some subjects are more heavily weighted than others. Such a suggestion is untrue.

Allen and Bell, (1993) state ‘It is important to realise that the -- analysis does not say that Physics is better than Art, or Art is worth more than Maths in Society, or that Physics is weighted more highly than Maths in Society. The dataset suggests that there are differences between the groups of students taking different subjects. Their overall achievement or OPs reflect this reality.’

Taking one subject instead of another will not produce any improvement in OP output unless the student is relatively better at the new subject in comparison to other students. This chapter examines some ways through which an individual student might select combinations of subjects that give the best outcome relative to other students.

The Overall Position obtained is a consequence of competition between students. The word 'position' indicates what the process is: 'a kind of a contest, competition or race'. (TEPA 2001) In the first instance it is student versus student in the same school. The subject Level of Achievement a student obtains is not the primary concern. What matters is how that result, when scaled using the QCS, so giving a Scaled Subject Achievement Indicator (SAI), compares with the SAIs of other students taking other subjects within the same school.

Another possible consequence of a student taking a subject is that it might affect the SAI performance by that student in another subject. Would studying Ancient History provide thinking patterns that are of value in Modern History? Would studying high level Mathematics influence SAI outcomes in Physics?

The early nineteenth century economist David Ricardo postulated the 'famous theory of comparative advantage’. (Samuelson 1958) That theory argued that even if one country was a more efficient producer of both of two commodities than another country, it would still be profitable for specialisation and trade to take place. Ricardo's demonstration that it is comparative advantage as opposed to absolute advantage is the fundamental concept that lies behind all arguments in favour of 'free trade'. A highly simplified and somewhat homespun example of the concept is: 'A traditional example used to illustrate the (apparent) paradox of comparative advantage is the case of the best lawyer in town who is also the best typist in town. Will he specialise in law and leave typing to a secretary? How can he afford to give up precious time from the legal field, where his comparative advantage is very great, to perform typing activities in which he has an absolute advantage but in which his relative advantage is least? Or look at it from the secretary's point of view. She is at a disadvantage relative to him in both activities; but her relative disadvantage is least in typing. Relatively speaking, she has a comparative advantage in typing.' (Samuelson 1958).

Since the OP system is essentially a competition between students, any given student will maximise OP output if the subject combinations taken are those at which the student is at a comparative advantage. Comparative advantage in this context is the taking of combinations of subjects that produce the best, or least bad, SAI results in comparison to other students of similar general ability.

Because subject combination selection may influence OP outcomes – depending on comparative advantage considerations – an examination of relevant SAI outcomes, separately and in combination, was indicated. This section attempts to do that by a consideration of SAI data for Physics and two levels of Mathematics for groups of students of similar general ability as measured by the QCS.

4.3 Methods.

With permission from the relevant Principals, detailed SAI and QCS data for four Government and one non Government school in Queensland was obtained from the Board of Senior Secondary School Studies. Teese (1995) noted that data must be ‘disaggregated’ rather than looking at ‘boys (or girls) as a group’. The most usual form of disaggregation is by socio-economic group. The QCS test results make it possible to disaggregate according to a measure of ability. Hence in this chapter disaggregation takes the form of comparing the SAI/OP outcomes of students with other students of similar abilities. The technique used was to apportion the students into ‘groups’ according to their QCS results. The number of groups into which the students were divided was a compromise. If a small number of groups, five perhaps, is chosen the range of ability is very wide in each group, leading to an unacceptable degree of unintentional averaging. On the other hand the larger the number of groups, the smaller the number of students in each group. The number of groups used in this paper is sixteen. Consequently the student numbers in each group area are frequently very small. For 'weak' groups as indicated by the QCS test there are often, and understandably, no students at all. The inevitable problem of a lack of robustness in the data was deemed less serious than the averaging problems inherent in wide groupings. In essence, the decision on group width was between the high risk strategy of narrow groupings which could give indicative results, or wide groups which could not possibly give valid results at all.

The sixteen groups used were 0.25 standard deviation (sd) (QCS) wide:

Group 1----------------more than 1.75 sd above state QCS mean

Group 2----------------between 1.5 sd and 1.75 sd above state QCS mean

Group 3----------------between 1.25 sd and 1.5. sd above state QCS mean.

down to group 16 (below minus 1.75 sd from the QCS mean). Note that the mean is at the Group 8/Group 9 interface.

In Queensland most students take either Maths A or Maths B. As a generalisation Maths B is the minimum requirement for entry to mathematically based tertiary study. Maths A is not acceptable for such courses. A student who takes Maths B may also take Maths C. Maths C contains material such as complex numbers, vectors, matrices, groups, dynamics (optional) and further calculus. It is generally regarded as being 'harder'. Maths C is also considered to be of assistance to students in some tertiary courses. Some universities give exemption from some first year coursework if a student has achieved highly in Maths C.

In this study three issues were considered, all pertaining to Maths B/Maths C/Physics and interrelationships between them:

(a) possible influence of taking Maths C on the SAI outcome for Maths B.

(b) possible influence of taking Maths C on the SAI outcome for Physics.

(c) comparative performance of males and females.

4.4 Relation between SAI and OP.

As noted previously, finally adjusted and aggregated SAIs lead directly to OP outcomes. Data from the Board of Senior Secondary Schools Studies, shown in table 4.2, demonstrates the effects of changes in average finally adjusted SAI on OP outcomes.

Table 4.2: Relation between mean SAI and OP band lower boundaries.

OP band	1	2	3	4	5	6	7	8	9	10	11	12	13
Band lower boundary	225	217	211	206	201	197	193	190	186	183	180	176	173

OP band	14	15	16	17	18	19	20	21	22	23	24	25
Band lower boundary	170	166	163	160	157	153	149	145	140	134	12	2

Source: QBSSSS data. 1998.

It is noteworthy that for the 'middle' OP bands, a change in average SAI of 3 to 4 produces a unit change in OP. To improve from OP5 to OP 1 requires a change in overall adjusted assessment of 24, a change that would produce an improvement from OP17 to OP7. Consequently the OP output is highly sensitive to small changes in average SAI for students at or near the average.

4.5 SAI outcomes: Maths B, with and without concurrent Maths C.

The possibility that the concurrent study of Maths C may affect the Maths B SAI outcomes was examined by a detailed consideration of SAI outcomes for students of similar ability as indicated by their individual QCS results. For each of the five schools, each student's SAI result for Maths B was taken. Those results were subdivided according to whether the student had taken concurrent Maths C or not. The results of that process subsequent to further subdivision according to the QCS grouping are as shown in Table 4.3.

Table 4.3: Maths B SAI means with and without concurrent study of Maths C.

(All scores are for Maths B only. Numbers in parenthesis are the numbers of students.)

	School A		School B		School C		School D		School E	
Group	B Only	B&C	B only	B&C	B only	B&C	B only	B&C	B only	B&C
1	---------	221 (1)	202 (2)	182 (1)	205 (2)	197(2)	--------	224 (1)	---------	213 (3)
2	209 (2)	---------	183 (2)	---------	206 (2)	---------	206 (1)	220 (1)	---------	---------
3	219 (1)	208 (3)	183 (3)	---------	194 (2)	220(3)	216 (1)	---------	196 (2)	---------
4	198 (4)	199 (2)	196 (3)	---------	178 (1)	---------	172 (1)	191 (1)	195 (2)	201 (3)
5	195 (2)	200 (2)	192 (2)	---------	178 (2)	218 (1)	177 (3)	214 (1)	198 (1)	203 (1)
6	179 (1)	196 (1)	195 (7)	206 (1)	178 (3)	---------	182 (8)	197 (2)	181 (5)	---------
7	179 (9)	188 (3)	172 (2)	223 (1)	189 (3)	---------	179 (7)	---------	195 (2)	---------
8	174 (6)	190 (1)	188 (5)	197 (1)	166 (3)	213 (1)	175 (6)	206 (2)	---------	191 (1)
9	178 (6)	---------	176 (6)	193 (1)	172 (4)	---------	177 (3)	190 (1)	180 (3)	---------
10	184 (3)	176 (2)	178 (3)	215 (1)	176 (4)	197 (2)	172 (6)	177 (1)	184 (3)	185 (1)
11	179 (2)	---------	193 (1)	---------	169 (1)	---------	166 (1)	---------	157 (1)	195 (1)
12	178 (1)	---------	165 (1)	---------	142 (1)	---------	157 (1)	---------	169 (4)	---------
13	154 (1)	---------	---------	---------	---------	---------	214 (1)	---------	---------	---------
14	---------	---------	---------	---------	---------	153 (1)	183 (2)	---------	155 (1)	---------
15	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------
16	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------

(data from five schools)

Although the students under the headings ‘B only’ and ‘B&C’ are physically different students, those students categorised in a particular ‘group’ are of similar ability as measured by the QCS. The very small numbers of students taking Maths C reduce the reliability of these results. Nevertheless, with a small number of exceptions a general pattern that students who study Maths C produce higher SAI outputs in Maths B is observable across the schools. To enable legitimate addition of results across the five schools to take place it is necessary to further readjust all SAIs to the relevant schools’ QCS means and deviations. After adjustment the results were aggregated. The mean Maths B SAIs are as shown in Table 4.4.

Table 4.4: Mean SAIs for Maths B, combined schools, with and without concurrent Maths C.

Group	1	2	3	4	5	6	7	8
MB (no MC)	200(4)	194(7)	188(9)	177(11)	174(10)	172(24)	163(23)	157(20)
MB (took MC)	209(8)	226(1)	214(6)	193(6)	203(5)	195(4)	189(4)	194(6)

Group	9	10	11	12	13	14	15	16
MB (no MC)	155(22)	159(19)	152(6)	137(8)	160(2)	153(3)	------	---------
MB(took MC)	184(2)	175(7)	185(1)	------	------	129(1)	------	---------

The small numbers in the groups make 'normal' confidence analysis difficult. However for Groups 3,5,8 and 10 they are large enough for a 1-tailed T-test to be applied. For each of those Groups the analysis shows that the MB (took MC) data is significantly greater than the MB (no MC) data. For group 3 the p-value is 0.04; for Group 5, p-value 0.027; for Group 8, p-value 0.002 and for group 10, p-value 0.044.

In 11 out of the 12 possible group comparisons students produced higher average SAI outcomes in Maths B if they also took Maths C. The weighted mean of those improvements is 25. Once again the changes in Maths B SAI outcomes for groups near to or just above the mean are noteworthy when viewed in conjunction with Table 4.2.

Within each Group, but at the individual level, it is possible to calculate the probability that a randomly selected student who took Maths C obtained a higher Maths B SAI than a randomly selected student from the same Group who did not take Maths C. For example in Group 4 the individual SAIs were: 'B only' shown in normal type, 'B took MC' shown in bold italics) 213, ***210,*** 209, ***205, 195,*** 191, 187, 185, ***183, 183, 181,*** 179, 177, 161, 160, 143, 143.

The probability that a randomly selected 'B took MC' number is higher than a subsequently randomly selected 'B only' number is 1/6*10/11+1/6*9/11+1/6*9/11+1/6*6/11+1/6*6/11+1/6*6/11 = 1/6(46/11) = 0.70. Similar probability calculations for the Groups where comparison is possible are as shown in Table 4.5.

Table 4.5: Probabilities that randomly selected (MB took MC) Maths B SAI > (MB no MC) Maths B SAI; by groups, to 2 decimal places

Group	1	2	3	4	5	6	7	8
P(MB and MC>MB noMC)	0.56	0.86	0.76	0.70	0.84	0.71	0.66	0.90
Group	9	10	11	12	13	14	15	16
P(MB and MC>MB no MC)	0.93	0.66	0.67	--------	--------	0.33	--------	--------

If there was no effect on Maths B SAI as a consequence of the concurrent study of Maths C, the probability that a randomly selected Maths B (took Maths C) result would be greater than the Maths B (no Maths C) result would be) 0.5 for each Group. The probabilities shown in Table 4.5 are greater than 0.5 in 11 out of the 12 cases. However the number of students in Groups 2,9,11 and 14 are very small indeed. Neglecting those it is clear that in the remaining groups the probability is noticeably greater than 0.5. Bearing in mind the sensitivity of OP outcomes to changes in SAI results, especially near to the mean, the improved probabilities are particularly noteworthy for the students in groups 4-8 and 10.

The probability analysis shown in Table 4.5 is indicative but not conclusive. However a consideration of the SAI/OP significance of each individual SAI leads to a much more conclusive outcome.

As mentioned previously, the OP system is a 'race', a race in which the measurement of success is given by the number of students who are 'beaten' by a given SAI outcome. In terms of any influence of Maths C on Maths B SAIs, success in the 'race' is reduced to the question "how many students of similar general ability have been beaten?"

What is required, then, is an analysis of the plethora of individual contests between students who took Maths C and those who did not. Reverting to the data for the students in Group 4 considered above, the SAI scores were:-
213, **210**, 209, **205, 195,** 191, 187, 185, **183, 183, 181,** 179, 177, 161, 160, 143, 143.
As before the results of students who also studied Maths C are shown in bold type.
Considering the student with an SAI result 210, it can be seen that the student was in eleven separate 'contests' with students who did not take Maths C but were of similar

general ability. Of these eleven individual contests the student 'won' in ten of them. The 205 result was also in eleven (no Maths C student) contests and won nine of them.

Over the group as a whole the Maths B (with Maths C) students were involved in 66 individual contests with students of similar general ability who took Maths B (no Maths C). They won 46 of those individual contests. If there were no advantage or disadvantage to be derived in Maths B from the concurrent study of Maths C, the probability of any given Maths B (with Maths C) 'beating' any given Maths B (no Maths C) would be 0.5.

Hence for all the contests between students of similar general ability and treating the data as Gaussian , we have n = 66, p = 0.5, q = 0.5; giving μ = 33 and s.d =4.062.

But, in reality, the Maths B (with Maths C) SAI is greater than the Maths B (no Maths C) in 46 cases. So x = 46, μ = 33, s.d. = 4.062.

Hence $z = \frac{46 - 33}{4.062} = 3.2$

So that the probability that there would be 46 'wins' out of 66 purely as a consequence of chance is 0.5 - 0.4993 = 0.0007. i.e. 0.07%.

If the data is treated as a binomial the result is even more extreme, giving $p<0.0004$.

It follows that for this group of students who were *all of similar general ability,* there is at most only a 0.07% probability that the generally superior results for those students who also took Maths C is a consequence of random chance.

The approach used for the students in Group 4 can be applied to each of the QCS based groups. Furthermore because each of those Group comparisons is relative to a series of individual contests between students who are of similar general ability they can legitimately be added. It would, of course, be entirely inappropriate to compare the SAI result of a student in Group 2 whose QCS result was between 1.5 and 1.75 standard deviations above the mean with another student in Group 11 whose QCS result was between 0.5 and 0.75 standard deviations below the mean.

When the approach used for Group 4 is applied to all the groups the results are that there are 697 'contests' between students who took Maths C on the one hand and students of similar general ability who did not take Maths C on the other. Of those 697 'contests', the students who took Maths C 'won' in 519 of them.

So for the overall cohort, n = 697, p = 0.5, q = 0.5.
Hence the mean is 348.5 and the standard deviation 13.2.

Giving $z = \frac{519 - 348.5}{13.2} = 12.9$

So the probability that the generally superior SAI outcomes achieved by individual students who also took Maths C in comparison with individual students of similar general ability who did not take Maths C were random is very small indeed.
($p < 10^{-16}$)

Although the existence of a correlation between the study of Maths C and improved Maths B outcomes does not necessarily imply cause and effect, it is unlikely that there is no degree of cause and effect at all. The results fit well with the common sense view that a student gains in Maths B if Maths C is also taken, in two ways. They are (a) some commonality and (b) thinking mathematically for twice as long each week.

4.6 SAI outcomes: Physics, with and without concurrent Maths C.

The concurrent study of Physics/Maths C is another subject combination that might have SAI consequences. In recent years the number of students opting to take Maths C has declined. Due to that fact, in conjunction with Physics enrolments that have not risen, few students are taking concurrent Maths C and Physics. Table 4.6 which shows mean SAIs are hence for the five schools aggregated.

Table 4.6: Physics SAIs: combined schools, with and without concurrent Maths C.

Group	1	2	3	4	5	6	7	8
Physics no MC	185 (4)	196(5)	197(1)	163(6)	155(2)	176(7)	166(11)	160(8)
Physics took MC	200 (6)	203(1)	193(6)	189(4)	186(6)	193(3)	197(2)	172(3)
Group	9	10	11	12	13	14	15	16
Physics no MC	163(2)	155(8)	139(1)	167(3)	114(1)	138(1)	---------	149(1)
Physics took MC	179(1)	160(7)	165(1)	---------	---------	---------	---------	---------

Whilst the small numbers make it hard to draw any firm conclusions about the results in any one of the groups individually and make confidence levels relatively weak ($0.2>p>0.1$ for groups four to eight inclusive) they do indicate an emerging pattern that is suggestive. In ten out of the eleven groups where comparison is possible the 'Physics took Maths C' result is higher than the 'Physics no Maths C' result.

The weighted mean of the improvements in SAI is 14, only about half of the improvements noted from Table 4.4 for Maths B outcomes. Nevertheless these improvements are again noteworthy when considered in conjunction with Table 4.2.
As for Maths B SAI outcomes, it is possible, at the individual level, to calculate the probability that a randomly selected student who took Maths C obtained a higher Physics SAI than a randomly selected student from the same Group who did not take Maths C. For example, in Group 4 the individual SAIs were: ('Physics only' in normal type, 'Physics took Maths C' shown in bold italics). 203, ***201, 199, 184,*** 178, ***173,***170, 164, 158, 104.
The probability that a randomly selected 'Physics took Maths C' number is higher than a subsequently randomly selected 'Physics only'' is
1/4*5/6 + 1/4*5/6 + 1/4*5/6 + 1/4*4/6 = 1/4(19/6) = 0.79 to 2 decimal places.
Similar probability calculations for the Groups where comparison is possible are as shown in Table 4.7.

Table 4.7: Probabilities that randomly selected (Physics took MC) Physics SAI>(Physics no MC) Physics SAI; by groups, to 2 decimal places.

Group	1	2	3	4	5	6	7	8
P(Ph and MC>Ph no MC)	0.75	0.60	0.33	0.79	0.92	0.67	1.00	0.71
Group	9	10	11	12	13	14	15	16
P(Ph and MC>Ph no MC)	1.00	0.55	1.00					

The tiny numbers of students taking Physics and/or Maths C in the five schools combined makes these figures less robust. Nevertheless the overall pattern is clear, with the exception of group 3, the probability that a randomly selected student who took concurrent Maths C scored more highly in Physics than a student from the same group but did not do Maths C is greater than 0.5. The removal of the groups in which only one student took either Physics (and MC) or Physics (no MC) are ignored (groups 2,3,9 and 11), does not alter the general pattern. As previously noted the results in the near average groups are of particular significance because of the high OP sensitivity to SAI changes in that part of the distribution.

As was the case for the possible effect on Maths B SAIs consequent to the concurrent study of Maths C, it is possible to analyse the effect on Physics by a consideration of the many individual 'contests' between the students.

The individual figures for the students in Group 4 listed above are:
203, **201, 199, 184,** 178, **173,** 170, 164, 1 58, 104.

Considering the student with an SAI of 201, it can be seen that the student was in six separate 'contests' with students who did not take Maths C but were of similar general ability. Of those six 'contests' the student 'won' in five of them.

When that method was applied to each of the groups it was found that there were 211 individual contests altogether. Of those, the Physics (took Maths C) figure was higher than the Physics (no Maths C) in 149 cases.

So for the whole cohort, n = 211, p = 0.5, q = 0.5.
giving a mean of 105.5 and a standard deviation 7.263.
But in reality the Physics (with Maths C) SAI is greater than the Physics (no Maths C) in 149 of those 211 contests.
So mean = 105.5, standard deviation = 7.263, and x = 149, giving:

$$Z = \frac{149 - 105.5}{7.263} = 5.989$$

So the probability that the generally superior outcomes achieved by those students who also took Maths C is a consequence of pure chance is 0.0000001%.

The fact that students who take Maths C generally scored higher in Physics than those who did not take Maths C is again not necessarily a matter of cause and effect. However it seems unlikely that there is no causal link at all. If students feel more comfortable mathematically, that would be a general help to their Physics. There is also a more direct linkage in the areas of complex numbers/vectors, and, where it is a part of a school's Maths C programme, dynamics.

4.7 Opinions of students in Year 12 Maths C.

Year 12 Maths C students in the five schools completed a short questionnaire within a few weeks of finishing that year (Appendix 3, part A. q.v.) when they were ideally qualified to give opinions on what it is like to take Maths C and so comment on any wider implications. Only 51 students in the five schools combined took Maths C. Of that number 44 were present (and of course responded) when the questionnaire was given. Relevant questions and responses were as follows:
In response to the question 'In Maths B, do you think you were advantaged compared to a student who does not do Maths C?' 32 % replied 'a lot', and 64 % 'a little'. Only 4 % thought they had not been advantaged at all. However only 14% considered that they had been advantaged in Physics 'a lot', 52 % by 'a little', 18% 'not at all'. 16% did not do Physics.

These responses, showing that students felt that they were advantaged in both Maths B and Physics, but to a greater extent in Maths B, tie in well with the earlier SAI analysis. Overall 26% of the students were 'very glad' they had taken Maths C, 36% were 'glad', 26% were 'not bothered' and 12% 'wished they had never started it'. Whilst it is possible that these responses are to some extent a form of self justification, it seems more likely that they are the responses of people who recognise that they have profited by the subject. That view is strengthened by the students' responses to the question ' If a Year 10 student asked you whether she/he should take Maths C in Year 11'. 26% said that they would 'strongly advise taking it', 55% 'mildly advise taking it', 14% said it 'doesn't matter', 2% ' would advise against' and 2% ' were 'strongly against'. This is important opinion; no other people-parents, teachers, guidance officers or outside experts are as well placed to advise on what it is like to take Maths C.

In addition to responding to the questions the students were asked to make comments 'about Maths C or any influence on other subjects'. That request was placed in the context that '… you are the experts…we need your advice' (see Appendix 3 parts A and C). Of the 44 students who responded to the survey, 30 made comments.

The comments volunteered by the students are an excellent insight into the educational experience that is Maths C; student attitudes to the subject and, by implication, to student motivations to higher secondary education as a whole. Because the full richness of the responses, with all their various nuances, can only be appreciated by reading them all verbatim, they are reproduced in full and without amendment in Appendix 3 part D (q.v.). However, although they are all different from each other showing a divergence of opinion, frequently poor spelling and sometimes earthiness, there are some evident recurrent themes. In the following overview of those themes, individual student comments are referred to by the numbering in the Appendix 3 D.

The inter-relationship between Maths C and Physics is frequently referred to, not always positively. Comments (1), (8), (11), (20), (25), (27), (28) and by implication (21) state that it is advantageous to take both subjects. It is perhaps noteworthy that the 'helpfulness' is usually seen as being that 'Physics helps Maths C', not the other way round. That order may simply be a reflection of the order of topic consideration within the school. Comments (23) and (26) present an alternative view, one indicating that there is no 'help' between Physics and Maths C because of lack of integration, the other supporting that view by calling for subjects to 'confer'. Dynamics is an optional topic in the Maths C syllabus. The topic is specifically mentioned in a number of student comments: (8) and (20) refer to it as a positive link; comment (11) notes the absence of Dynamics as a disadvantage in terms of Physics linkage. Dynamics is the only topic that receives multiple comments. The only other topic mentioned specifically is Groups (14) that suggests the topic be moved to Year 12.

The inter-relationship between Maths C and Maths B is referred to less frequently than the Maths C- Physics linkage. Comments (2), (11) and (27) explicitly state that Maths C 'helps' Maths B. Comments (18) and (21) contend that Maths C is an extension of Maths B. That contention, if correct, implies that Maths C 'helps' Maths B. The fact that there are fewer comments about any relationship between Maths B and Maths C than there are about the relationship between Physics and Maths C is worthy of consideration. The SAI evidence examined earlier in this chapter indicates that the influence of Maths C on Maths B is greater than its influence on Physics. Furthermore the student responses to questions 5 and 6 in the questionnaire referred to above showed that they thought they'd been advantaged more in Maths B than in

Physics. It is probable that the smaller number of more extended comments on the Maths C/Maths B linkage is because the connection between them is less topic specific than the connection between Maths C and Physics. There is no clear equivalent of the Dynamics link. The advantageous linkage between Maths C and Maths B is more amorphous, being more to do with the amount of time per week spent thinking mathematically than any specific topic.

There is no commonality of opinion on either the relative difficulty of Maths C or the work load involved. Comments (5),(11), (15), (16) and (30) state the subject is definitely 'hard', at least some of the time; comment (14) views it as conditionally 'hard'. On the other hand (3),(21), (24) and (29) consider Maths C to be not particularly 'hard'. Similarly (3) and (22) consider the work load in Maths C to be heavy but (27) disagrees. It is evident that many students view Maths C, and presumably other subjects, in a practical almost mercenary fashion. Comments (2), (7), (9), (10), (11) and (13) all refer to a 'usefulness' in some way or another. Comments (6) and (17) take a similar approach: they implicitly advise that a person should consider whether it will be useful to them. Other students refer to the enjoyment/interest of Maths C. All of (12), (13), (14), (27), (28) and (30) refer to 'fun' or 'interest', i.e. to pleasure. Even the abnormally candid comment (25) pays a backhanded complement to Maths C and Physics: they are not berated as other subjects are. A number of the student comments tie in with some of the principals' comments. For example: (9), referring to the reduction in the 'need' to do Maths C because of the decline in the number of tertiary courses that stipulate it as a pre-requisite, fits well with Appendix 2 part B SGOV 3 and SIND 5. (12) and (27) refer to the quality of the teaching. The principal SGOV 21 (and others) would agree. The student comment (23) calls for better integration of subjects as does the principal who penned SIND 20.

The general trend of the responses from the Year 12 Maths C students fit well with the earlier SAI analysis. The evidence points to there being OP output advantages in taking the combination Maths B/Maths C/Physics, that advantage being maximised if the dynamics unit is included in the Maths C.

4.8 Student reasons for subject selection.

4.8.1 Students in Year 12 Maths C

In the questionnaire referred to above (Appendix 3, part A, q.v.), the Year 12 Maths C students were also asked about their reasons for taking Maths C. 'When, at the end of Year 10 you decided to take Maths C was that because:

(a) You thought it would help you get to university. True 89% False 11%

(b) You liked Maths and wanted to do plenty of it. True 41% False 59%

(c) You thought it would help you with other Year 11 subjects. True 59% False 41%

(d) You didn't really want to do Maths C but the alternatives were even worse. True 11% False 89%

(e) You were advised to take it True 68% False 32%

The sources of advice quoted were overwhelmingly parents or teachers. Once again the impression is of students who were operating, or trying to operate, in a calculating manner. They were concerned with functionality – was it useful? That impression is also given by many of the students' comments given previously. Such 'rational' behaviour is consistent with Williams and Bell (1998) who found that 'overall senior students appeared to act in a mature, calculating manner'.

4.8.2 Opinions of students in Year 10

The SAI data, combined with the responses and comments of the Year 12 students indicate that there are advantages to students if they take the combination rigorous Maths and Physics. In order to examine the thinking of students at the time subject choices were being made a short survey/questionnaire of Year 10 students was administered. (Appendix 3, part B, q.v.) Each school applied the survey only to those students considered to be relevant to the survey. The criterion used was that previous records indicated that a student could reasonably be expected to succeed in Maths B. In reality only those students were in a position to choose, or not to choose more rigorous Maths or the physical sciences. The survey took place in October/November, that being the time when the students were in the process of subject selection. They were therefore more likely to be able to give relevant and informative responses than at any other time of the year.

Those students who were intending to take Maths B and were hence eligible to take Maths C and had decided to take Maths C (n=53) were asked whether they had made that decision because:

'You think it would help you get to university.'	True 74%	False 26%
'You like Maths.'	True 75%	False 25%
'You think it will help you in your other Year11/12 subjects.'	True 73%	False 27%
'You think it would help you when you are at university.'	True89%	False11%
'You have been advised to take it.'	True 43%	False 57%

Only a small minority of the students stated the source of such advice. However, the majority of those that did, stated that either teachers or parents were the most frequent advisors.

Those students eligible to take Maths C but who had decided not to take it (n=182) were asked whether they had made that decision because:

'You have heard it's hard.'	True 57%	False 43%
'You don't really know what it is.'	True 30%	False 70%

‘You don’t think you could do it.’	True 61%	False 39%
‘You see no point in taking it.’	True 71%	False 29%
‘You really want to take another subject on that line	True 58%	False 42%
‘You want to take a subject which you think will need less work.	True 32%	False 68%
‘You have been advised not to take it.’	True 33%	False 67%

Again only a minority of students stated the source of such advice. Unlike the sources claimed by students who intend to take the subject, this group gave very few specific sources. The most frequent source given being the vague ‘people’, a response which probably more to do with general rumour than specific information. Only two students referred to ‘teachers’. There was very little variation in either of these sets of responses between the five schools. The number of students who state that they ‘don’t really know’ what Maths C is must be of concern to the schools. A lack of knowledge about subjects being offered reduces the student's ability to make informed decisions.

Those students who had decided to take Physics and/or Chemistry were asked whether they had made those decisions because:

	Chemistry (n=87)		Physics (n=134)	
	(True/False %)			
‘You think it will help you get to university.’	90	10	91	9
‘You like Physics.’ (Chemistry)	79	21	77	23
‘You think it will help you with your university studies.'	93	7	87	13
‘You have been advised to take it.’	70	30	63	37

As was the case for those intending to take Maths C, few students stated who the source of advice was. Of those who did, the most common sources of advice were teachers and parents.

Those students who had decided not to take Physics/Chemistry were asked whether they had made those decisions because:

	Physics (n=148)		Chemistry (n=104)	
	True/False%		TrueFalse %	
'You have heard it's hard.'	56	44	38	62
'You don't really know what it is.'	23	77	11	89
'It's no use to you.'	77	23	77	23
'You have been advised not to take it	8	92	10	90

The remarkably low numbers claiming to have been advised not to take Physics/Chemistry do not fit well with the much larger number who have 'heard it's hard'. When asked to rank the Year 11 science subjects into an order of difficulty, over 90% of the Year 10 students ranked Physics hardest and Chemistry second hardest. (Appendix 3, Part B, Qn 11. q.v.) As for students not taking Maths C, these students must be working on what is 'common knowledge', i.e., on rumour. The percentage of students who 'don't really know what Physics is', whilst smaller than for Maths C. is still high and twice as high as for Chemistry. A possible contributing cause of that level of ignorance is that the word 'Physics' is seldom mentioned in the commonly used textbooks for Years 8/9/10. Again the ability of students to make informed subject selection decisions is reduced by an inappropriate level of ignorance.

4.9 Discussion.

The subject selection decisions made at the end of Year 10 are of critical significance for most if not all students. Such decisions not only determine the subjects to be taken in Years 11 and 12, but also by extension are a major determinant of the students' future at Tertiary level and beyond. In so far that student decisions are of a calculating nature rather than being based on emotion or effort minimisation it is important that they are always be based on the best information available. Furthermore it is important that 'information' that is either irrelevant or, by implication, erroneous must *not* be given.

It is in that context it is noteworthy that:

(a) No OP advantage accrues to a student by the study of one subject instead of another.

(b) At present many schools are 'informing' their Year 10 students that some subjects are 'High OP' subjects whilst others are 'Low OP subjects.' Schools are basing that 'information' on the known historical QCS means for each subject student cohort. The implication - that the students' OP will be improved by the taking of a 'High OP' subject - is entirely unsupported in the literature. Such 'information' serves not to lead but to mislead.

(c) The taking of a given subject might influence the final OP outcome if the taking of that subject produces an improved result *in other subjects* that are being taken anyway.

(d) The SAI analysis above demonstrates that the taking of Maths C produces an improvement in the outcomes for both Maths B and for Physics. (MB>Ph)

(e) Year 12 student opinion confirms the advantages noted in (d).

(f) Year 10 students are unaware of the advantages noted in (c) and (d) above.

(g) Year 10 students have at best an unreliable level of knowledge about the subjects they are choosing/not choosing.

Chapter 3 demonstrated that for many Queensland students there is a discontinuity between Year 10 and Year 11 in terms of mathematical and scientific knowledge and understanding. This Chapter demonstrates another problem facing students as they make their important subject choices at the end of Year 10. They frequently know little about the subjects in Year 11, all too often they do not *know* what the subject 'is', how difficult it is, or the OP implications demonstrated in this Chapter.

CHAPTER 5

MALE PERFORMANCE IN MATHEMATICS AND THE PHYSICAL SCIENCES IN QUEENSLAND

CHAPTER 5

5.1 Male performance: introduction

A vast amount of literature exists on the topic of female/male performance. For example the references given for one of the submissions to the House of Representatives Parliamentary enquiry *'Boys: getting it right'* consists of 195 sources. However only a minority of the material refers specifically to female/male performance in rigorous Maths and the Physical Sciences. A good analysis of regional/socio-economic influences is in Teese (1995). Very little material is specific to Queensland. Matters, et al (1999) in part examines comparative female/male performance in Maths C. Education Queensland via the Equity Programs Unit provides a slide presentation 'Boys, Gender and Schooling' for use within schools that addresses (in part) comparative female/male performance in Maths B, Maths C, Physics and Chemistry.

By far the best source of hard data in respect of outcomes is available from the Board of Senior Secondary School Studies, now the Queensland Studies Authority.
(http://www.qsa.qld.edu.au/publications/senior/statistics/Subject_stats.html)

In recent years concern about the relatively poor performance of males in terms of educational outcomes has moved well beyond the domain of educational research journals or government Education Departments. Concern has been expressed by governments per se and in the general press. For example Dr David Kemp, Federal Minister for Education stated that 'It is vital that we try to understand why boys academic performance is lower than that of girls' (Kemp 2000)[2]. In the context of this work it is noteworthy that Kemp also gave 'Boys declines relative to girls in year 12' as one of the four reasons that the 'Government was concerned'. In the wider domain, Kristine Gough, in a major article in 'The Australian' stated that the evidence that the 'perception that girls are steaming ahead' academically 'appears irrefutable'. (Gough, 2000)

The assumption that 'the girls beat the boys' is almost an accepted wisdom. Although it has been analysed in terms of socio-economic status - 'which boys, which girls', there is little questioning of the veracity of the assumption that girls are 'beating the boys'. One of the objectives of the work reported here is to examine whether that 'wisdom' is necessarily true. The 'wisdom' also includes the idea that 'in the past, boys have traditionally outperformed girls in maths, and that's no longer the case.' (Forgasz 2000). This statement was made with the implication that (hence) boys could similarly 'catch up' with the girls in English.

The Longitudinal Survey of Australian Youth Report number 22 (LSAYR 22, 2000) referred to in Chapter 2, demonstrated that when other factors are removed, gender is not a major determinant of final educational outcomes in Queensland. 'Overall and in NSW, gender has a low but statistically significant correlation with ENTER score. The correlations in Victoria, South Australia and Queensland are not statistically significant.' (LSAYR 22, 2000) However the report also states that '…achievement growth during the final years of secondary school is greater for females than for males.'

5.2 Female/Male OP performance in Queensland

It is the intention of the section of the work reported here to examine the school exit performance data for Queensland.

In Queensland at secondary level the data used to demonstrate the perceived problem of relatively weak male performance is the Overall Position (OP) ranking. Recent details of the percentage of females and the percentage of males who achieved each of the OP bands are as shown in Table 5.1.

Table 5.1: Distribution of OP eligible students, by order band/sex.

OP band	1	2	3	4	5	6	7	8	9	10	11	12	13
Eligible Females %	1.93	2.24	2.83	3.57	4.16	4.08	4.97	4.97	4.99	5.43	5.24	5.23	5.49
Eligible Males %	2.39	2.69	3.04	3.06	3.44	3.47	3.94	4.31	4.30	4.59	5.04	4.58	5.08

OP band	14	15	16	17	18	19	20	21	22	23	24	25	Total
Eligible Females %	5.63	5.16	4.82	4.61	4.46	4.17	3.89	3.24	3.24	2.52	1.82	1.31	100
Eligible													Total
Males %	4.88	5.29	5.29	4.91	4.65	4.17	4.45	4.09	4.27	3.36	2.51	2.18	100

(QBSSSS. 1998)

The substantial difference in participation rates between males and females (15000 to 12000) makes any simple comparison of performance difficult. More males than females may have obtained employment, moved to TAFE or are taking a subject selection at school which does not make them eligible for an OP result. It is only possible to speculate what OP result any given one of those males would have obtained had he stayed at school and been eligible for an OP. Nevertheless, collectively, unless almost all of the ‘missing’ males would have obtained an OP in the range 14 up to 6, a most unlikely event, the figures suggest male under-performance in that part of the distribution. Although males are performing relatively poorly in bands 4 and 5, they are not performing relatively poorly in the range 1 to 5 inclusive, the cumulative male percentage in those ranges being very similar to cumulative female performance. However male performance is poor in all OP bands from 6-14 inclusive. From band 15 downwards male percentage is higher than that for the females.

The data considered above was for the 1998 cohort. For each year since then the pattern has remained similar to that for 1998. Using the same criteria as for 1998, male performance in 1999 was cumulatively relatively poor in bands 5 to 15, in 2000 it was cumulatively relatively poor in the bands 5 to 16, and in 2001 in the band 5 to 15. Noting that the mean of the twenty five bands is at the band 12/13 interface, the relatively poor male performance is near to and somewhat above the mean.

This analysis is open to the possible criticism that in fact the vast majority of the 'missing males' *would* have all obtained OPs in the range 5-15. If that had been true then those males would have, taken collectively, achieved QCS results greater than the mean for the whole cohort, the remaining males performing level in accordance with *their* QCS results. However a consideration of female/male performances by students of comparable ability indicates that some males are performing more poorly than females of similar general ability.

5.3 Female/Male OP performance cf. QCS.

5.3.1 General.

In addition to being used as a scaling instrument, an individual's QCS outcome is shown on that student's Senior Certificate as one of five broad groups A, B, C, D and E. In 2001, over the State as a whole, 13.9% of the females were placed in QCS group A. An examination of the OP results for that year shows that 13.9% of the females were placed in bands 1, 2, 3, 4 and 0.67 of band 5. 14.8% of male students were in QCS group A. 14.8% of males were placed in bands 1,2,3,4 5 and 0.04 of band 6. Hence the males performed somewhat worse in OP terms than their female counterparts of similar general ability. When the QCS groups A and B together are considered the outcomes are that a total of 43% of females were in those groups and that 43% of females were placed in OP bands 1 to 10 inclusive plus 0.35 of band 11. 41.8% of males were in QCS groups A and B combined. 41.8% of the males were placed in OP bands 1 to 11 inclusive plus 0.4 of band 12. Again male performance is noticeably poorer than that of their female counterparts of similar general ability.

The same pattern: that males under-perform in the region above the mean in comparison to females of comparable general ability also occurred in 2000, 1999 and 1998. The 2001 data is hence not aberrant but typical.
It has to be noted however that in the very highest OP bands the males out-performed the females. For example more males (in absolute numbers) achieved OP1 or OP2 combined than did females, even though the total number of females in the cohort was 23% greater than the total number of males. All the indicators are that the analysis immediately following Table 5.1 is correct and that males are performing relatively poorly in the OP bands near to and somewhat above the mean.

Any analysis of performance in school *subjects* and OP also must consider the general ability level of the students concerned. In the following analysis the same approach as that used in Chapter 4 is utilised. The QCS results are used as the measure of general ability. The students' QCS results are broken up into the same 16 groupings as before, the group width being 0.25 of the standard deviation of the QCS data.

It is crucially important to note again that valid female/male comparison cannot be performed by simply looking at 'how well' the female students have done compared to the male students in any given subject. The QCS results of the various groups show that they are of differing general ability. That factor has to be factored into any analysis of comparative Female/Male outcomes

5.3.2 Female/Male performance, Maths B, with and without concurrent Maths C. 5 schools.

An examination of the method used to derive the OP results (see Appendix 5) shows that relatively poor OP performance happens, and can only happen because other students obtain higher Scaled Subject Achievement Indicators (SAI). Consequently in so far as some males may be under performing in terms of OP output in comparison to females of similar ability, their SAI results must, in general, be poorer than those obtained by the females. It is hence of relevance to examine the Maths B SAI outcomes subdivided by gender. As before, the question is: what improvement in Maths B occurs if concurrent Maths C is also taken? The extra subdivision into female/male in conjunction with poor participation rates in Maths C compels the use of data from the five schools combined. Results are as shown in Table 5.2.

Table 5.2: Maths B. SAI outcomes, with/without concurrent Maths C.
Total schools and by gender.

	Female		Male			Female		Male	
Group	B only	B & C	B only	B & C	Group	B only	B & C	B only	B & C
1	200 (4)	193 (2)	---------	211 (6)	9	163(14)	190 (1)	145 (8)	190 (1)
2	193 (7)	---------	---------	222 (1)	10	168(10)	---------	165 (9)	174 (7)
3	189 (6)	---------	195 (3)	204 (6)	11	188 (2)	---------	156 (4)	190 (1)
4	183 (6)	191 (3)	188 (5)	195 (3)	12	148 (3)	---------	162 (5)	---------
5	184 (6)	206 (2)	171 (4)	200 (3)	13	---------	---------	166 (2)	---------
6	178(17)	203 (1)	167 (7)	190 (3)	14	176 (2)	---------	147 (1)	129(1)
7	172(12)	---------	161(11)	191 (4)	15	---------	---------	---------	---------
8	165(14)	189 (3)	174 (6)	196 (3)	16	---------	---------	---------	---------

For females comparison is only possible in six groups, i.e. 1,4,5,6,8 and 9. In five of those group comparisons the 'B and C' outcome is higher than the 'B only' indicating that females have generally achieved higher results in Maths B if they had also taken Maths C. The weighted mean of those changes is 15. For males comparison is possible in ten groups. In nine of those groups the 'B and C' outcome is higher than the 'B only' outcome. That indicates that males also have generally achieved higher results in Maths B if they also took Maths C. The weighted mean of the improvements is 19, a result that is somewhat higher than for females. Although it would be inappropriate on the basis of this data to claim that males are more advantaged than females, there is no indication at all of the reverse, i.e. that females are more advantaged. Because comparative advantage requires only that males do as well as females, the combination of Maths B and Maths C is a probable area of comparative advantage for males.

5.3.3 Female/Male performance, Physics, with and without concurrent Maths C.

A similar subdivision to that applied for Maths B, when applied to Physics gives SAI outcomes as shown in Table 5.3

Table 5.3: Physics SAI outcomes, with/without concurrent Maths C.
Total schools and by gender.

	Female		Male			Female		Male	
Group	Phy.**no** M.C.	Phy.**and** M.C.	Phy. **no** M.C.	Phy.**and** M.C.	Group	Phy. **no** M.C.	Phy.**and** M.C.	Phy. **no** M.C.	Phy.**and** M.C.
1	194 (3)	177 (2)	----------	203 (5)	9	158 (1)	179 (1)	167 (1)	----------
2	197 (3)	---------	213 (1)	----------	10	167 (1)	169 (1)	153 (7)	158 (6)
3	195 (1)	169 (1)	173 (2)	198 (4)	11	---------	---------	139 (1)	165 (1)
4	158 (4)	188 (1)	170 (2)	192 (3)	12	---------	---------	161 (3)	---------
5	152 (1)	190 (2)	171 (2)	182 (3)	13	---------	---------	114 (1)	---------
6	189 (3)	---------	172 (4)	193 (3)	14	---------	---------	140 (2)	---------
7	161 (2)	---------	165 (8)	181 (3)	15	---------	---------	---------	---------
8	154 (2)	160 (1)	155 (8)	172 (2)	16	---------	---------	149 (1)	---------

As was the case for the Maths B SAIs, the Physics SAI improvements when concurrent Maths C was taken is noticeable for males as well as for females. For females the 'Physics and Maths C' outcome is higher than the 'Physics only' outcome in five of the seven possible comparisons, the weighted mean improvement being 8. For males the 'Physics not Maths C' outcome was higher in all the eight groups where comparison was possible, the mean improvement being 16. Again the evidence is that males have been advantaged by at least as much as the females. Hence the subject combination Physics/Maths C is another probable area of comparative advantage for males. The very small number of students in Table 5.3 is a reminder of the very low participation rates, and hence the small pool from which Tertiary physical Science and Engineering departments can draw.

The finding that males are relatively advantaged by the concurrent study of Maths B, Maths C and Physics is in harmony with Matters et al. (1999). They demonstrated that 'Girls and boys taking the most "popular" combinations of subjects in non-state schools have about the same distribution of overall achievement. In state schools, on the other hand, the boys are ahead, markedly so in the middle third of the achievement range. At the other extreme (the most "odd" combinations), girls are ahead in achievement, especially so in the state sector.'

5.4 Comparison of Female/Male OP performance with general ability measures (QCS). Statewide.

The SAI comparisons for the five schools indicating that males do at least as well as females of similar general ability when they take the combination Maths B/Maths C and Physics, cannot consider trends over time. In all cases used in this chapter comparison has been in respect of one year and on the effect of the concurrent study of Maths C upon other subjects. An alternative method of examining the relative performance of Females/Males is to consider their 'results' in terms of the rates of achievement in each subject individually at the two highest levels-Very High Achievement and High Achievement'. Such a comparison has no significance at all if it is done at the rudimentary level used by the Equity Programs Unit. Fortunately the QCS data for each subject group is available for the state as a whole, so is possible to compare actual achievement level outcomes with those that would have been expected in the light of the QCS data. That approach has the advantages that it is possible to look at any trends that may be occurring over time, and is over the state as a whole. The methodology used to compare Female/Male performance in Physics is shown in 5.4.1.

5.4.1 Male/Female performance in Physics

Relevant data sets that are available are:

(a) Student Levels of Achievement for each subject for each year. The numbers achieving each Level of Achievement are also subdivided Female/Male and Total.

(b) Scaling test (QCS) results for each of those groups for each of those years. That data (μ and σ) is also subdivided Female, Male and All.

The objective is to examine how the known 'Total' number of the two highest Levels of Achievement ('Very High' and 'High') might be expected to have been sub divided between females and males in the light of the differing 'strengths' of those groups as measured by the scaling test (QCS). The 1997 data for Physics is used in the following example of the calculation method.

The Physics LOA results for 1997 were as shown in Table 5.4.

Table 5.4: **Student results, Very High Achievement, High Achievement and Total of all 5 Levels of Achievement. Physics, 1997.**

	VHA	HA	Total (Took all 4 semesters)
Male	559	948	4702
Female	289	579	2183
All	848	1527	6885

(QBSSSS data)

Bearing in mind the fact that the OP system re-scales data on the assumption that the data is Gaussian, it follows that any analysis of the data in Table 5.4 must use the same method. The total number of students awarded Very High Achievement or High Achievement is 2375, a number that is 34.5% of the total number of students that completed all four semesters. 0.345 is the area to the right of a z-score of 0.399.

The QCS data for the Physics students over the whole State in 1997 were as shown in Table 5.5:

Table 5.5: Mean and standard deviation of QCS results, Physics cohort 1997

	Mean	Standard deviation
All students	142.8	27.7
Females	148.2	26.0
Males	140.3	28.1

(QBSSSS data)

Calculation: Stage 1.

For 'all' the students, QCS μ=142.8, σ =27.7

The earlier stage of the calculation indicated that only the student group that had a z - score > 0.399 would expect to achieve either a VHA or an HA.

Substituting into $z = \frac{x-\mu}{\sigma}$ we have

$$0.399 = \frac{x-142.8}{27.7} \text{ giving } x = 153.9$$

so for the whole student cohort, a QCS result of 153.9 would be the 'expected' score to achieve a VHA/HA in Physics in 1997.

It should be noted that the use, by the (then) QBSSSS, of the mean and standard deviation in essence assumes that the overall distribution is Gaussian. Clearly that may well not be strictly true. However the fact that the techniques used in the actual calculation of the Adjusted SAIs (and hence OP outcomes) assume that the distribution is normal may be considered to legitimise the technique shown in Stage 1 above.

Calculation Stage 2.

In order to estimate how the Total number of VHA/HA results might be expected to subdivide for the female and Male cohorts, it is necessary to examine the QCS distributions for those groups separately.

Figure 5.1 represents the two normalised probability QCS distributions for the groups - assumed Gaussian and significantly different from each other.

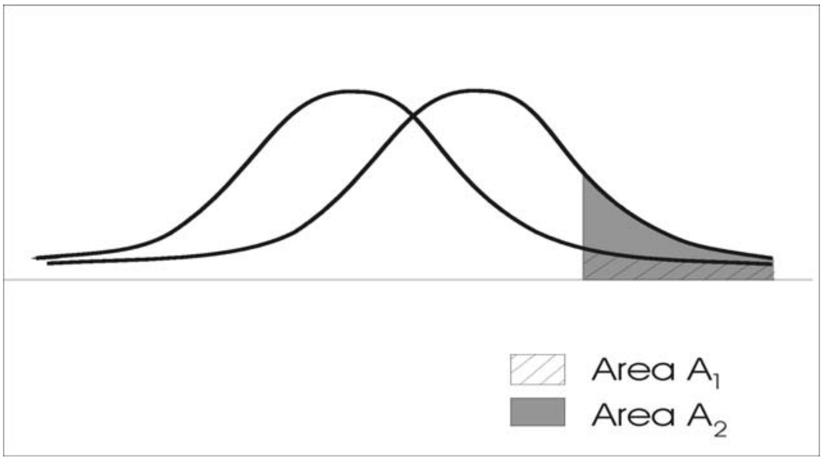


Figure 5.1 Two normalised Gaussian Distributions

It is necessary to find areas A_1 and A_2 which when multiplied by their respective sample numbers N_{p1} and N_{p2} will give the expected number from each of the populations that will exceed *x*.

Using *z* values:

$$Z_2 = x - \mu_2$$

$$Z_1 = (\mu_2 - \mu_1) + Z_2$$

We can calculate A_1 and A_2

$$A_1 = 1/2 - 1/2 \, \mathrm{erf}(Z_1/(2)^{1/2})$$

and $$A_2 = 1/2 - 1/2 \, \mathrm{erf}(Z_2/(2)^{1/2})$$

From data in Tables 5.4 and 5.5 we have:

μ_1 = 140.3; σ_1 = 28.1; N_{p1} = 4702; μ_2 = 148.2; σ_2 = 26.0; N_{p2} = 2183

Hence we obtain $N_{p1}A_1$ = 1475, and $N_{p2}A_2$ = 901

i.e. 'expected' number of males achieving VHA/HA would be 1475, in actuality 1507 were awarded VHA/HA. For females the 'expected' number would be 901 but in reality 868 females achieved that level.

These results cannot be taken as being precise. They are nevertheless highly suggestive. The difficulties with the calculation are that:

(a) the QCS data is for all students who took even one semester of the subject, the 'total' number used is for those who completed all four semesters. This problem is almost certainly not as serious as it may seem to be because most of the students who 'drop' a subject do so because they are performing poorly. Few students who are working at a VHA or HA level will drop the subject. Furthermore, the percentage 'drop out' rate is similar for Males and Females.

(b) The standard deviation data available is only given to three significant figures. (In reality many more significant figures are used in the actual calculation of OP outcomes.)

(c) None of the three distributions used, i.e. for Females, Males and All are necessarily perfectly Gaussian.

Despite these caveats in respect of the approach the fact that when the approach is repeated for a subject over a period of years and for a number of subjects fairly consistent patterns emerge. That can be seen from the 'predicted' and actual VHA/HA results for Physics over the period 1992 to 2001 as shown in Table 5.6

Table 5.6: 'Predicted' and actual numbers of VHA/HA results, by gender, Physics 1992-2001.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Female, Predicted	830	856	811	843	796	901	902	889	892	867
Female, Actual	827	858	812	813	804	868	861	834	879	853
Male, Predicted	1712	1607	1534	1419	1332	1475	1498	1558	1527	1615
Male, Actual	1711	1601	1533	1445	1329	1507	1533	1616	1539	1625

('Actual' - QBSSSS data. 'Predicted'- calculated.)

An examination of these figures sheds some light on the two questions/assumptions: are the males doing notably poorly and are they getting progressively worse? The responses have to be that (a) males are not performing poorly in Physics in comparison with females of similar ability as indicated by the QCS test, and (b) there is no sign at all of any deterioration over time. In particular it is noteworthy that for all of the most recent years 1997 to 2001 inclusive the females' 'actual' number is less than the 'predicted' number whereas the reverse is the case for the males.

5.4.2 Female/Male performance in Maths C

Much of the earlier work reported here demonstrated the SAI effects of the concurrent study of Maths C, Maths B and Physics. That work indicated that both males and females were advantaged in both Maths B and Physics if they also took Maths C, and furthermore that because the males gained at least as much as the girls the concurrent study of those subjects is a comparative advantage for males. In simple terms the SAI results indicated that more males should take Maths C. That work did not examine the outcomes in Maths C itself. An analysis similar to that used above for Physics but for Maths C produces a clear picture of relative male/female outcomes in Maths C over the period 1992-2001 as shown in Table 5.7.

Table 5.7: 'Predicted' and actual numbers of VHA/HA results, by gender, Maths 2 1992-1994, Maths C 1996-2001, Maths 2+Maths C 1995.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Female, Predicted	548	576	472	554	495	512	452	517	482	448
Female, Actual	588	654	551	575	520	514	468	569	503	490
Male, Predicted	1331	1341	1090	1172	965	968	956	980	922	982
Male, Actual	1276	1263	1012	1153	939	962	942	931	902	942

('Actual'- QBSSSS data. 'Predicted'- calculation.)

The introduction of the then new syllabus Maths C in place of the former Maths 2 took place over a number of years. However for all years except 1995 the numbers taking Maths 2(1992-1994) or Maths C (1996-2001) were preponderant. In 1995 the numbers were more nearly equal. Hence for that year the figures given are for the sum of the two subjects.

For this subject the position is radically different from that for Physics. For every year the females' 'actual' result is higher than that 'predicted'. On the other hand the male 'actual' performance is consistently worse than 'predicted'. It is important to note however that there is no sign whatsoever that the females have been 'catching up'. It is meaningless to talk of 'catching up': the females have always been ahead.

The undoubted superiority of female performance in Maths C at the VHA/HA level shown by this analysis disguises a difference in Maths C outcomes according to school 'type'. Matters et al (1999) state that for 'males and females who take Maths C and attend state schools, the females are *always* ahead', but that ' there is no clear difference between the results of males and females who take Maths C and attend non- state non-Catholic single sex schools. The state school Maths C outcomes somewhat complicate the other Matters et al finding referred to earlier, i.e. that state school males do better than females if they take popular combinations of subjects. The two facts are not mutually exclusive. The SAI analysis shows that males gain relatively by taking Maths C due to a relative improvement in both Maths B and Physics. Hence when the males relatively lose in Maths C itself, they still make an overall relative gain. Not so much a case of 'swings and roundabouts' but one swing and two roundabouts.

5.4.3 Female/Male performance in French

Subjects such as Maths C, French etc are abnormal in a number of ways. Firstly one gender or another predominates numerically, secondly virtually half of the students are awarded either a VHA or an HA. It is convenient at this point to look briefly at French in Queensland for the years 1992, 1997 and 2001. Those years were the start, middle and end of the period that was considered for Physics and Maths C. The results are an extreme example of the inappropriateness of a consideration of simplistic percentage outcomes as a measure of male/female performance. In 1992 33% of males but 'only' 27% of females were awarded a VHA. In 1997 42% of males but 'only' 37% of females were awarded a VHA. At the end of the period under consideration, i.e. 2001, males again 'beat' the females by 40% to 37.5%. At a rudimentary level it appears that the males are doing much better than the females. However, when the same analytical method as was used for Physics and Maths C is applied to the French results the outcomes are as shown in Table 5.8.

Table 5.8: 'Predicted' and actual numbers of VHA/HA results, by gender, French, 1992, 1997, 2001.

Date	Female Predicted	Female Actual		Male Predicted	Male Actual
1992	290	298		106	98
1997	307	316		103	98
2001	347	349		97	97

('Actual' - QBSSSS data. 'Predicted' - calculation.)

There is now no indication at all that the males are outperforming the females. On the contrary, the data from both 1992 and 1997 indicates that they are somewhat under performing, and that only in 2001 are they performing as well as females of similar all round ability as measured by the QCS test.

The analysis above for French is of interest in that it is dealing with a subject in which male participation levels are very poor (much lower as a percentage than is female participation in Physics). The analysis indicates again the importance of comparing 'like with like' in terms of the relative general 'strength' of the groups, but the numbers involved are very small and the students involved are located in relatively few schools. In 2001 only 557 students completed four semesters of French. That small number was spread across 103 schools, an average of fewer than six students per school. As noted earlier very small numbers place a serious strain on staff resources. The number of schools in 2001 that were offering English at Year 12 level was 349. The vast majority of students in Years 11 and 12 in Queensland do not have the opportunity to study French in Years 11 and 12.

5.4.4 Female/Male performance in Maths B

The level of Maths in Years 11/12 that is regarded by the universities as sufficient to enter, and subsequently succeed at, tertiary subjects that are mathematically based is Maths B. Any student in Years 11 and 12 who is studying Maths C must also be taking Maths B. Those facts, together with the quite high and relatively stable participation rates make a female/male comparison highly informative. If the females are not 'beating the males' in Maths B, and/or 'catching up' with them, then the whole set of assumptions to do with 'poor male performance' is close to complete collapse. The relevant Maths B subject results and QCS data is as shown in Table 5.9.

Table 5.9: Upper Levels of Achievement and QCS results, Maths B, 1992, 1997, 2001.

	VHA	HA	Total (4 sems)	%VHA/HA	QCS. (μ/σ)
1992, female	664	1232	5756	32.9	143.9/26.9
1992, male	859	1355	6880	32.2	142.9/27.8
1997, female	653	1380	6314	32.2	138.5/25.1
1997, male	857	1279	6995	30.5	135.5/27.5
2001, female	776	1426	6028	36.5	147.5/24.9
2001, male	993	1452	7032	34.8	143.5/26.8

(QBSSSS data.)

The data follows the usual pattern each year. The percentage of females awarded a VHA/HA is consistently higher than the percentage of males receiving those levels of achievement. That data could be used to reach the simplistic conclusion that the females are necessarily doing better than the males. However the QCS data also follows the common pattern that the males have a lower mean and a higher standard deviation than the females. That factor must also be included in any comparison of female/male success. When the QCS results are considered then, using the same calculation system as was used for Physics, Maths C and French, the 'predicted' and actual numbers of VHA/HA results were as shown in Table 5.10:

Table 5.10: 'Predicted' and actual numbers of VHA/HA results, by gender, Maths B, 1992, 1997, 2001.

Date	Female Predicted	Female Actual		Male Predicted	Male Actual
1992	1909	1896		2206	2214
1997	2056	2033		2109	2136
2001	2275	2202		2377	2445

('Actual'- QBSSSS data. 'Predicted' - calculation.)

These results give no support whatsoever to the proposition that females are outperforming males. For each of the three years, the females actual performance was lower than the 'predicted'. The males actual performance was higher than that 'predicted' for each year. The problems with the calculation system used (referred to previously), make it inappropriate to claim that males have 'beaten' the females in 1992 and 1997. The most recent data set, for 2001, is more convincing. Two matters are, however, beyond reasonable doubt: firstly there is no evidence whatsoever in this data to support the claim that the females are outperforming the males, and, secondly, the females are obviously not 'catching up'. On the contrary it is possible to argue that they may be falling behind.

The importance of the Maths B analysis to the female/male debate is hard to overestimate. Maths B is not, and cannot be viewed as a relatively specialised subject with a low participation rate (as both French and to a lesser extent Maths C may be viewed), it is a major subject, taken by more than one third of all year 11/12 students. The mean QCS results for Maths B are always higher than for the whole student cohort but lower than for Maths C. For example. In 2001, the mean for all students was 132.4, for Maths B students 145.4 and for Maths C students 153.4. Hence the Maths B cohort is distributed over the middle to upper part of the overall distribution, but not concentrated almost entirely at the extreme upper end as must be the case for Maths C. In particular many of the students will be in region of the OP distribution (5 to 15) in which relatively poor male performance has already been identified.

5.4.5 Female/Male performance in Chemistry

In the examination of enrolments in Queensland it was noted that the history of enrolments in Chemistry is very different from that for Physics or Maths C. (see Chapter 1 Table 28). In particular it was noted that although total enrolment had remained relatively stable over the last decade, the ratio of number of females to males has changed dramatically. That ratio change has occurred because male enrolments have declined by 11%, female numbers have increased by 10%.

The fact that Chemistry has an enrolment history drastically different from other subjects considered so far in this Chapter makes an examination of female/male performance in the subject of particular interest. The relevant subject result data is as shown in Table 5.11.

Table 5.11:Upper Levels of Achievement and QCS results, Chemistry, 1992, 1997, 2001.

	VHA	HA	Total (4sems)	%VHA/HA	QCS.(μ.σ)
1992, female	486	782	3068	41.3	149.2/27.6
1992, male	715	1016	4358	39.7	147.3/28.3
1997, female	494	1027	3430	44.3	143.5/25.8
1997, male	570	1029	3866	41.4	141.3/27.3
2001, female	597	1046	3362	48.9	151.2/25.1
2001, male	614	1032	3898	42.2	148.1/26.7

(QBSSSS data.)

Although the usual patterns: a higher female percentage at VHA/HA, higher female QCS mean but lower standard deviation, is evident, it appears that change has occurred over the period. Firstly the female 'lead' in percentage VHA/HA is increasing such that by 2001 the gap is remarkably large. Secondly the QCS mean 'gap' has increased to more than three units. The consequences of the usual analysis when applied to this data set are as shown in Table 5.12.

Table 5.12: 'Predicted' and actual numbers of VHA/HA results, by gender, Chemistry, 1992, 1997,2001.

Date	Female Predicted	Female Actual		Male Predicted	Male Actual
1992	1282	1268		1718	1731
1997	1522	1521		1603	1599
2001	1603	1643		1684	1646

('Actual' - QBSSSS data. 'Predicted' - calculation.)

The trend seems reasonably clear, female performance in comparison to that of males of similar general ability has probably improved. Caution is needed however because in 2000, the female 'Predicted' was 1729, the actual number being 1718. In the same year the male 'Predicted' was1614, the actual number being 1627. If the 2001 figures are not aberrant and are replicated over the next few years then it is possible that Chemistry is an example - the only one out of the subjects considered in which it could be said that the females have 'caught up'.

5.4.6 Female/Male OP performance: discussion

The differences between Physics and Chemistry are manifold. (a) The number of females taking Chemistry is increasing whilst male participation is declining. (b) In Chemistry, females, in 2001 (but not 2000), are slightly outperforming males of similar ability. (c) The percentage of students awarded VHA/HA in 1992 was nearly the same in Chemistry (40.4%) as it was in Physics (40.2%). By 2001 it was notably greater: Chemistry 45.3%, Physics 41.8%.

Point (c) above raises the question as to the relative ease of obtaining a VHA/HA in the subjects Maths B, Maths C, Physics and Chemistry. In each calculation performed to find the 'predicted' numbers of VHA/HA it was necessary to find the minimum QCS value required to obtain a VHA/HA (referred to as x in the worked example on page 113 of this chapter). If these are taken as an indication of 'difficulty', then for the years 1992,1997, 2001 the orders are (hardest to easiest):

1992. Maths C 157.4, Maths B 155.6, Physics 155.3, Chemistry 154.9.

1997. Physics 153.9, Maths C 152.6, Maths B 149.9, Chemistry 147.2.

2001. Physics 155.3, Maths B 155.0, Maths C 154.8, Chemistry 152.7

The only common factor for all the years is that if the QCS data is taken as a yardstick it is easier to get a VHA/HA in Chemistry than in the other three subjects. The fact that it is below Maths B is particularly surprising because Maths B is such a widely taken subject.

The overwhelming indication of the work reported in this chapter is that in Maths B/Maths C/Physics/ Chemistry, males are performing as well as females of similar general ability in two ways. Firstly males are comparatively advantaged in both Physics and Maths B (in terms of SAI outcomes) if they study concurrent Maths C. Secondly males are performing at least as well as females of similar general ability in Maths B and Physics. Maths C is the one subject where the evidence indicates that males are being, and always have been, outperformed by females of similar general ability. The situation in Chemistry is somewhat unclear (see table 5.11 and subsequent discussion), but it is probable that male performance is similar to female performance. Because comparative advantage in this work requires only male parity of performance, the concurrent study of Maths B/Maths C/Physics/Chemistry is an area of comparative advantage for males. With the possible exception of Chemistry there is no indication at all that the females have 'caught up'.

It is necessary to recognise that these conclusions are contrary to all 'received wisdom' and also to a mass of other indicators. Oft quoted indicators of inferior male performance in Queensland are:

(a) Average results (Levels of Achievement) in English are lower for males than for females. That statement is true for every year from 1992 to 2001 without exception. The difference in LOA is about one third of an achievement level. (QBSSSS data)

(b) Average results (LOAs) in Maths B are generally lower for males than for females. In the ten year period 1992 to 2001, female average LOA was superior to that of males on seven occasions, the male result was superior once and in 1993 and 1998 the results were the same. (QBSSSS data)

(c) Total Average Levels of Achievement, i.e. over all subjects were higher for females than for males in every year from 1992 to 2001. The differences consistently about one quarter of an achievement level. (QBSSSS data)

(d) As was seen earlier in this chapter male OP performance is consistently poor in the range of bands 5 to 15.

Although it appears that there is a clear conflict between the outcomes of analysies used in this work and the contrary indications in (a) to (c) above, it has to be recognised that (a) to (c) above are comparisons of groups that may or may not have been comparable, whereas the analysies in this chapter (and Chapter 4) all utilised the QCS outcomes as an indication of general cohort strength.

5.5 The scaling tests: historical Female/Male performances

As discussed previously the usual indicator, in the public domain at least, of relatively poor male performance in Queensland is the OP outcomes. The final OP result and its predecessor the 'Tertiary Entrance Score' are both outcomes consequent from a calibration of school subject results.(see Appendix 4). Since the mid 1970s school subject outcomes are the consequence of a highly organised peer moderated system under the auspices of the QBSSS or QBSSSS. There has been no essential change in that aspect of the system for nearly thirty years. However there was a major change in the test used for calibrating/scaling the subject results. Originally the scaling test was the Australian Scholastic Aptitude Test (ASAT) which consisted of two multiple choice papers with a total of ninety questions. Those questions were founded on a wide variety of types of stimulus material. Examples of ASAT scores are as shown in Table 5.13.

Table 5.13: ASAT basic data, selected subject groups, 1973 to 1988.
(rounded to nearest integer)

	English μ,σ		Physics μ,σ		Maths C μ,σ		Maths B μ,σ		Chemistry μ,σ	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1973	51/12	49/12	56/11	60/10	56/11	60/10	52/12	54/11	55/11	58/11
1974	51/12	49/12	56/11	60/10	56/11	60/10	52/12	54/11	55/11	58/10
1975	51/12	49/12	56/11	60/10	56/11	60/9	53/12	54/11	56/11	58/10
1976	52/12	48/11	57/10	60/9	58/10	61/9	53/11	54/10	57/10	57/10
1977	52/12	49/11	58/11	61/10	59/11	61/10	54/11	55/11	57/11	58/10
1978	51/12	49/12	58/10	61/9	59/10	61/9	55/11	56/10	57/11	58/10
1979	52/12	49/12	58/10	61/9	59/10	60/9	55/11	55/10	58/11	58/10
1980	51/12	49/12	57/9	60/8	57/9	60/8	55/10	56/10	57/9	58/9
1981	52/12	49/12	58/10	60/10	59/10	60/10	56/11	55/10	58/10	58/10
1982	53/12	48/11	59/10	59/10	60/10	59/10	56/11	54/10	59/10	57/10
1983	52/12	49/12	58/10	60/10	59/10	60/10	56/11	55/10	58/11	57/11
1984	50/12	50/12	57/10	61/9	58/10	61/9	55/10	57/10	57/10	59/10
1985	51/12	49/12	59/11	61/10	60/11	61/10	56/11	56/11	58/11	58/11
1986	52/12	49/12	59/10	61/10	60/10	61/10	56/11	55/10	58/11	58/10
1987	52/12	49/12	59/10	60/10	60/10	60/10	57/10	55/10	58/10	57/10
1988	51/12	49/12	59/11	61/11	60/11	61/11	56/11	55/11	58/11	58/11

(QBSSSS data)

All the ASAT figures available from BSSSS have been standardised by the Board to an overall mean of 50 and a standard deviation of 12. The results for English have been used as a reasonable substitute for data for 'all' the students, data for which cohort is not available. A number of trends are observable:

(a) The male mean in English is higher than the female mean in all years without exception. The 1984 result that shows equality is in fact a consequence of rounding, the more accurate results being a male mean of 50.47, the female mean was 49.79.

(b) That male domination is totally reversed for Physics, where the female mean is higher than that for males in every year except 1982. In that year both male and female scored a mean of 59.04. The cohort of female students of Physics has always been and continues to be highly self selected and hence very talented. It is worth noting that for every year during 1973 to 1988 the mean of the males taking French was very much higher than the mean for females. In that sense French is simply Physics in reverse.

(c) For another supposedly 'male' subject, Maths C, the females again outscored the males in all years except 1982 and 1987.

(d) For both Maths B and Chemistry the mean result for the females was substantially better than that achieved by the males in the earlier years. Later the males are doing rather better. However it must be remembered that the male 'improvement' in those subjects was in a context of an overall set of data in which the males were outscoring the females every time.

The successor to the ASAT test as the scaling device is the Queensland Core Skills Test (QCS). It is this test that has been used throughout the work reported in this thesis. The QCS test is structurally different from the previous ASAT test. In addition to two Multiple Choice papers there are also a short response test and a separate writing task. In the ten year period 1992 to 2001 considered in this chapter the QCS results were as shown in Table 5.14.

Table 5.14: QCS mean and standard deviation, all students in total and by gender, 1992-2001.

		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
All	μ	126.9	133.3	129.4	129.9	125.3	123.8	122.9	114.8	119.0	132.4
	σ	31.9	32.3	31.0	30.9	28.6	29.2	28.7	29.8	28.4	29.1
F	μ	126.1	133.7	129.7	131.0	125.9	124.5	123.0	115.7	119.7	133.0
	σ	31.3	31.1	30.0	29.7	27.5	27.8	27.9	28.8	27.5	28.1
M	μ	127.7	133.0	129.1	128.7	124.6	123.1	122.7	113.8	118.1	131.7
	σ	32.6	33.6	32.0	32.1	29.8	30.6	29.7	30.8	29.4	30.3

(QBSSSS data)

With the exception of 1992, the pattern is consistent: the female data has a higher mean and a lower standard deviation than the male data. The difference between the outcomes shown in Table 5.14 for the QCS results and those shown in Table 5.13 for the ASAT outcomes is stark indeed.

The QCS data available from QBSSSS is subdivided in various ways. The separated results for the various parts - Multiple Choice, Short Answer and Writing Task - are all available by gender and for every subject grouping. It is worth noting that the Writing Task is weighted at about 30% of the total.

The results for the sum of the two Multiple Choice plus the Short Answer sections are also subdivided into 'hard', 'medium' and 'easy'. The Writing Task is naturally not included in that subdivision. The plethora of detailed information makes it possible to see not just who 'won' overall, but in what sub-sections that 'winning' took place.

Table 5.15 shows a very simplified summary of the QCS female/male outcomes divided into 'hard items', 'medium items', 'easy items', total Multiple Choice plus Short Answer, the Writing Task and the overall female/male outcome. A female mean result higher than the male mean result is shown F, a male mean result higher than the female mean result is shown M. In one case the two means were identical, that result is shown M/F.

Table 5.15: QCS outcomes by item difficulty, Hard (H), Medium (M), Easy (E), by total(H+M+E), by Writing Task (WT), by Total Score and gender.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Hard (H)	M	M	M	M	M	M	M	F	M	M
Medium(M)	M	M	M	M	M	F	M	M	M	M
Easy (E)	M	M	M/F	M	M	M	M	M	F	M
H+M+E	M	M	M	M	M	M	M	M	M	M
W.T.	F	F	F	F	F	F	F	F	F	F
QCS total	M	F	F	F	F	F	F	F	F	F

(QBSSSS data)

The effect of the Writing Task is clear. The males' outcomes are generally superior to those of the females for the 'Hard' items (9/10), the ''medium' items (9/10) and for the 'Easy' items (8.5/10). Consequently the males outcomes are always superior to those achieved by the females for the whole of the QCS test except for the Writing Task. However the females' superiority in the Writing Task is large enough to outweigh the other results so that overall the females QCS outcome is higher than that achieved by the males in nine out of the ten years. In the absence of the Writing Task the QCS outcomes would be almost the same as occurred on the ASAT test.

The QCS is a scaling instrument. (see Appendix 4). For mixed schools that have a predominance of students from lower socio-economic backgrounds the effect of the Writing Task on final OP outcomes could be significant. Boys from such backgrounds are generally much weaker at English than at other aspects of their education, and weaker than boys of higher socio-economic backgrounds. It is hence possible that the males' poor Writing Task results - and hence seriously weakened QCS results - will adversely affect *all* the students, both female and male, in that school. That would occur because in Stage 2 of the OP calculation the mean and standard deviation of all the students in the school is used in the cross-school part of the scaling system. It is, of course, by no means certain that that would take place. One thing is certain, however: either the Writing Task does have an effect on OP outcomes via the re-scaling process or it does not. If it does have an effect then some students must gain and others must lose. If it were to be the case that students from poorer areas are relatively disadvantaged then the use of the Writing Task as part of the scaling process becomes a social justice issue. If it has no effect on final OP outcomes then it is hard to see why it is used in the scaling process at all.

The additional detail of outcomes available from the QCS test as opposed to the earlier ASAT test makes it possible to examine not just overall comparisons of female/male QCS results but also make comparisons according to each part of the QCS test for each subject. Table 5.16 shows an abbreviated version of QCS outcomes for Physics. As before H+M+E is the sum of the Hard, Medium and Easy items in the Multiple Choice and Short Response sections; W.T. is the result of the Writing Task. All data are the means for the relevant cohort.

Table 5.16: Mean QCS outcomes by test section, total and gender.
Physics. 1992-2001

		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	H+M+E	115.3	120.2	116.6	115.1	106.4	105.6	101.8	101.3	104.0	112.4
F	W.T.	37.9	39.2	38.1	39.4	43.5	42.6	44.5	38.9	38.6	43.4
	TOTAL	153.2	159.4	154.7	154.5	149.9	148.2	146.3	140.1	142.6	155.8
	H+M+E	112.0	116.9	112.3	110.2	101.8	102.1	98.5	97.0	99.0	106.7
M	W.T.	34.2	35.0	34.4	34.5	39.7	38.2	41.0	34.6	34.6	40.5
	TOTAL	146.3	151.8	146.7	144.7	141.5	140.3	139.5	131.6	133.6	147.2

(QBSSSS data)

The pattern, that for the cohorts of students taking Physics the females outperform the males in all parts of the QCS test, is repeated every year without exception.

Unlike the QCS data shown in Table 5.15 for all the students the female Physics students do not depend on their superior Writing Task performance to 'beat' the males, their QCS results are superior in all facets. The females are, as mentioned previously, self selected and gifted. That fact further confirms a number of matters. Firstly the erroneous nature of a simplistic interpretation of VHA/HA outcomes (Table 5.4) in the absence of a consideration of the relevant QCS outcomes. Secondly the results shown in Table 5.6 that demonstrated that males perform at least as well as females of similar general capacity cannot be explained by a claim that the females' QCS results have been inflated by the Writing Task.

5.6 Summary

In summary there is evidence from SAI analysis that the concurrent study of Physics/Maths C/Maths B advantages all students in terms of OP output. That advantage is as great for males as for females, making that concurrent study an area of comparative advantage for males. There is also evidence from a consideration of student Level of Achievement Outcomes in comparison to their general ability that with the exception of Maths C females are not outperforming males of similar general ability. With the possible exception of Chemistry there is no evidence from this analysis that females are 'catching up'. In total over the subjects Maths B, Maths C, Physics and Chemistry the evidence confirms that males are advantaged by taking those four subjects concurrently. The common assumption, made both by some academics and politicians, that females are outperforming males, notably in Maths and Physics will have, and perhaps already has had, an effect within the schools. All schools when advising students in respect of subject selection into Years 11/12, will use the 'information' available to them. Some at least of that 'information' is that males do poorly compared to females in high level Maths and the Physical Sciences. Consequently the schools may tend to discourage males from the study of those subjects. The evidence presented in this chapter indicates that in Queensland that 'information' does not stand up to analysis in terms of comparative advantage.

In comparative advantage terms males are advantaged in SAI and hence OP outcomes if they take the combination Maths B/Maths C/Physics/Chemistry. It would be unfortunate indeed if, on the basis of dubious analysis, males were discouraged from taking subjects and subject combinations in which they have a comparative advantage and consequently took other subjects in which they are comparatively disadvantaged. The consequences would be poorer OP results for some of those students and a concurrent decline in participation levels in rigorous Maths and Physics at Secondary level and hence a further reduced pool of adequately qualified students from which the relevant Tertiary departments can draw.

CHAPTER 6

SUMMATION

Chapter 6

6.1 Summary of participation in Physics and rigorous Maths

Australia as a whole has not been exempted from the widespread decline in student enrolments in Physics and rigorous Mathematics. Whilst university enrolment numbers in some level of Physics and Mathematics may appear fairly robust, Third Year enrolments, a much more appropriate indication of the strength of the disciplines, are now low. The apparently substantial numbers enrolled at First Year is, at least to some extent, a consequence of many students' weak previous experiences. There is evidence that Universities are taking steps to provide basic level Physics for students who, a decade ago, would have had that exposure at Secondary level. They are compelled to provide that basic level material because of the concurrent long term declines in participation in Physics and especially rigorous Mathematics in Secondary Schools. However in terms of complete three or four-year courses most universities appear to have been unsuccessful in their attempts to address the shortfall in the basic 'enabling' sciences of Physics, Chemistry and Mathematics.

Total Tertiary participation Physics and rigorous Maths for the State of Queensland, other than in first year is small; the total of the Third year enrolments in Physics has been hovering at about 60 for some years now. Such low numbers do not auger well for the future.

Two solutions have been suggested for the problem of maintaining technological scientific and professional standards in Australia. One solution is that being adopted by the medical profession where there is a trend towards postgraduate programmes for medicine. The other solution, which is preferable for the educational well being of a technological society, is to improve participation in the sciences and rigorous Mathematics in the two final years of Secondary School. These two suggested solutions are of course, not mutually exclusive.

The source of supply into Tertiary departments is the Secondary school system. Hence the Secondary data for Physics and rigorous Mathematics is relevant not just to the students within those schools, but also to the Tertiary sector.

At the Secondary level in Queensland, Physics enrolments have declined by about 15% over the last decade. That fact allied to the increasing number of schools must result in a decline in the number of students per school studying Physics; a fact that puts internal pressure on staffing within some schools. The condition of the most rigorous Mathematics, Maths C, is far worse. In the decade up to 2001 enrolments declined by 51%. Many schools have enrolments in single figures, a circumstance that schools will have difficulty in maintaining under conditions of tight teacher/pupil ratios. Although the female: male enrolment ratio has remained virtually unchanged, the fact that male numbers started from a much higher base makes it inevitable that the declines in absolute numbers are overwhelmingly declines in male participation. Between 1992 and 2001 male participation declines accounted for 85% of the total decline in Physics and 76% of the total in Maths C. In summary, the condition of the 'enabling sciences' (Batterham 2000) is generally poor and deteriorating at both at the Secondary and Tertiary levels in Queensland.

Since the critical decision to take or to 'drop' Physics, Chemistry and rigorous Mathematics are made by Secondary students two years prior to leaving school, the reasons for their decisions must lie within the 14 - 16 year age group. It is probable that the reasons will be multiple, including perceived difficulty and irrelevance, inertia, the offering of attractive alternative subjects, society's low esteem of the Physical Sciences and Mathematics in comparison with Engineering and Medicine, and the perhaps false perception that 'Scientists don't get jobs'. However most of those reasons are directly or indirectly 'demand side' problems. It is not possible for governments or educational institutions effectively to influence demand. It is possible that some of the 'supply side' hindrances might be amenable to governmental and/or educational institutional amelioration. Romer (2000) writing in the US Tertiary context provides powerful evidence that demand side action is ineffective, and that manipulation of the supply side is more effective. There are supply side issues that will affect participation rates into year 11. Those issues lie within the schools themselves, in particular student experiences provided by the schools in Years 8, 9 and 10.

6.2 Importance of lower Secondary schooling

The Longitudinal Survey of Australian Youth Report 22 (2001) showed that of all the variables that affect student outcomes at Year 12 exit (the ENTER score, in Queensland the Overall Position), by far the most significant are literacy and numeracy in Year 9. Furthermore the report showed that the correlation between Year 9 numeracy and ENTER is slightly higher than that between Year 9 literacy and ENTER. This result emphasises the importance of lower secondary school Mathematics on later within school outcomes. (Wolf 2000[1]) demonstrated that major longitudinal studies in both US and UK show the importance of lower secondary schooling as an influence on life far beyond formal schooling outcomes.

6.3 Political/governmental/economic considerations

Jan Thomas of the Victoria University of Technology, commenting on outcomes of the Third International Maths and Science Study TIMSS study drew attention to a 'crisis' in Maths in Australia. The use of the word 'crisis' was criticised as 'politicising' the discussion. Horwood and Thomas (2000) make the point that such a criticism is a 'very strange statement as anything like the TIMSS study will always be political.'

Because the overwhelming cost of education at all levels is borne by the government and hence the taxpayers and because Australia is a democracy, it is inevitable that education is a political matter. Furthermore, because all governments have restricted financial resources they have to make choices as to where those scarce resources are to be used. The current fashion in education management is to emphasise those things that are simplest to measure - the number of students. When the Queensland parliament debated the Bill to replace the Board of Senior Secondary School Studies and two other statutory bodies with a single body the Queensland Studies Authority, the Minister for Education stated that the Act was intended to be 'a significant step forward in our determination to improve the numbers of young Queenslanders completing twelve years of schooling or their equivalent.' (Bligh 2001)

The constant drive over recent decades, agreed by all political parties in Australia and elsewhere, that continued expansion of total Tertiary graduate numbers is economically essential for a nation is questioned, and probably discredited by Wolf [1](2002), major outcomes of whose work are:

(a) The balance of evidence is against the belief that Tertiary education enrolments and economic growth of a nation are directly linked.

(c) The only part of current education that shows clear evidence of (national) economic benefits is the 'central "academic" skills of Primary and Secondary Education, such as Mathematics and reading and writing skills'. (Wolf 2002[1] p.249)

(d) The UK labour market rewards mathematical skills, notably 'A' level mathematics (higher level mathematics up to secondary exit), even after the controlling of all other variables. This result is true for mathematics only.

(e) From an individuals' viewpoint obtaining as much education as possible makes sense because it is a 'positional good', it puts that individual 'above' those who do not have that educational level.

(f) Because, as a generalisation, 'the poor do not go to university. The children of the middle classes do,' it follows that 'the chant in favour of more education is actually a chant for regressive taxation. The fight against university fees isn't a major campaign for equal opportunity - quite the contrary'. (Wolf 2002[1] p.253)

(f) Education has a major economic importance, but, (at the risk of sounding Orwellian), some parts are more important from a *national* economic viewpoint than others. 'So governments do have a legitimate economic reason to be concerned for the provision of mainstream school education in all the basic (and traditional) subjects, and to provide the infrastructure for a thriving university and research sector that produces practitioners and innovators in medicine, engineering, physics, chemistry and genetics'. (Wolf 2002[1] p.245)

All the indicators are that it is lower secondary schooling that is the educational sector that has the greatest influence on enrolments in rigorous maths and physics in the upper secondary school and hence beyond; on final ENTER outcomes and subsequent earning capacity. It is a level of schooling that is available to all irrespective of socio/economic background and is an area that can be influenced by governments and the educational systems.

6.4 Outcome audit failure

When, at the end of Year 10, most students in Queensland schools make subject selections for their studies in Years 11 & 12, they depend on advice, previous experiences, data and perceptions. Much of that 'perception' was shown in Chapter 4 to be little better than rumour. The previous experiences and data available to the students and their parents must be relevant to later BOSSSS studies, (now the Queensland Studies Authority), particularly highly sequential subjects. Ainley’s work shows that for physical science courses previous experience is of particular significance to boys, especially those from lower socio-economic backgrounds. It follows, therefore, that if the student’s previous experience in maths and science is unsatisfactory the result will be inadvertently discriminatory against boys from lower socio-economic backgrounds. The nature of that previous experience in Years 9 & 10 in Queensland as a whole is unknown, and with the present structures, unknowable. As was shown in Chapter 2, Education Queensland does not know, the BOSSSS (and its recent successor, the Studies Authority) cannot know and the former QSCC did not wish to know. In maths there are two different syllabi in operation – a manifestation of division between government and non- government schooling. In the absence of any hard data the opinions of the school principals become significant. The survey of principals' opinions, carried out as a part of the work reported here, strongly indicate that there is reason for concern. Education in Queensland at the Year 9 and 10 levels costs some hundreds of millions of dollars annually. For that investment the taxpayers, the parents and the students receive, in toto, an unknown amount of variable educational experiences with unknown and unreliable outcomes which are of unknown value as a preparation or a predictor for success at later studies. In such circumstances it is unsurprising that rumour influences student decision making

The overall impression emerging from the survey of secondary principals in Queensland is one of dedicated professionals trying to do their best but operating in a state-wide knowledge vacuum and of classroom teachers with no effective structured opportunities to interact with teachers from other schools. One of the principals surveyed in the work reported here summed up the situation by commenting *"It is time that some very in-depth research is done into the state of middle schooling years – the Dept. is dragging its feet"*. (SGOV Peninsula)

Although the work reported here has concentrated on middle schooling in Queensland the fundamental importance of the middle schooling years is common to all jurisdictions. Consequently this examination of the situation in Queensland may have implications in a wider context especially for those jurisdictions which have limited auditing of educational experiences and outcomes.

6.5 Physics: a numerical science

Physics is a numerical Science. The heart of the Newtonian revolution lies in the fact that Newton gave mathematical structure to Science, ' by the time he died, on account of his works, (the physical world) was known to be governed by mathematical laws of great accuracy' (Simmons 1997). To make Physics a purely descriptive discipline, to strip it away from its mathematical base is a reversion to the pre-Newtonian science of the seventeenth century. Subsequent very accurate measurements (that were inevitably expressed numerically) demonstrated that Newtonian Physics was not able to predict with total accuracy under certain conditions. However it is noteworthy, and again inevitable, that the explanations of those inaccuracies in prediction were themselves mathematically stated by Einstein and others.

In the absence of Mathematics there would not be, could not be, Boyle or Hooke or Lorenz-Fitzgerald or Maxwell or Thermodynamics. Would non-mathematically based 'Physics' be Physics at all? To perhaps a lesser extent Chemistry also depends on Mathematics, especially analytical Chemistry. No Maths then no moles or concentrations or Avogadro.

6.6 The centrality of Mathematics

It is in that context, that Mathematics is not just of value in itself, but is an essential tool in other disciplines especially Physics and Engineering, that there is mounting evidence and opinion that the condition of Mathematics in Australia is only second rate. That concern is expressed in a wide variety of publications and publication types. Forbes (2000), in collaboration with eleven other Mathematicians, in a letter published in the Higher Education section of *The Australian* stated that 'Mathematics is the fundamental language of modern technology'. They also claimed that 'without a large pool of mathematically trained people a nation is simply incapable of contributing to, or even just using, many modern technical and financial products'. They further argue that Australia should do 'whatever it takes' to ensure that good Mathematics 'at all school levels must be a national priority'.

Hearne Scientific Software in a 'what's new item' (2001) commented that '52% of the Australian (Engineering) lecturers surveyed feel that Mathematics skills in Engineering undergraduates have worsened over the last ten years'. They also note that the situation in UK, France, Germany, Denmark and Italy is even worse. Thomas[2] (2000), referring to a 'national crisis engulfing Mathematics', draws attention to the poor numbers of secondary students who study 'high level' Mathematics, and to the weak Mathematical background of many teachers of Mathematics in lower secondary schooling.

Not all material in the general media takes the view expressed by Forbes, Hearne or Thomas. The Brisbane *Courier Mail* published an article (Bentick 2000), under the title 'We are the clever state'. The article commented on Queensland students performance on the Third International Mathematics and Science Study - Repeat (TIMSS-R), claiming that Queenslands performance was 'significantly better than the rest of Australia in Maths and Science', Australia as a whole being a mid-table performer. However Thomas (2000) reports that nationally 'there appeared to a deliberate attempt not to draw attention to the difference between the highest scoring nations and Australia, but to concentrate on how well Australia did relative to other English speaking nations.' As reported earlier in this work, any idea that Mathematics in Queensland by Year 10 exit is satisfactory, the product of a clever or smart state, is fatally undermined by the Allen Report 'Maths as a Foundation.' (Allen, 2001). It is a matter of grave concern that Bentick, a respected and influential columnist places such a great - and somewhat triumphant emphasis - on TIMSS presumably because it showed that Maths in some other jurisdictions are even worse than it is in Queensland. TIMSS is a system that attempts to show comparative strengths. The Allen Report is a far more detailed examination of actual student achievement in

Mathematics in Queensland at the end of Year 10. It provides an amount of information that is orders of magnitude greater than TIMSS and, as was demonstrated in Chapter 3, shows that student outcomes are highly variable and frequently poor. In that light TIMSS can be viewed as merely showing that some places are even worse than Queensland.

6.7 Condition of Mathematics

Winston Churchill, in a desperate plea to Franklin Roosevelt for armaments in the 'darkest hours of World War 2 said 'give us the tools, and we will finish the job'. Armaments were, and are, a necessary but not sufficient condition for success in warfare. Similarly, the possession of Mathematical tools, from the addition of single digit positive integers to calculus, is a necessary but not sufficient condition for success in mathematics and the physical sciences. However, just as it is essential in a war that troops using armaments know how and when to use those military tools - a capacity that can only be acquired by lengthy training - so also it is necessary that people are trained how and when to use Mathematical tools.

Gaudry (1999), criticising current Mathematics teaching fashions, asserts that '….because (the students) spend so much time on these rather foolish, fuzzy investigations instead of doing mainstream mathematics, they are denied the tools and techniques and powerful ideas of mathematics that they would otherwise learn'. In a comment specifically about algebra, Askey (1999) states that 'students who are going to use mathematics in any way at all need to know much more algebra.'

Askey's comment is important and justified because the introduction of formalised algebra is the most important enabling tool in lower secondary school mathematics. The ability to generalise, to form and solve equations revolutionises a student’s capabilities in a plethora of circumstances in both mathematics and physical science.

In Queensland there is text book evidence that algebra is perceived not as a tool but as a nuisance, something that has to be 'done', a hard purposeless chore. The solution of equations is repeatedly placed at or near the end of the academic year. ‘Word problems’ are few and frequently too simple. As a consequence of those problems and the shortage of adequate maths teachers it is unsurprising that the recent study

'Year 10 Maths as a Foundation' shows that even by Year 10 exit student ability and willingness to use algebra is highly variable. Only a small minority of even the most mathematically gifted groups (those taking Maths C in Year 11) are reliably able to translate a simple word problem into algebra or logically sequence their work or test the validity of their solutions.

The use of algebra in science texts to Year 10 has declined and is now approaching zero. Some of the most recent texts also indicate minimal use of Arithmetic. Over the whole of Queensland there is no knowledge available at all as to outcomes in science up to Year 10 exit. However the variability now known to exist in mathematics is unlikely to be any less in science. Current textbook indications are that for numerical physics any variability would be between very little on the one hand and nil on the other.

6.8 Discontinuity at the Year 10/11 interface

There is undoubtedly a discontinuity between Years 10 and 11 for maths. That is known because, and only because, Allen's report provides solid information as to the condition of maths at year 10 exit. Because there is no equivalent of Allen's report for science (or any other subject), the condition of science at year 10 exit is unknown. However an examination of text-books indicates that there is also a discontinuity in physics. It is understandable therefore that many capable Year 10s, listening to older students who are inevitably struggling with rigorous mathematics and physics, conclude that they are the hardest subjects in Years 11/12 – and don't take them. As remarked previously, in the absence of data there is nothing left but rumour.

6.9 Algebra in Years 8/9/10

It is certain that the condition of maths in years 8/9/10 is poor and that many, possibly tens of thousands of students every year, are being seriously disadvantaged. Any remediation of the situation requires a radical re-think of early secondary maths, starting in Year 8. The present de facto policy of providing the algebraic tools after they would have been useful is at best inefficient.

The ability to solve (mainly linear) equations of clearly specified forms; to substitute into formulae and to translate simple word problems into algebra is central to a student's mathematical development. With that algebraic foundation students are empowered to use algebra as a language and a tool in a vast number of situations that will arise in lower secondary school maths and physics (assuming that any numerical science is still studied). It would also enable the mathematics curriculum to be more unified.

This specified material needs to be handled in full in the first year of secondary schooling. The time expended on such material would be an investment of the scarce resource, time, which would reap a high return subsequently. After ensuring the availability of necessary pre-knowledge, especially negative numbers and fractions, a possible list of equation sub forms might be:
(1) A = B x C. (2) A = B x C x D. (3) A = (B x C)/2. (4) A = B/C. (5) A = (B x C)/100. (6) A = BC + D. (7) $A^2 = B^2 + C^2$. In all cases solving for A, B, C or D given all other values. Such a tool kit, simple as it is, would revolutionise the student's progress in later work. Furthermore the equation forms would occur frequently in other 'parts' of maths and numerical science (assuming that any is done) so providing an almost continuous positive feed back. As a result more students would be equipped to take and to succeed in rigorous maths and physics in Years 11 and 12.

It is relevant to note the difference between the assumptions re student readiness to think in terms of formal algebraic procedure shown in a Year 8 text from 1970 and more recent texts for the same school Year. Hubbard et al, Year 8 (1970) emphasise deduction and conventional procedure, it is formal and highly symbolic maths. The solution of 'sentences' is handled half way through the text. Most significantly it is clearly assumed that all Year 8 students are ready to handle symbolic, algebraic material. On the other hand, as has been previously observed, more recent texts deal with no algebra at all until the last chapter. There is hence a clear assumption that no Year 8 students are ready to handle algebraic material until that time - if then. Both elementary common sense and simple observation indicate that the variation in 'readiness' between students in Year 8 is very wide indeed, There is solid evidence of a wide variation in cognitive development at the Year 8 (and Years 10/12) in Endler and Bond (2000). In a long-term study of students in a North Queensland school they examined changes to cognitive development levels over time. It is relevant to the work reported here that at the Year 8 level nearly 30% of the students were still at the Early Concrete level, nearly 40% at either the Early Formal or the Late Formal levels. Hence it is simplistic to operate on the assumption that all Year 8 students are, or are not, ready for algebraic thinking. Some are ready at the start of the year, some are never ready. There are clear internal school organisational implications in those differences.

6.10 OP implications of subject selection

Most students make, or attempt to make, calculated decisions when making their subject selections for Years 11 and 12. Whilst there is some tendency, especially amongst those students who are determined to minimise their workload, to (in common student parlance) take one subject as a 'bludge' subject, most decision making is essentially utilitarian. One of the perceived 'uses' is whether a subject is a pre-requisite to later study, another is a real or imagined effect on OP outcomes.

The data from the five schools considered in this study indicates that from an SAI and hence OP view point, students may have been generally advantaged by taking the combination Maths B/ Maths C/Physics. Because of the inter connections between physical Chemistry and Physics, the complete combination Maths B/Maths C/Physics/Chemistry is likely to optimise OP outcomes. It is difficult to quantify with precision the OP improvements that might result as a consequence of taking that subject combination. However it is noteworthy that SAI improvements are most reliable near to and somewhat above the mean, the area where OP outcomes are most sensitive to SAI change. It hence appears probable that for students near to or slightly above the centre of the distribution the improvement would be in the range from one to three OP bands. In the context of the relatively course grained 25 band OP system such an improvement is valuable.

The opinions of the Year 12 Maths C students are in general agreement with the outcomes of the SAI analysis. Most perceive that advantages accrue in Physics and Maths B from the concurrent study of Maths C. The opinions of the Year 10 students at the time of subject selection indicate a degree of ignorance about Maths C and Physics that is of concern. It is entirely inappropriate and a failure of professional responsibility, that many students are making critical decisions with potential lifelong effects based more on hearsay and rumour, than on solid information.

If the prospect of improved OP outcomes motivated more students to opt for rigorous Maths and Physics the pool of students from which Tertiary physical Science and Engineering departments can draw would be proportionately increased.

6.11 Female/Male performance in rigorous maths and numerical Science

It is noteworthy that the magnitude of the SAI advantage accruing to males by the concurrent study of Maths B/Maths C and Physics is similar to that for females. In recent years the relatively poor OP performances of males has been a matter of public concern. Poor performance occurs because their SAIs are generally lower than for females. It follows therefore that in Ricardian terms, any area in which the males do as well as females is an area of comparative advantage for males. Consequently it would be advantageous if more capable males were encouraged to take the combination Maths B/MathsC/ Physics/Chemistry.

An alternative way to examine comparative female/male performance is to consider subject Levels of Achievement in comparison to Queensland Core Skills Test data. That analysis over Queensland as a whole indicates that:

- Males perform as well as females in Maths B and Chemistry. In Physics males outperform the females whilst in Maths C the females outperform the males. In total, therefore, males do as well as females of similar general ability as indicated by the QCS. Hence in Ricardian terms those subjects are an area of comparative advantage for males.

- With the weakly possible exception of Chemistry there are no indications that the females are 'catching up'. In Physics the males slightly outperform the females and always have. In Maths C the females outperform the males and again always have done.

- Any deductions made from the fact that the greater percentage of females than males obtain VHA/HAs in Physics (or vice versa in French) is over simplistic and misleading.

It is most unfortunate if information available to Year 10 students and their advisors is in any way misleading. School students are, to a great extent, powerless to influence school curricula or assessment methods. They have no influence over BOSSSS techniques that produce the OP results. There are very few points in their school career when they have any control over matters that might affect their final results. Subject selection at the end of Year 10 is one decision that *can* be made by the student. It is a moment of empowerment. In terms of maximising OP output it is essential that boys take combinations of subjects in which they perform as well as girls, for it is there that they have a comparative advantage. Whilst many are not capable of taking the combination Maths B/Maths C/Physics/Chemistry, a large number are.

6.12 Summary

- Declining participation in Physics and rigorous Maths is an Australia wide and even a global trend (see, for example, Ridd & Heron 1998). Enrolments at third year Tertiary level in Queensland are low. However, the universities are providing a large number of students with more basic, essentially secondary level, Maths and Physics during their first year at university.
- The vast majority of students pursuing those disciplines beyond first year originate from upper secondary schooling.
- The number of students enrolled in Physics and Maths C at the Year 11/12 levels in Queensland is declining. In the case of Maths C the numbers are so small in many schools as to be non-viable. Most of the declines in total enrolments are due to declines in male enrolments.
- When Year 10 students choose whether or not to take Physics and Maths C in Year 11 they depend on their experiences in lower secondary school. Ainley (1993) showed that participation in Physical Science is 'most strongly shaped by earlier achievement' and that for males that earlier achievement 'is independent of, and much stronger than, socio-economic status'. The Longitudinal Survey of Australian

Youth (2001) demonstrated that 'the strongest influence on tertiary entrance performance is literacy and numeracy achievement in Year 9'.

- Queensland Government legislation, vis-à-vis statutory bodies, has resulted in there being no knowledge at all as to student outcomes at Year 10 exit. The only hard data is the Allen report that showed that the standard of Maths at Year 10 exit is highly variable, and frequently poor, even among students who have all been awarded an internally assessed but unmoderated Very High Level of Achievement. The indication from textbooks is that up to the end of Year 10 numerical science is weak to the point of insignificance.
- Algebra is not adequately integrated into lower secondary mathematics and is regarded not as a tool but as a nuisance. As a consequence of the low emphasis on algebra less than 20% of students can, with any reliability, logically sequence their work using appropriate terminology, layout and sequence. Very few of even the Maths B classes can reliably apply algebra.
- The ability to apply algebra (and calculus) is central to Maths B and Maths C in Years 11/12. There is hence a disconnection at the Year 10/11 interface. That disconnection applies also to Years 11/12 physics where the students' weak algebra exacerbates their (probable) negligible experience in numerical science in Years 8/9/10.
- Males are performing relatively poorly in terms of OP outcomes in the area near to and just above the mean.
- The maximisation of OP outcomes is one of the factors that some students consider when making subject selection for Years 11/12. It is hence germane that the evidence is that both males and females are advantaged vis-à-vis OP results if they take concurrent Maths B/Maths C/Physics and Chemistry. Because the males 'gain' as much as females if they take that combination it is an area of comparative advantage for males.
- As shown in Chapter 5, there is little or no evidence that females do 'better' than males of similar general ability in maths and the physical sciences. There is no evidence at all that females are 'catching up' in those subject areas.
- The relatively good male performance in maths and physical science may be, at least in part, due to the fact that assessment procedures in Queensland have not (yet?) reached the stage described by Rowe in terms of literacy expectations in maths in South Australia. 'The level of nomenclature and sophisticated verbal reasoning skills

that are required - to even understand what the problem is-is on average four times greater than what is required in Australian history and English literature'. (Rowe, quoted in Parliamentary inquiry 'Boys: getting it right. 2002)

- There is powerful evidence from Australia and overseas that secondary school mathematics is of crucial importance both to the students and to the economic future of a nation. It is also socially equitable because all children are involved in lower secondary education. (Wolf[2], 2002) states that children with 'equivalent GCSE grades (Year 10) have the same chances of A level (Year 12) success, regardless of their parents' occupation'. That social equity does not, and cannot, apply to tertiary education because many students from lower socio-economic groups have been irreversibly damaged long before the stage of tertiary entrance.

6.13 Suggested remedial actions

There is a clear commonality between the interests of many students, especially males on the one hand, and those of the disciplines of mathematics and the physical sciences on the other. It would be in the interest of both if maths and numerical science in lower secondary school were to be drastically improved. At present it is inadequate for many. As a prerequisite for improvement to occur it is necessary that all involved in education recognise and accept that a systemic problem exists and take steps to rectify that problem.

All governments and political parties would do well to change their focus and their thinking away from their pre-occupation with tertiary enrolment numbers, and start to pay far more attention to the problems that exist much earlier i.e. in lower secondary schooling.

It is most strongly recommended that the Queensland government emphasise to the new Studies Authority the importance of setting up a system of moderating student outcomes at Year 10 exit. The Government would evidently need to provide some additional financial support so that that can occur. The additional costs would be minuscule when compared to the many hundreds of millions spent annually on education at the year 8/9/10 levels. In the context of assessment/moderation it is of concern that the QSA legislation does not mandate the existence of a Moderation Committee within the Authority. Both the QBSSSS and it's predecessor the QBSSS were compelled to have such a committee by legislation. Parliament would do well to reconsider this issue in the light of the possibility that the absence of a legislated requirement is 'sending the wrong message' and giving the impression that it no longer regards moderated assessment as of any great importance.

It is important that the Studies Authority set up that Year 10 moderation system as soon as possible. It is recommended that that system should be similar to the tried and proven system operating in Years 11 and 12, i.e. centrally organised and administered but teacher driven. Moves are already underway to terminate the present rather scandalous 'two syllabus' structure - one syllabus for government schools, another for non-government schools - that presently exists in mathematics at the year 8/9/10 stage. However the new syllabus that is currently being developed appears to fail to meet the need for a much greater emphasis on the use of algebra as a tool. It is also important that the Authority emphasises the importance of numerical science at the lower secondary stage.

The Authority should consider, as a matter of urgency what effect, if any, the Writing Task has on final OP results of all students. That could be done by re-running the whole OP calculation for any recent year using the individuals-and hence subject and school-QCS scores *in the absence* of the WT results. A comparison of the student and school outcomes from that calculation with the actual OP results for that year would indicate the effects, if any, of the inclusion of the WT as a part of the scaling process. In the interests of both openness and justice the collective school results, with and without the inclusion of the Writing Task should be made public.

The Authority needs to ensure that in all existing and particularly in new syllabuses the 'assessment procedures for maths and sciences must, as a first requirement, provide information about students' knowledge, skills and achievement on the subject, and not be a de facto examination of students' English comprehension and expression.' (Parliamentary inquiry, 'Boys: getting it right', 2002, Finding p.22).

Secondary institutions bear a great responsibility. Between school differences (as opposed to between systems) were shown in LSAYR 22 to have the second highest correlation with ENTER (OP). Only Year 9 Numeracy and Literacy had a higher correlation (Numeracy > Literacy). Each school should reconsider their internal organisation to Year 10 exit to ensure that students are provided with a vastly improved mathematical foundation, especially the use of algebra as a tool. In addition they will need, as a minimum, to consider whether completely mixed ability groupings for mathematics in Year 8 - and subsequently - have maximised student potential in the past and whether they are likely to in the future. Whilst alternatives to completely mixed ability classes - group formation within each class, streaming or setting for example - are only 'palliatives' (Ridd 1971), palliation is better than no treatment at all. The schools also would do well to re-consider the appropriateness of the current trend towards fewer, longer Mathematics lessons per week. A strong foundation at Year 10 exit together with an improved knowledge of Year 11/12 subjects and of the OP implications of subject selection is essential for informed decision making.

Education Faculties at Universities are highly influential, to the point of actual power. That fact inevitably leads to their responsibility to ensure that their work, both lecturing and research, is very firmly grounded on the sometimes harsh reality that is secondary, especially lower secondary schooling. All students being trained as secondary teachers, irrespective of their supposed specialist field, are likely to have to teach some maths and/or science in years 8/9/10. Hence it is necessary that Education faculties ensure that those students really do have an adequate mastery of mathematics per se. Education Faculties and others who are seen as authoritative need to be extremely careful not to inadvertently mislead schools and hence students with comments based on data that has been inappropriately analysed. Examples of such comments were critically examined in Chapter 5.

Tertiary institutions, in particular departments involved in maths and/or physical science should, 'as an integral part of strategic planning, recognise that what happens in secondary schools, and in particular subject selection at Year 10 exit is of crucial importance to them. Elementary self interest demands that Tertiary processors should take an interest in, and if possible have an influence on, the quality of secondary processing. (Ridd 2002).

Appendix 1

Part A: Covering letter.

The Principal,

xxxxxx school,

Dear xxxxxxx,

I am a retired teacher, now a student again, who is presently researching participation in Physics, Chemistry and Mathematics. A paper to be published in 'Australian and New Zealand Physicist' by myself and Professor Mal Heron demonstrated the serious problems facing Maths and the Physical Sciences at Tertiary level. We also demonstrate the decline in Secondary participation in Physics and the most rigorous Mathematics in all States and Territories of Australia. Some of the declines are spectacular e.g. in N.S.W. the decline in numbers opting for their most rigorous Maths has declined by 49% in a short space of time.

Obviously these changes will have a multiplicity of causes. However it is possible that one of them lies in the educational systems up to and including Yr. 10 especially Yrs. 9 and 10.

In an attempt to examine what is happening in schools up to and including Yr. 10 I have approached the Ministers of Education throughout Australia requesting information on syllabuses, time allocations for subjects and Statewide systems of oversight - if any.

However, it is obviously important to ask those with the most practical experience - the Principals. I am at present restricting myself solely to my home state of Queensland.

To that end I have randomly chosen (from the BOSSS schools list) a number of Queensland schools to write to in order to obtain a few pieces of information and some vitally important opinions. Since essentially I shall be paying the costs of this research I can't afford to ask every Principal.

Naturally, since I am hoping for your frank opinions, I realise the importance of total confidentiality. Hence please do NOT put your name or the name of your school on the enclosed questionnaire. I just don't want to know! I am asking which BOSSS District you are in and BOSSS school 'type' since they may be relevant factors.

The survey is very short as I only need very specific facts and opinions. I cannot emphasise enough how critical your opinions are on the matters I raise in Questions 8, 9 and 10. Principals are the only people who have this solid knowledge. The last part is not a question, but a place where you can expatiate if you are so inclined. I of course enclose a stamped addressed envelope.

I thought for a long time as to when in the school year would be the best time to ask you to help in this matter and decided that although there was not best time, the early part of semester two might be the least bad.

Please accept my apologies for bothering you, but be assured that my motives are entirely the same as yours - the best future for the education we provide for our children.

With thanks for your help.

<u>Part B:</u> **<u>Survey of Information from, and Opinions of Principals of Queensland Secondary Schools.</u>**

(1) In what BOSSSS district is your school? --

(2) School type (SCAT or SGOV or SIND etc)---

(3) Approximate Year 10 enrolment.--

(4) <u>Total</u> number of periods per week in the school timetable.-----------------------

(5) (a) Number of periods allocated per week for Maths in Year 9------------------

(b) Number of periods per week allocated for Maths in Year 10-----------------

(c) Number of periods per week allocated for Science in Year 9----------------

(d)Number of periods per week allocated for Science in Year 10----------------

(6) <u>If</u> you have records of Maths/Science time allocations from past years, please indicate below, e.g. 6/30 in 1975 or 5/35 in 1990. If not-go on to Qn 7.

(a) Maths Year 9--

(b) Maths Year 10--

(c) Science Year 9--

(d) Science Year 10---

(7) Does your school subdivide the Year 9 and/or Year 10 Maths students into 'levels' according to their Maths 'ability'?. YES/NO (circle one please)

If YES please describe-

----

(8) From your experience over the years do you think that there are differences in "standards" <u>between schools</u> notably in Maths and Science at Year 10 exit?

YES/NO (circle one please)

If YES. Do you consider the existence of these differences is

(a) of serious concern (b) of some concern (c) of no concern. (circle one please)

(9) Do you think that parents (and the public at large) can depend on comparability of "standards" between schools in Maths and Science at Year 10 exit:

(a) totally, (b) significantly, (c) to some extent (d) not at all. (Circle one please)

(10) If you circled (a) Of serious concern or (b) of some concern in question 8, what organisation do you think should accept the primary responsibility to rectify the situation? (a) State Department of Education (b) BOSSSS (c) Other (please specify)

(Circle one please)

COMMENT

If you have any comments at all on the topics raised in Questions 1-10, or on allied matters, please give them below. Also, if you have any suggestions to make which might make my research more valuable please give them also. Anything relevant may be valuable-even stating that my efforts are pointless!

RESPONSES SHOWN IN APPENDIX 2 PART B.-------------------------------------
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Thank you very much for your assistance.

Appendix 2

Part A. Responses to Survey Question 7.

"Does your school subdivide the Year 9 and/or the Year 10 Maths students into 'levels' according to their Maths ability? If YES please describe.

School. **Response**

SIND 1. Divided into three classes at both year levels. 1 Top class, 3 middle level classes, 1 low (small size).

SIND 2 In Year 9 only. Classes are set. Four class groups are given five teachers. A small bottom group 8 - 10 varies in its composition on the basis of pre-tests for each unit of work. Three 'middle' classes of equal ability. One 'top' class, but the bottom of it overlaps significantly with the top of the three 'middle' groups.

SIND 3 Extension classes and core classes, time-tabling permits, we use three levels; extension/middle/core.

SIND 4 During Year 10 second semester: Advanced/Ordinary.

SIND 5 Choice of both Maths Advanced and Maths Ordinary. Streaming occurs in Maths Advanced after each semester.

SIND 6 Three classes streamed.

SIND 7 Core and Extension.

SIND 8 Advanced Maths - pre Maths B; Ordinary Maths - pre Maths A. School advises at the end of each semester in Year 9 but parents and students decide.

SIND 9 No subdivision. (Note: less than 10 students in Year 10).

SIND 10 Year 9: Accelerated (4); Core (3) classes. Year 10: Advanced (3); Ordinary (4) classes.

SIND 11 No subdivision.

SIND 12 Core Extension Core (remedial)

<u>SIND 13</u> Advanced and Ordinary, initially based on demonstrated performance in Year 8; later based on parental requests and student performance.

<u>SIND 14</u> (1) Divided by subject: Advanced, Ordinary, General. (2) Streamed within subjects e.g. Advanced Maths has three streamed classes.

<u>SIND 15</u> Year 10 two classes - Advanced - Ordinary. 10 -12 in each.

<u>SIND 16</u> Year 9. Semester 1 - One Maths subject streamed with 4 classes. Semester 2 - One modified Maths class and three streamed Maths classes. Year 10 one Ordinary Maths class, two streamed Advanced Maths classes.

<u>SIND 17</u> One Extension group, four General (mixed) groups, one support group. There is freedom of movement between levels.

<u>SIND 18</u> Streaming upon entry.

<u>SIND 19</u> Stream out lowest achievers, then two homogeneous groups.

<u>SIND 20</u> 3 x form classes -- 4 x Maths; 1 extension class, remainder is modular: Core followed by Extension or re-visit Core if needed.

<u>SIND 21</u> (1) Since 1994, Years 8.9 and 10 have worked a Core -- re-visit or Extension - Core - Core re-visit or Extension model. (2) In 1997, Year 8s began to use a pre-dash test …level of learning for the topic tested.

<u>SCAT 1</u> Maths Advanced - Maths Ordinary - Maths General.

<u>SCAT 2</u> Maths is taught at Advanced, Ordinary and Core levels. Classes are streamed. There is movement across groups.

<u>SCAT 3</u> Two Advanced classes. Three Ordinary classes.

<u>SCAT 4</u> Classes are 'graded' according to semester results and students are 'moved' after exams - to maintain the 'graded' nature of the classes.

<u>SCAT 5</u> Extension Maths; Core Maths; Living Maths. Living Maths is for those students least mathematically able.

<u>SCAT 6</u> Higher ability graded classes x 4.

SCAT 7 Advanced/General.

SCAT 8 Year 9 - no divisions. Year 10 - after Easter, classes divided into Core and Extension.

SCAT 9 Year 9 - common course - two levels. Year 10 Advanced and Ordinary Maths - teacher judgement taking into account student's and parent's wishes.

SGOV 1 An 'Extension Maths' group is identified and placed in discreet classes by middle of Year 9. Also a lower level is identified and in a separate class by the start of Year 9. Essentially, then, three 'levels' for most of Years 9 and 10.

SGOV 2 Based on their Year 8 results - ability groupings.

SGOV 3 In Year 10 the students and their parents decide whether they should do Core or Extension but the classes are not streamed.

SGOV 4 No subdivisions.

SGOV 5 HOD creates Year 9 classes at the beginning of Year 9. Classes are based on Year 8 results. Throughout Years 9 and 10 students are able to move to other 'ability' groups based on performance.

SGOV 6 No subdivisions.

SGOV 7 Core -- Core and Extension.

SGOV 8 Levels of achievement used to determine classes and an ability to move through the levels is available - based on performance.

SGOV 9 Year 10. On results into Core or Extension to the Core. Students in Core classes can re-visit the Core until they attain a sound achievement.

SGOV 10 Due to staffing numbers and class size (nineteen students) our school has a single class at each year level. However, our Maths work programme divides into Extension group ad Core group in the same class with different work being covered.

SGOV 11 Year 10 - three levels - top to extend in Algebra; other two to achieve highest results they can.

SGOV 12 After initial units, classes divided into Core only groups and Core plus Extension groups.

SGOV 13 Yes.

SGOV 14 Core - (basics). Advanced. Middle.

SGOV 15 In 9/10 Maths students are divided. We have an Extension and Core division in Year 10 with less formal divisions in Year 9.

SGOV 16 Year 10 only. Extension A - semester one. Extension B - semester two.

SGOV 17 Junior Mathematics is divided into Extension and Core. Approximately 50% of students attempt the Extension programmes. Variation and review of group allocations occur each semester.

SGOV 18 Year 10 only.

SGOV 19 Two classes of more able students. Two classes of mid range students. Two classes of less able students. Students able to move up or down. Not locked into group.

SGOV 20 Year 9 - Extension classes of more able students (3 out of 10). Year 10 - Extension classes to cover the Algebra component (3 classes). Basic Core classes to provide fundamental Maths (2 classes). Core and some Extension (not Algebra 5 classes).

SGOV 21 We operate a vertical curriculum in which students work at the level at which they have the best chance of success. So students who are chronologically in Year 10 might, and do, work at Year9 or 10 or 11 level if they have the ability.

SGOV 22 Level 1,2,3.

SGOV 23 Progressive tests administered regularly and students assigned to two levels. Students are changed from level to level as appropriate.

SGOV 24 Core and Core and Extension groups.

SGOV 25 Most able students in one class. Remainder mixed ability groupings - currently trialing boys class, girls class for these mixed ability groups.

SGOV 26 No subdivision (only 12 students).

SGOV 27 (1) Core unit - test - regroup into Extension or Core Extension or re-visit Core. Year 10 semester two - Year 10/11 transition groups.

SGOV 28 Classes put in groups of 3/4. Top thirty students given Extension. 'Remedials' have enrichment. Remainder strive for solid sound achievement.

SGOV 29 In Year 10 streamed for Algebra etc.

SGOV 30 Yes.

SGOV 31 As students show (usually by previous results) readiness to attempt Extension work they are placed in appropriate Extension class.

SGOV 32 Two out of ten classes per year level do harder (Extension) work.

SGOV 33 'Streaming' in Year 10. Three or four classes blocked.

SGOV 34 Year 9. September we divide students into Core/Extension. Year 10 March we divide students Core/Extension.

SGOV 35 Students are grouped according to ability in order to be able to provide appropriate work for students.

SGOV 36 From term 2 Year 9. A 'top'/Extension Maths class is formed. Students stay in this course based on results to the end of Year 10. In Year 10, two or three 'foundation' classes are formed - based on results. Aim at sound achievement on Year 10 exit. Rest of classes homogeneous.

SGOV 37 Only in Maths and only after term one Year 10.

SGOV 38 Offer Extension Maths and Science as electives in Year 9. Divide all Year 10s into appropriate groups in Year 10 semester two as preparation for Year 11.

SGOV 39 Core and Extension.

SGOV 40 Only at middle of Year 10 - purpose - to permit those capable of higher Maths to pursue a study of Algebra and other topics which lead into the more complex Maths courses.

Unknown School type Core/ Extension opportunities. Students re-sorted after each unit.

Part B. General comments.

SIND 1 Close comparability of standards is not necessarily desirable or practical at Year 10 although some problems occur when students change schools. However, minimum standards should be expected (QSCC). We reserve the right to make our courses more rigorous to better prepare our students for Years 11 and 12. Because of the high retention rates from Years 10 to Year 11/12, and the demise of the compulsory Junior Certificate, the resources which would be required to ensure close comparability could probably not be justified.

SIND 2 There is a lingering community confidence in the comparability of Year 10 results based on a belief that they are still moderated by BSSSS as they were before 1987. I am looking forward to the provision of syllabi from QSCC with appropriate bench marks. However while it is important to maintain appropriate standards, both for the sake of the rigour of the subjects and as an adequate base for senior studies, the absence of moderating of standards has freed teachers and schools from the potential tyranny of teaching for the exam rather than learning for its own sake. In some places, however, the pendulum seems to have swung too far, and students may well have been disadvantaged by impoverished courses and a false confidence in their achievement levels.

SIND 3 I believe the teachers are there, courses are there, text books, know how etc.; the problem is in student perceptions of what is important, many can't see the point of studying and being conscientious at Junior level. Having an external motivator such as a STATE wide TEST and or certificate could help enormously. Maybe the 'wheel' is turning again. I do appreciate your concern and efforts.

SIND 4 The abolition of the accreditation and monitoring process at Year 9 and 10 has increased the gap between Year 10 and Year 11. Only an independent (statutory) body should write syllabuses/not a government department. Extensive consultation should take place.

SIND 5 In this school Maths is a compulsory subject to the end of Year 12. This is to aid students in preparation for the Core Skills Test. I believe the decline in numbers selecting Maths C is the result of two reasons: (1) Maths C is not listed as a prerequisite for many university courses. The subject it replaced however, was listed more often as a prerequisite. (2) As it is an elective, there is competition with an increased number of curriculum choices.

Maintaining the Advanced Maths/Ordinary Maths choices at Years 9 and 10 has allowed appropriate preparation for students for the rigour of Year 11 and 12 Mathematics.

SIND 8 Essentially schools choose a Year 8 - 10 Maths course to suit their clientele to best prepare for Year 11. Little use is made of Year 10 results in the wider community and so the need for comparability diminishes significantly. Where TAFE or some other group requires a sound Year 10 Maths it would be best if they administered their own entry test.

SIND 10 With KLAs imminent (ALL subjects in) KLAs should be granted equal time. Vertical curriculum/vertical class timetabling does seem to present opportunities for students to achieve in Maths and Science and other subjects.

SIND 15 Students vary in their learning styles. Many students say they just can't do Maths. Could it be that the very sequential nature of Maths teaching and learning does not fit well with global random learners? But how do we reach global random's concepts that depend on sequence and detail? I can't help.

SIND 17 In the decline indicated, is it raw numbers or percentage as I feel numbers are steady but proportions are declining as increase retention rates are made up of less academic students. An increase in the number of uni courses not requiring Maths/Science prerequisites has had an impact on the 'need' to complete certain Maths/Science subjects. Greater diversity and choice in senior and middle school subjects has meant that students are 'forced' into these subjects. For students not requiring complex Maths, the 'other' Maths courses provide a more relevant and practical course that will assist students beyond school. Note that our school has the study of Maths as mandatory in Years 11 and 12. Related to 'relevance' students and their families are more discerning about what they study related to careers; interests and abilities; getting the best result. Complex Maths is needed for limited careers appeals to few, is too hard for many and will not assist in getting the best result if students are likely to score poorly. At senior level the most complex Maths involves studying two subjects. Adding Physics and Chemistry the course becomes limited in scope and therefore lacking appeal except for a small percentage.

SIND 18 This school caters for secondary indigenous students, largely ESL status. Literacy and numeracy is usually limited. Education histories - often truncated; employment possibilities usually limited; cultural barriers exist.

SIND 19 I wish you well- the erosion of standards in Years 9/10 has been an ongoing process even in literacy/numeracy areas. One question does need to be asked - Is Year 11/12 Maths done in order to prepare them for university or for life? We cannot do both.

SIND 20 We need to revisit syllabus and critically re-examine what is taught. I believe it is essential that Algebra is given its true significance. There is a need for formal integration of Maths/Science topics. Quantitative analysis should be mandatory in Science programmes - a degree of rigour is not the death knell of interest!

SIND 21 While a consideration of the possibility of lack of comparability of standards at Year 10 is important, I suggest that the bigger issue is the lack of real teacher talk/dialogue at Years 8,9,10. No one gets to see what others are doing any more, with the possible result that in-class teaching and learning at Years 9 and 10 is being professionally stultified.

SCAT 1   There needs to be some degree of comparability among schools. Some schools curriculum is dominantly assessment driven. Some schools teach in the content/skill area but the assessment is dominantly in the unfamiliar domain.

SCAT 2   Concern about declining interest in Maths and Science (especially Physics and Chemistry) in the senior school led us to introduce an elective at Year 10 level - Challenge Maths Science - an extension subject with emphasis on practical applications.

SCAT 6   To be 'totally' useful a more intensive study of one or two schools may be more use.

SCAT 9   Maths and Science have been cut back from Maths A and B and Science A and B - two subjects for each for the more able students - back in the 1970s. Effect is having half the time table time - disadvantages students choosing Maths B and C, Physics and Chemistry. Note - these subjects not valued as much now -Science not seen as a choice for university study for those wishing to 'make their mark' or get rich! These subjects in senior school are regarded as difficult - why do? Resulting in 'dumbing down'. Too many things being squeezed into schools - less time for purely academic pursuits.

SGOV 1 The serious decline in the number (and percentage) of students opting for Math C and Physics is of great concern to me, for the academic future of our nation. In my school of over 1200 students we struggle for senior classes in both. Tertiary institutions declaring that Maths C and Physics are pre-requisites is probably the cause of this problem. The problem is dynamic: fewer students MAC & PHY - few teachers qualified to teach MAC & PHY in the following generations - less capacity of organisation to teach MAC & PHY - fewer students studying MAC & PHY -- .

SGOV 2 (1) It is time that some in depth research is done into the state of middle schooling years - the department is dragging its feet. (2) We need hard data re the effectiveness of the BSSSS re the alignment of real learning versus the assessment requirements. Blind Freddy knows that we are assessment driven and not learning driven. (3) We have seen a significant turn towards academic science subjects in our school especially Chemistry. However Physics and Maths C aren't too far behind. I believe this is as a result of our promotion and university motivations.

SGOV 3 Much teaching/tutoring of Maths is done by our staff out of class time, from Year 8 to Year 12. It was therefore decided to increase Maths teaching time as per the 1996 outline. Critical thinking has also been introduced into Years 8 and 9 to provide problem solving strategies. The irony is, of course, that while we are attempting to provide our students with the necessary skills for Maths B & C, tertiary pre-requisites are changing rapidly and reducing the need for these subjects. We are happy with the numbers of students choosing Maths B,C, Chemistry and Physics and with their results overall, although most won't use these as a basis for tertiary choices.

SGOV 4 The withdrawal of Board monitoring of Junior work programmes and student ratings has undermined confidence in the comparability of results. Often the quality of the programme and student's results is indirect proportion to the quality of the HOD in charge.

SGOV 6 As a Maths/Science teacher I believe standards are similar to what I taught 10 years ago. The difference is more Year 10s of lower ability remaining at school who would previously have left. There is significant correlation in standards but from experience I question the reliability of some non-State school results.

SGOV 8 Older people will remember Science A and Science B. This effectively created a double allocation.

SGOV 10 I believe that the 'streaming' of classes in bigger schools (and smaller ones where staffing allows) leaves to better outcomes for students given a positive school outlook. An issue is the addition of so many a additional responsibilities into the general school curriculum. Twenty years ago more able Maths/Science students studied Maths A and B and Science A and B at Year 9 and 10 level - four subjects out of eight subjects.

SGOV 13 We find that students lack the determination to work hard at subjects which seem to be challenging. The instant gratification of the television and computer generation seems to act against working at subjects which don't offer instant success.

SGOV 15 There has been a dramatic decline is students taking Physics, Maths C etc. Science is not seen as an attractive option for many students. There is still a negative view of Maths/Science in Years 8.9 & 10.

SGOV 18 Outside school curriculum documents have a responsibility to be 'deliverable' i.e. they should easily fit into the time that is reasonably expected to be available. However they should not fill the time, so leaving some school flexibility beyond an agreed core. This core, once established should be widely communicated as a reasonable expectation. Extension opportunities beyond the core could be available from syllabus documents or be developed across 'subjects' and other applications.

SGOV 19 If there is some difference in standards at Year 10 exit this is less of a problem than if the difference existed at Year 12 exit. This results from the fact most students are returning to complete Years 11 and 12 education.

SGOV 20 These questions do not appear to be able to locate any specific areas of concern. This is presuming that this is the purpose of the questionnaire. It does not address the impact of other factors on a students time e.g. work, social, family, placement of lessons work ethic of class group impact of other activities within the school. It would probably be worth asking what students are doing in stead of Maths and Science (top level subjects) in Years 11 and 12, that is if indeed school numbers were declining in that area.

SGOV 21 Of more concern than differences between schools is the differences in the ability of teachers to engage students and enthuse them. E.g. (a) Science teachers often appear to be so engrossed in completing the content that they forget about scientific process and enquiry and method. (b) Maths teachers often seem not to relate Maths to the real world of the student. (c) Those that do make the subject LIVE for their students.

SGOV 23 Declining enrolments in Physics and Maths C in particular is of grave concern to Science and Mathematics HODs, being in the order of 50% over the last decade. This reflects community attitudes and values - where academic study no longer guarantees future employment. Many students are seeking security when considering future careers and this in turn influences their subject selection in Years 11 and 12. They are, at present, more career orientated and less willing to 'take risks' academically, preferring instead to work well within their known ability levels.

SGOV 26 (1) Quality of teacher graduates a concern - do not have basic literacy and numeracy skills themselves - especially primary teachers. (2) Teaching strategies irrelevant need vast improvement - especially in relation to Aboriginal students and Torres Strait Islander students. - Understanding of Aboriginal English and Indigenous world views - preferred learning styles essential for success for these students.

SGOV 27 (1) All key learning area programmes from Years 1 - 10 should be accredited by the Curriculum Council (as for BOSSSS in Years 11 - 12.) (2) Standards of work should be moderated at Years 6 or 7 and at Years 9/10 in at least English and Maths. (3) Attracting and holding on to suitable teachers in Maths and Science should be one of the highest priorities for all employing authorities.

SGOV 28 Please also highlight the lack of assessment continuity from 8/9/10 to 11/12 in Maths. Students and parents would be better served if the same structure flowed from Year 10 to Year 12.

SGOV 29 The role of Maths/Science teachers in ensuring comparative outcomes to other subjects is critical. Our Science team have inspired excellent numbers and success in Year 11 and 12 subjects by a quality junior programme with lots of practical work/interesting sections/participation in Science based competition/Science trip to Brisbane for enrichment etc. Our Maths team have worked really well at individualising instruction/learning by self paced modules with built in re-mediation and extension. There is no intrinsic reason for the decline in Maths/Science stream across the country - just poor teaching, boring delivery and a lack of promotion. Year 10 certificates are near worthless these days. The desirability of moderating Year 10 results is questionable and almost pointless. One area of concern is however the Algebraic skills of senior student s, especially the average learners.

SGOV 30 We simply don't know standards in other schools in the junior area. What do standards mean in this context, and does it matter.

SGOV 31 As you are aware, there are no current assessment guidelines for the allocation of standards in 1 - 10 Mathematics and this syllabus is not up for review for another couple of years. This may well have contributed to a difference in 'standards' at exit from Year 10, but in the absence of any meaningful moderation process, a judgement relating to this matter could only be based on perception and hearsay. My concern is that the current situation will continue for a number of years. This cannot be good for Mathematics.

SGOV 32 I think that the decline in numbers in Physics and the 'harder' Maths is because tertiary institutions (in general) do not require them for entry into many courses. There are also bridging courses if students find they do need them.

SGOV 34 Our numbers in Maths B, Maths c are still healthy but it takes a lot of hard work to maintain them. Maths B 50% of students, Maths C 20% of Year 11 students.

SGOV 35 Some extra time spent on Science in Year 10 might be advantageous for those intending to do Sciences in Years 11 and 12. The problem is that the 'basics' have expanded over the past 25 years to include so many things (Computer ed., drug and alcohol ed, AIDS ed, LOTE, human relationships education, arts education, etc.) that now the curriculum is overcrowded. If we are to cover all of this adequately we need to extend the school day and the school year and this would require additional staff, resources etc.

SGOV 36 Even though schools have the opportunity to pretty well do as they please with Year 10, as there are no checks and balances my experience across a number of schools indicates a very high level of professional integrity and ethics in ensuring that exit levels of achievement awarded are valid. Of greater concern is the apparent ' jump' from Year 10 Maths to Year 11 Maths A/B/C. Teachers do not over inflate Maths results in Year 10 as they know that students would soon be brought back to earth by their semester 1 Year 11 results.

SGOV 37 I believe that Maths teaching (and to a lesser extent, Science) is of less quality than it should be across the whole State. The students seem less happy with the Maths curriculum and quality of Maths teaching than all other parts of school life.

SGOV 38 With respect to 'standards' the issue is that some schools provide programmes to extend the better kids and others don't. This seems to be directly related to the quality of people who are Maths HODs.

SGOV 39 Problem is largely one of teacher competence in the junior school.

SGOV 40 This of concern to this school (i.e. comparability in Maths/Science) as we draw many students from another school for Years 11 and 12. As part of an attempt to get some commonality with our Year 11/12 feeder school we have taken part (as a cluster) in the QSCO and P-10 Science trial. Secondary departments, by their small nature, usually have problems compounded by generally changing/inexperienced staff.

Appendix 3. Student Questionnaires

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Part A. Survey of opinions of Year 12 maths C students.

(1) Your age ----------------------------------

(2) Female/Male ----------------------------------

(3) Going on your Maths C results so far what final result do you expect to get at the end of Year 12? ----------------------------------

(4) When, at the end of Year 10 you decided to take Maths C was that because: (circle TRUE or FALSE for each part) **TRUE/FALSE**

(a) You thought it would help you get to university? **TRUE/FALSE**

(b) You liked Maths and wanted to do plenty of it? **TRUE/FALSE**

(c) You thought it would help you with other Year 11 subjects? **TRUE/FALSE**

(d) You really didn't want to do Maths C but the alternatives were even worse? **TRUE/FALSE**

(e) You were advised to take it? **TRUE/FALSE**

(If TRUE who by? E.g. parent/teacher/students?) --

(5) In Maths B, do you think that you are advantaged compared to a student who does not do Maths C by (circle one only please)
A LOT
A LITTLE
NOT AT ALL

(6) In Physics, do you think you are advantaged compared to a student who does not do Maths C by (circle one only please)
A LOT
A LITTLE
NOT AT ALL
DON'T DO PHYSICS

(7) Do you intend to go to university? (Circle YES or NO please) **YES/NO**

IF YES GO TO QUESTION 8, IF NO, GO TO QUESTION 10.

(8) Do you intend to study something which will involve Maths? (circle YES or NO) **YES/NO**

(9) At university, do you think you will be advantaged compared to a student who
A LOT
A LITTLE

has taken Maths B only by (circle one only) NOT AT ALL

(10) Which of the following best describes your feelings towards Maths C now? (circle one only please)

VERY GLAD I TOOK IT
GLAD I TOOK IT
NOT BOTHERED
WISH I'D NEVER STARTED IT

(11) So far as you can remember, what if any was the general opinion among <u>your Year 10</u> about the DIFFICULTY of Maths? (circle one please)

VERY HARD
HARD
O.K.
EASY

(12) Now that you have a lot of experience with Maths C, how do you think it compares in difficulty with Maths B?

MATHS C A LOT HARDER
MATHS C A BIT HARDER
THEY ARE EQUALLY HARD
MATHS C IS EASIER

(13) Thinking about your answers to questions (5), (6), (9), (10) and (12), if a Year 10 student asked you whether she/he should take Maths C in Year 11, would you (circle one please)

STRONGLY ADVISE TAKING IT
MILDLY ADVISE TAKING IT
SAY IT DOESN'T MATTER EITHER WAY
STRONGLY ADVISE AGAINST IT

==

<u>OPTIONAL COMMENT</u>

If you have any other comment to make about Maths C or any other influence on other subjects please write them below. Remember, you are THE EXPERTS on what it's like to do the subject. WE NEED YOUR ADVICE.

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____

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____

____

<u>Student_comments_given_in_Part_C</u>

<u>THANK YOU SO MUCH FOR YOUR HELP</u>

Part B. Survey of opinions of Year 10 students.

(1) Your age ------------------------------------

(2) Female/male -------------------------------------

(3) How good do you think you are at Maths? (circle one only please)

EXCELLENT
VERY GOOD
GOOD
O.K.
NOT MUCH GOOD.

(4) If you can remember you result in Maths on your last report card, write it here please. -------------------------------------

(5) When you go on into Year 112 you will have to take one of the subjects Maths A, Maths B, or another school based subject. Which one do you think you will take? --------------------------------------

(6) If a student takes Maths B, she/he may also take Maths C. Do you think you will take Maths C? (circle YES or NO please) **YES?NO**

IF YES GO TO QUESTION 7; IF NO GO TO QUESTION 8.

(7) Did you decide to take Maths C because: (circle TRUE or FALSE for all parts).

(a) You think it would help you get to university. **TRUE/FALSE**

(b) You like Maths. **TRUE/FALSE**

(c) You think it will help you with your other Year 11/12 subjects **TRUE/FALSE**

(d) You think it would help you when you are at uni. **TRUE/FALSE**

(e) You have been advised to take it. **TRUE/FALSE**

IF TRUE, by whom? (e.g. teacher/parent/other students. No names please!)

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(8) Did you decide NOT to take Maths C because: (circle TRUE or FALSE for all parts)

(a) You have heard it's hard. **TRUE/FALSE**

(b) You don't really know what it is. **TRUE/FALSE**

(c) You don't think you could do it. **TRUE/FALSE**

(d) You see no point in taking it. **TRUE/FALSE**

(e) You want to take a subject which you think will need less work. **TRUE/FALSE**

(f) You have been advised not to take it. **TRUE/FALSE**

IF TRUE, BY WHOM? (e.g. teacher/parent/other students. No names please!

____

(9) How good do you think you are at Science? **VERY GOOD**
(circle one only please) **GOOD**
O.K.
NOT MUCH GOOD
TERRIBLE

(10)If you can remember your result in Science on your last report, write it here please. --------------------------------

(11) In Year 11 there are a number of 'Science' subjects: Biology, Chemistry, Marine Science, Multi Strand Science and Physics. From what you know or have been told, put them in order of difficulty.

HARDEST SUBJECT----
SECOND HARDEST-----
THIRD HARDEST--------
FOURTH HARDEST-----
EASIEST SUBJECT------

(12) Do you think you will take Chemistry in Year 11?
(circle YES or NO) **YES/NO**

IF YES GO TO QUESTION 13, IF NO GO TO QUESTION 14.

(13)Have you decided to take Chemistry in Year 11 because: (circle TRUE or FALSE for each part)

(a) You think it will help you get to university.	**TRUE/FALSE**
(b) You like Chemistry	**TRUE/FALSE**
(c) You think it will help you with your university studies	**TRUE/FALSE**
(d) You have been advised to take it	**TRUE?FALSE**

If TRUE, by whom? (e.g. teacher/parent/other students. No names please!)

GO ON TO QUESTION 15

(14)Have you decided NOT to take Chemistry in Year 11 because: (circle TRUE or FALSE for each part)

(a) You have heard it's hard	**TRUE/FALSE**
(b) You don't really know what it is.	**TRUE/FALSE**
(c) It's no use to you.	**TRUE/FALSE**
(d) You have been advised not to take it.	**TRUE/FALSE**

If TRUE, by whom? (e.g. teacher/parent/other students. No names please!)

----

(15)Do you think you will take Physics in Year 11?
(circle YES or NO please) **YES/NO**

IF YES GO TO QUESTION 16, IF NO GO TO QUESTION 17.

(16) Have you decided to take Physics in Year 11

because: (circle TRUE or FALSE)

(a) You think it will help you get to university TRUE/FALSE
(b) You like Physics. TRUE/FALSE
(c) You think it will help you with your university studies. TRUE/FALSE
(d) You have been advised to take it. TRUE/FALSE

If <u>TRUE</u>, by whom? (teacher/parent/other students. No names please!)

--

(17) Have you decided NOT to take Physics in Year 11 because: (circle TRUE or FALSE for each part)

(a) You have heard it's hard. TRUE/FALSE
(b) You don't really know what it is. TRUE/FALSE
(c) It's no use to you. TRUE/FALSE
(d) You have been advised not to take it. TRUE/FALSE

If TRUE, by whom? (e.g. teacher/parent/other student. No names please!)

--
==

THANK YOU FOR COMPLETING THIS FORM SO CAREFULLY.

If you feel extra helpful you may like to add a few comments:

<u>OPTIONAL COMMENT</u>
If you have any comments to make about subject selection into Year 11/12, especially about why you decided to take, or not to take, Maths C or Physics or Chemistry, please write them below. Remember your opinions are IMPORTANT.

<u>PART C. Verbatim comments of students in Year 12 Maths C.</u>

<u>Five schools combined. Year 12. By gender.</u>

(1) Physics helps with Maths C so those who are thinking of taking Maths C as a subject should be advised to also take Physics. (Female)

(2) Maths C is very useful because it helps you in Maths B, especially Maths B assignments. Also, according to what I have been told, Maths C is going to be a great advantage at university. (Male)

(3) Don't do Maths C unless you need it for your future career. It's not much harder than Maths B but you have to do Maths B as well, so why double your amount of Maths workload when you don't have to. (Male)

(4) Maths C is a perfectly good subject for those who enjoy Maths. I personally do not like Maths and therefore cannot find any point in doing it although I do realise it is extremely important in many occupations if not all occupations. I just cannot find any relevance in it and it does not interest me. I far prefer Chemistry and Physics. Even Maths B is better than Maths C. (Female)

(5) It was very hard (Male)

(6) It depends on what they want to do after they finnish High School. (Male)

(7) Maths C is a good subject to take to help with other subjects including O.P. score, but assignments should not be given at the same time as the Maths B assignments since both Maths could drive a person nuts. (Male)

(8) I would advise a student taking Maths C to also take Physics because it helps with dynamics studied in Maths C. (Male)

(9) Maths C seems to have no meaning for many university courses and should only be done by someone for whom it is absolutely necessary to get into their course of choice e.g. you do not need Maths B or C to do Maths at university! (Male)

(10) I advise you to take Maths C if you intend to do well in school result and if you need it for university course. (Female)

(11)I found that Maths C only helped a bit in Maths B and Physics only. This subject deals with more in depth study like proofs of laws and formulas and I feel it will be a good advantage over people who don't do Maths C and intend to study Maths and hard sciences in uni. I wish we could have covered a bit more, though it was hard, it would have been more complete. I don't know if we should have looked at dynamics in conjunction with Physics as we didn't do it. (Male)

(12) I really can't remember why I took it but it was easy anyhow. In year 12 it would not have been so easy if had not been so enjoyable, this is due to the teacher -----------, many of my other subject I've not enjoyed due to this factor. (Male)

(13) Maths C starts off easy and fun, but if you aren't comitted to the work, it can really piss you off. My advise is, unless you need it, and are going to be really into it, don't take it or you'll be disappointed. (Male)

(14) It is tricky Maths, challenging yet rewarding. If you are going to do something that says Maths C optional and you like Maths, best to do it. If you don't like Maths it will be very hard. (Male)

(15) It was hard as expected and what made it really hard is there is no set formulas, just use general knowledge and apply weird things to it. (Female)

(16) In Year 11 and half way through Grade 12 Maths C was easy and easier than Maths B; But in semester 4 Maths C got a lot lot lot lot lot lot lot lot lot harder!!!! (Male)

(17) The value of Maths C depends on what the person wishes to do afterwards. (Male)

(18) Maths C is just an extension of Maths B(in my opinion). (Male)

(19) Take (the topic on) Groups out of the Year 11 course. (Male)

(20) Physics influences dynamics in Maths C. (Male)

(21) Maths C isn't necessarily more difficult than Maths B, it just extends further and works on more Physics related topics. I would reccommended it to any VHA Year 10 student. (Male)

(22) Students should only take Maths C if they are confident they can deal with the added workload. (Male)

(23) It doesn't help with Physics at all. Maybe you could integrate it more. (Male)

(24) It's pretty good – don't stress over it, it's no harder than any other subject as long as you pay attention and work occasionally. Remember – you will be taught everything you need to know, you're not expected to be brilliant or insightful. (Female)

(25) Doing Physics advantages us in Maths C. Maths B is boring and too easy. God help zomby Maths. The pannel is stupid and should be reviewed. English sux. (Male)

(26) Physics and Maths C should confer so that when the same thing is being learnt one can help the other e.g. inclined planes etc. (Female)

(27) This subject has helped with Physics and Maths b and is good for someone who likes a challenge. The workload isn't as much as Maths b however a lot of it takes more patience and determination. It has basically more fun than Maths b but that could be to do with the teaching. If you need it or think you may later, go for it. (Female)

(28) Maths C is worth doing a lot. It is my favourite subject because I'm interested in maths rather than english Doing Physics and Maths C works together. (Male)

(29) It's not necessarily harder but it just takes a lot of concentration and being at class is very important with its success. If you miss a lesson it is hard to catch on. (Female)

(30) It's a great challenge for students who are willing to work hard. It's a different Maths – very interesting. (Female)

Appendix 4

The calculation of Overall Position OP--simplified

We follow a student 'Toni" (T) through the system.

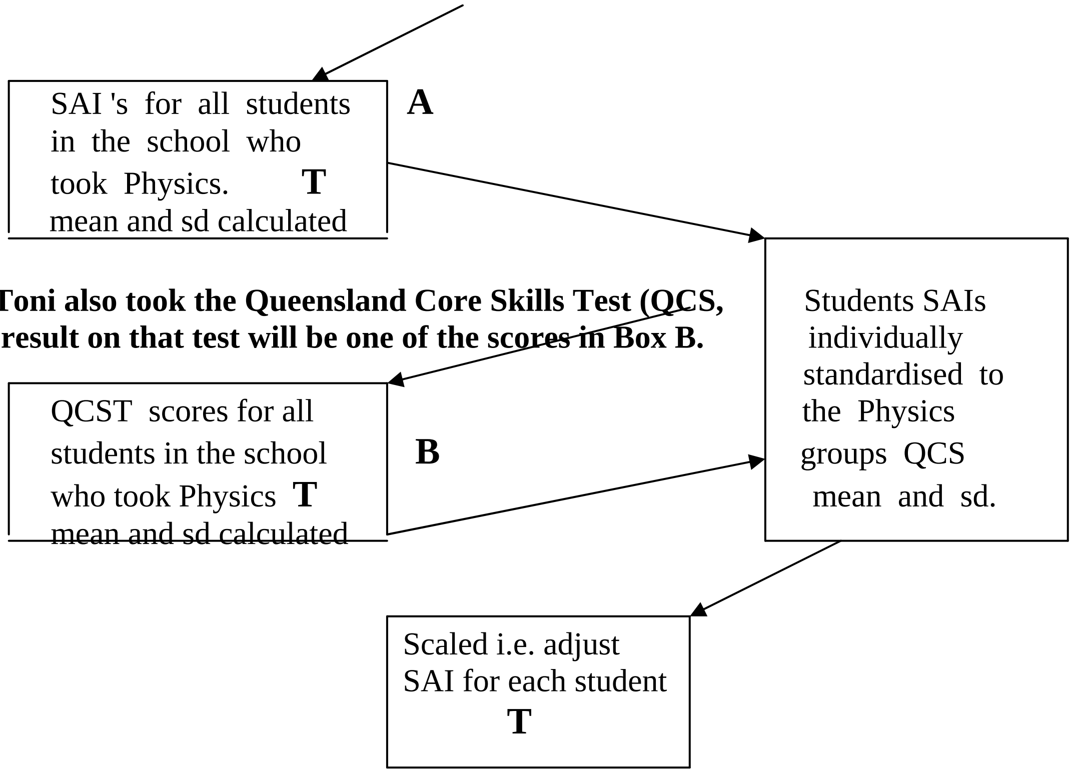
Stage 1. *Within* school scaling.

(1) **Toni takes Physics. As a result of her results in Physics her school awards her a Subject**

Achievement Indicator (SAI), that is a number on a 200 point scale.

So Toni is one of the students in Box A.

(*2*) Toni also took the Queensland Core Skills Test (QCS, her result on that test will be one of the scores in Box B.



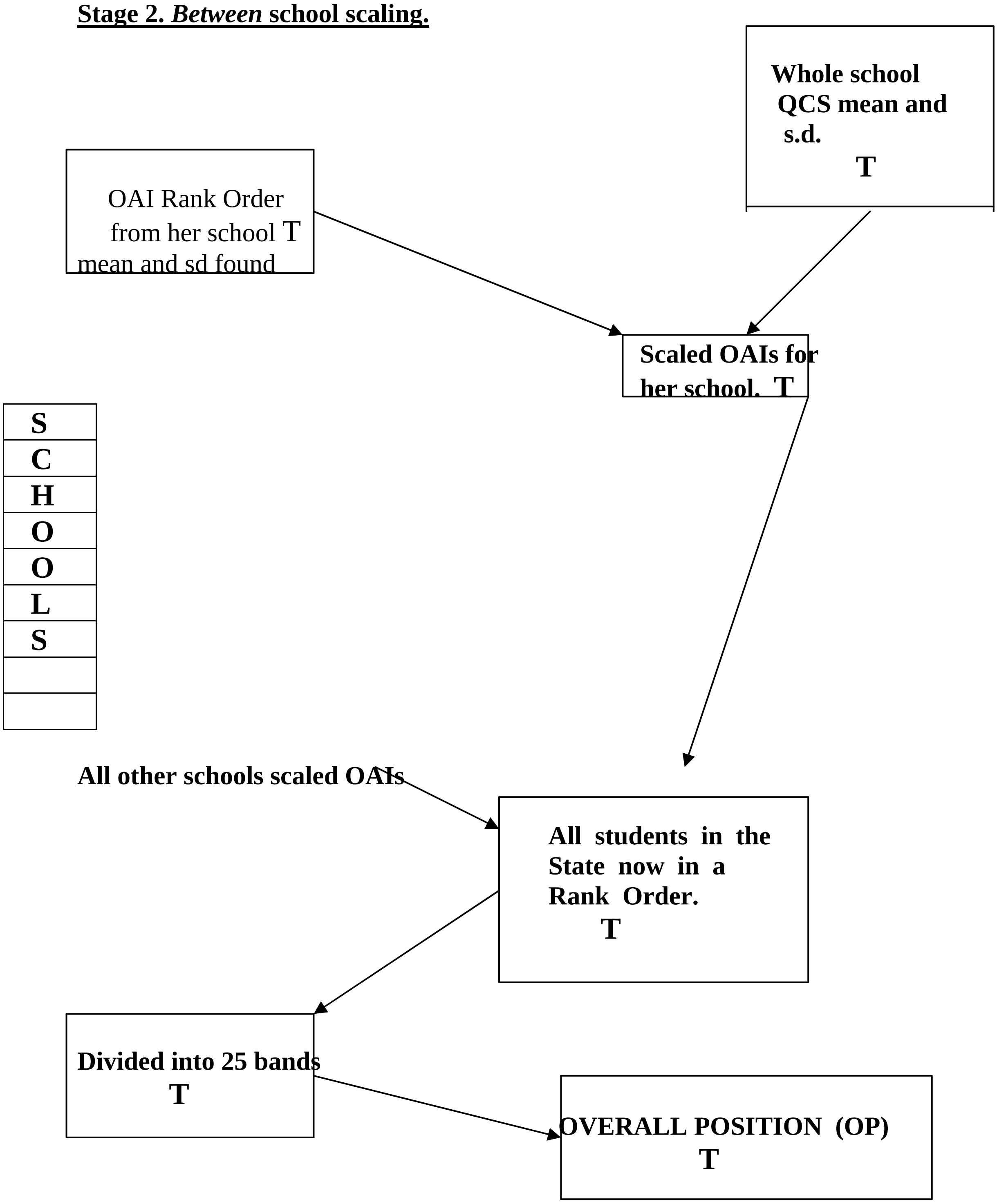
Toni now has an adjusted (or scaled) SAI for each of her six subjects. The best five of them are added so giving her an "Overall Achievement Indicator".

All of the other students in her school have also got an OAI, so now they can be put in a Rank Order-----but this order is only *WITHIN TONIS' SCHOOL.*

But the OP is a ranking across the whole State. Hence the Rank Order from her school must be combined with the Rank Order from all the other schools.

That inter-school ranking is what takes place in Stage Two.

Stage 2. *Between* school scaling.



Notes.

This outline of the OP system is highly simplified. It shows the 'normal' process by which a students' OP is calculated.

However it should be noted that there may be other processes operative in 'unusual' circumstances:

(1) If a subject group within a school is 'small'(<10), and for 'intermediate' groups(10-13), the statistical methods shown in the outline above are inappropriate. Different methods are then used that compares a student with **all** the student in the state who take the subject.

(2) If a student's QCS result is notably different to her/his overall subject achievement, then a measure, the 'Within School Measure' (WSM)is used to re-scale the subject result. The WSM is '--derived directly from the SAIs (by interpreting these results as 'wins' and 'losses' against other students in the school in a type of round-robin tournament)'. The objective of that approach is to prevent a given students abnormal result affecting other students in the group. 'Consequently, for example, a student who has an off day on the test, for whatever reason, does not affect the validity of the scaling for subjects taken by that student. So too, for example, a student who performs well on the test but has not achieved well in school does not thereby contribute an unfair 'boost' to other students in subjects taken by that student'. (Calculating OPs: The basic principals. Tertiary Entrance Procedures Authority 2001.)

Appendix 5

Tertiary subject definitions: Department of Education Science and Training.

Part A. Definitions up to and including 2000

090401 Mathematics - General.

Courses that provide, or develop further the abilities of, individuals with an understanding of logic, symbolic languages, abstract axiomatic systems.

090402 Applied Mathematics.

Courses that prepare, or develop further he abilities of, individuals to describe real world systems by deterministic and probabilistic models.

Principal subject matter usually includes some of the following: vector calculus, differential equations, dynamics, operations research, computational mathematics, probability, hydrodynamics.

090403 Pure Mathematics.

Courses that prepare, or develop further the abilities of students to describe number, form, arrangement and associated relationships, using rigorously defined literal, numerical and operational symbols.

Principal subject matter usually includes some of the following: differential and integral calculus, introductory analysis, projective geometry, linear algebra and geometry, differential equations, probability theory, mathematical statistics, theory of numbers, mathematical logic, linear programming.

090404 Statistics and Operations Research.

Courses that prepare, or develop further the abilities of, individuals to analyse management problems using probability theory, distribution theory, mathematical programming, queuing theory, Markov processes, inventory models, simulation, game theory and other mathematical and statistical techniques and models, and to apply appropriate theories and techniques to collecting, describing and interpreting numerical data.

Principal subject matter usually includes some of the following: probability theory, theory of zones, operational research, sampling theory, stochastic processes, analysis of variation, mathematical statistics, multivariate analysis, non - parametric statistical inference, econometric statistics.

090499 Mathematics - Other.

Any mathematics course not described above.

090502 Chemistry.

Courses that prepare, or develop further the abilities of, individuals to analyse, and apply their knowledge of the micro and macro structure of matter, the changes that matter undergoes, the energy involved in such changes, and the models, theories and relevant laws to such phenomena.

Principal subject matter usually includes some of the following: principals and methods of chemistry, theories of chemistry, physical chemistry, analytical chemistry, chemistry of the elements, inorganic chemistry, quantum chemistry, industrial chemistry.

090505 Physics.

Courses that provide, or develop further the abilities of, individuals with an understanding of the physical properties and interactions of matter and energy, including equilibrium, power, wave phenomena, heat, electricity, magnetism, mechanics, sound, light, special relativity and the particular nature of matter.

Principal subject matter usually includes some of the following: physics, optics, physical optics, electricity, magnetism, theoretical mechanics, electromagnetic theory, electric circuits, atomic and nuclear physics, optical instruments, electrical measurement and measuring instruments, electronics, advanced mechanics, classical thermodynamics, theoretical physics, statistical mechanics, quantum mechanics, relativity, solid -state physics, physical metallurgy, structure of metals.

Part B: Definitions post 2000.

010101 Mathematics.

Mathematics is the study of deductive systems, including algebra, arithmetic, geometry, analysis and applied mathematics.

Examples of topics in this detailed field include: algebra, calculus, differential equations, combinatorics, geometry, mathematical analysis, numerical analysis, optimisation, set theory, topology, trigonometry.

010103 Statistics.

Statistics is the study of collecting, describing, arranging and analysing numerical data.

Examples of topics in this detailed field include: biometrics, central limit theorem, law of large numbers, linear models, multivariate models, probability estimations, statistical distribution, estimation and hypothesis testing, statistical significance tests, stochastic processes, time series analysis.

010199 Mathematical Sciences not elsewhere defined.

Mathematical Sciences not elsewhere classified is the study of all mathematical sciences not included elsewhere in Narrow Field 0101 Mathematical Sciences.

010501 Organic Chemistry.

Organic Chemistry is the study of the description, properties, reactions and preparations of carbon compounds.

Examples of topics in this detailed field include: aromatic chemistry, carbon - carbon bond formation, free radicals, hydrocarbons, isomerism, organic synthesis.

010503 Inorganic Chemistry.

Inorganic Chemistry is the study of the description, properties, reactions, and preparation of all the elements and their compounds, with the exception of carbon compounds.

Examples of topics in this detailed field include: crystallography, main group metal chemistry, non metal chemistry, structural basis of inorganic solids.

010599 Chemical Sciences not elsewhere classified.

Chemical Sciences not elsewhere classified is the study of all Chemical Sciences not included elsewhere in Narrow Field 0105 Chemical Sciences.

Examples of topics in this detailed field include: analytical chemistry, colloid science, environmental chemistry, theoretical chemistry, physical chemistry.

010301 Physics.

Physics is the study of the laws governing states and properties of matter and energy.

Examples of topics in this detailed field include: acoustics, electromagnetic theory, gravitation, mechanics, nuclear and particle physics, optics, solid and liquid state physics, thermodynamics, wave theory.

Appendix 6. The Core Skills Test.

As noted in Appendix 4 and elsewhere, the subject results produced internally by each school are re-scaled using the Core Skills Test.

The 2000 Core Skills Test consists of 87 A4 pages. The documents are readily available from
The Queensland Studies Authority,
PO Box 307,
Spring Hill,
QLD 4004

for $2.75 per complete set.

There are four parts:

- The Writing Task
- Multiple Choice 1
- Short Response
- Multiple Choice 2

In this appendix are shown the 'Directions' page and the first few pages of each part in order to illustrate the level and emphasis of each part.

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