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

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Background of submission.

The title at the top of this submission is in fact the thesis topic title of a PhD that I was awarded a few months ago. The similarity between my PhD thesis title and the Inquiry title is remarkable and fortuitous. Consequently this submission is founded on six years of investigation all of it directly relevant to this House of Representatives Inquiry. The complete thesis and another document that considers a wide range of educational topics in a perhaps more readable form are attached. Inevitably this submission is also influenced by my background and past experience: I am a retired State High School teacher who worked as Head of Maths Department in schools and a Training College in UK, Nigeria and Queensland.

Summary

In this submission the declining level of participation in physics and the allied discipline of rigorous mathematics at tertiary and upper secondary level is examined. 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 also be having some influence. Because it may be possible to manipulate supply side influences, various supply side constraints are considered, in particular the condition of maths and physics in lower secondary schools, particularly 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 and especially rigorous mathematics in the last two years of secondary schooling has been in medium to long term decline across Australia. In general 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. Evidence from a large sample of school Principals in Queensland indicates a high degree of concern in the schools about the condition of both mathematics and science in Years 8,9 and 10. Although the problems were specifically identified for Queensland, there is no reason to suppose the situation is different in other States.

An inappropriate structure of relevant Statutory Authorities in Queensland has led to there having been, for 15 years, no collection 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 the most rigorous mathematics at the Year 11/12 levels. An analysis of effects on student ENTER results consequent to the concurrent study of Maths B, Maths C and Physics shows that students are significantly advantaged by that concurrent study. Hence student decisions not to take those subjects may have a deleterious effect on their final outcomes. A survey of students confirms that students who are taking the combination of rigorous maths and physics are comfortable with it and recognise that it has been to their advantage. That survey demonstrates a degree of ignorance about both physics and rigorous maths amongst the Year 10 students, so compounding the already existing discontinuity at the Year 10/11 interface. The ENTER advantage gained by taking the combination 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. Hence it remains to the comparative advantage of males to take rigorous maths and the physical sciences. There is therefore a clear commonality of interest between many males on the one hand and the disciplines themselves on the other.

It is suggested that a major overhaul of both mathematics and physical sciences in lower secondary schools 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 all Parliaments, 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.

Declining participation.

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 an Australian Minister for Education who commented that '--concern remains that too few choose to continue with science--'. (Kemp, 2000). 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 evidence of changes in participation levels in physics, chemistry and rigorous mathematics at both secondary and tertiary is strong and has been repeatedly demonstrated over many years. It is hence not necessary to itemise those declines. The Committee is referred to Jennings et al. (1996), de Laeter, Jennings and Putt (2000), de Laeter and Dekkers (1996), Dekkers and de Laeter (2001), Dekkers and Malone (2000), FASTS and the first chapter of the thesis attached to this submission.

One effect of declining enrolments that has not, perhaps, been given adequate attention is the number of relevant students per school. Due to the combination of an increased number of schools and a decline in total participation, the numbers per school are falling. In Queensland for example the mean number of Physics students per school declined to 17.4 by 2001. Consequently there must be a significant number of schools that struggle to maintain a physics class at all. In Maths C, the most rigorous maths the position is much worse. 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.

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 risk that some, perhaps many, schools with small total enrolments will stop offering the subject hence preventing some students from having the opportunity to take the most rigorous form of mathematics,

Female participation as a percentage of total enrolments has shown very little change in either Physics or Maths C. The most important change, especially from a tertiary entry viewpoint is the decline in male enrolment in absolute terms. Male participation in physics has dropped by 328, female by 58. Hence the male decline is responsible for 85% of the overall decline. Similarly for Maths C male decline was 778 (28%), female decline 247 (24%), hence male enrolment decline was by far the biggest contributor to total decline, being 76% of the total.

The data for chemistry in Queensland 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 in Queensland is in good condition.

Possible influences on 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. Some enrolment data from Canada tends to support a thesis that demand side factors are highly significant. However there is evidence from both USA and Germany that supply side factors are also significant, In USA 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". So for US Computer studies the fall in enrolments cannot be explained in terms of demand side factors. The problem must be mainly supply side driven.

Zadehs remarks 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.

It is hard to envisage any actions that may be taken by and within governmental, industrial and educational institutions that will change the *demand* side of the equation. However 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 this submission concentrates on supply side possibilities.

Supply into Years 11/12: the centrality of lower secondary schooling.

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.

The influence of students' previous experience in Years 9/10 on subsequent participation in natural science was examined by Ainley. (Ainley 1993). 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.-------- 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, (called TES or OP et al in the various jurisdictions). The Longitudinal Survey of Australian Youth (LSAYR 22, 2001) showed that numeracy/literacy *in Year 9* was by far the biggest determinants of final student performance. Furthermore the effect of numeracy was greater than the effect of literacy in every State. The second biggest determinant was the *individual* school. Note *not* the school sector or type.

Gender was not a major determinant. However it is known that a disproportionate number of males are doing poorly (overall) at the end of Year 12. There is hence an apparent dichotomy: gender per se is not a major factor influencing ENTER 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, employing authorities and both State and Commonwealth governments. They must ensure that experiences in, and outcomes from, the lower secondary years receive a level of attention and commitment proportionate to that level of importance.

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). 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 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 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.

The great importance of Years 8/9/10 raises the question 'so what is happening in those years?' Which raises the next question: 'what are the assessment/auditing systems for those years?' As a working generalisation it is legitimate to assume that assessment systems in those years are weak, unreliable, of dubious validity at best and form a weak data set for students as they make their choices for later study. In Queensland the situation is very simple and has been for nearly twenty years. There is no system at all. When the (then) Queensland Minister for Education was contacted and asked for data, 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. That appalling situation has arisen as a consequence of inappropriate statutory body arrangements that resulted in nobody having responsibility for assessment to the end of Year 10.

Unsurprisingly the consequences of the lack of any valid assessment at all have been a wide divergence of standards from school to school and a major problem at the Year 10/Year 11 interface.

A survey of 100 Secondary school Principals that had a startling 70% response rate indicated widespread concern in respect of the situation in Years 8/9/10, enrolment numbers in physics and rigorous maths, and linkages between Years 10 and 11.
A few of the outcomes are relevant to the work of the standing committee:

Time allocation.
For both maths and science in Years 8/9/10 Government schools allocated somewhat more time than did non government schools. More importantly for both subjects and for both school types the allocated times varied in a 2:1 ratio.

"Standards."
80% of the Principals averred that there were differences in 'standards' at Year 10 exit. (74% Govt. 93% non Govt.). A heavy majority thought the differences were 'of concern.' 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, and frequently must be mislead as to the adequacy and relevance of their work to later studies.

Relevant, freely made, comments by principals (coded SGOV - Government, SIND - Independent, SCAT - Catholic) were:

"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)

"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)

"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)

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 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)

It is crucial that the standing Committee does not make the mistake of thinking that the problems in Queensland are unique. They are not. For example the new mathematics syllabus for the Years up to Year 10 in NSW has an assessment 'system' (using the word very loosely) that is staggeringly complex, time consuming, non numerate and depends ultimately on something called an 'on-balance judgement'. There is no system that provides for State wide comparability and there is no apparent system that ensures any validity in the wider context. Furthermore the syllabus, on the first page, under a heading 'what is different?' states that:

There is a significant reduction in the number of outcomes from the current Mathematics 9-10 syllabus (1996) and the Mathematics Years 7-8 Syllabus outcomes (1999).

The Standing Committee may find the content of that statement a matter of concern. They may also find the nonchalant, casual, manner of it's stating of even greater concern.

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 were very common in the comments made by the principals. Clearly they recognised the importance of algebra *as a tool* that was of prime importance in the context of later studies in mathematics and the physical sciences.

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 numbers 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.

One expert mathematician, criticising mathematical teaching fashions, asserted that ' *….because the students spend so much time on these 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 another authority stated that *'students who are going to use mathematics in any way at all need to know much more algebra'.*

Those important comments are 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.

Sadly there is overwhelming evidence that algebra is not integrated into other work, not used as a tool *that makes life easier for the students* but is treated as a nuisance, something that has to be 'done', a hard purposeless chore. The reality is that 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. 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.

Stacey and MacGregor emphasise the significance of algebra both as a language and as a method, a tool for solving problems, contending that it is *'…….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). Silver considers algebra to be *'..a gatekeeper to educational opportunity.'* (Silver 1995).

Allen (2000) as a part of a detailed examination of the condition of mathematics at the end of Year 10 in Queensland, considers the general area 'Applying Techniques', i.e. the *use* of mathematical tools, notably algebra, and concludes *' that there are **no** items showing perceptions of general widespread familiarity'* (Their emphasis) (Allen, 2001, p15). Worse still, for the specific topic 'translate simple word problems into algebra' only 9% of the Year 11 groups are considered to be to have reliable abilities on this topic. Even for Maths B groups the percentage reliable is only about 15%. Only for the Maths C groups, supposedly the most able, is the level of reliability greater than 30% (Allen, 2001, p.15). Furthermore

Allen demonstrates beyond any shadow of doubt that even between students who have all been awarded the highest level of achievement there are huge differences in standards. Some of the samples of supposedly very high quality student work shown are lamentable. That variation was, as mentioned previously, quite inevitable because of the complete lack of valid assessment systems for many years.

For any readers who may still doubt the veracity of that statement the following quotation should lay any such lingering doubts to rest. *'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.) Mr Wells was at that time the State Minister for Education.

There are a number of factors, all of which will tend to downgrade the standards in both maths and the physical sciences.

Syllabuses are weak and getting weaker. They present almost no challenge to the more gifted children - the very ones who are most likely to take rigorous maths, physics and chemistry in Years 11 and 12.

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. See, for example, (Thomas, 2000).

The shortage of secondary maths teachers is common throughout the western world. In Australia it is a nation wide problem. (Thomas, J. 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.)*

In stark contrast to the generally poor level of mathematics, especially the use of algebra as a tool, at the end of year 10 the Maths B and the Maths C syllabi for Years 11/12 heavily emphasise the use of mathematics as a tool. *E.g.'---develop an understanding of the use of differentiation as a tool in situations---' and 'emphasis should be placed on the application of function to solve problems in a range of life – related situations'.*

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 Years 11/12 in which they are expected to use a variety of mathematical concepts and techniques, notably Calculus, as tools. Many of the students are grossly under prepared for later studies. There are inevitable effects on enrolments.

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. For example earlier texts required the students to be able to apply simple mathematical (including algebraic) techniques to questions in dynamics, pressure, density, current electricity etc. Presently all too many textbooks have few numbers/measurements and effectively no calculations at all.

The most complex(!!) question appears to be:

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

As a clever but sarcastic Year 9 remarked recently *'it is untrue that there are no numbers in the science text book; there is one at the bottom of every page.'*

If students cannot solve simple equations then, unless numerical science is avoided altogether (as is almost the case in some texts and presumably in some schools), simple physical laws have to be memorised in multiple forms so as to make each variable the 'subject of the formula'. Thus, from another slightly older but still 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.'

The reduction in the use of, and hence need for, mathematical/algebraic thinking in current science text books to Year 10 exit ill prepares students for Physics at the Year11/12 levels. A 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.*

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. That consequent discontinuity at the year10/11 interface will have implications for both participation in, and success at, rigorous maths and physics in the last two years of Secondary schooling. Because of Ainleys remarks mentioned earlier it is much more than reasonable to suppose that males will be more affected by poor maths and physical science in lower secondary schooling than will the females. Bearing in mind the fact that the declines in enrolments in rigorous maths and physics have been overwhelmingly declines in *male* participation, we have a clear indication that there is a strong commonality of interest between the males and the disciplines themselves.

Consequences of subject selection.
(a) ENTER Analysis.

Calderon et al (2000) examined some consequences of subject selection on Equivalent National Tertiary Entrance Rank (ENTER) outcomes in Victoria. 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 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). That test is a measure of all round ability, a measure of the relative academic strength of the various cohorts of students. Hence in Queensland it is possible to compare like with like. An examination of the QCS results shows that the cohorts taking high level maths, LOTE, physics and chemistry were much stronger than the average

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. An example of such inadequate comparisons is to be found in a set of slides put out by Education Queensland, via its Equity Programs Unit. It showed that in 1996 a higher percentage of females than males taking, for example, Maths C and Physics obtained a High or Very High Level of Achievement, i.e. the females 'did better'. It did not mention that the QCS results for those subjects. Even the most cursory glance at the data demonstrates without 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.

The existence of full and accurate data, both subject results and QCS, permit of a legitimate consideration of the consequences of subject selection on final Year 12 results (ENTER)

Noting that all ENTER systems are races, dog eat dog, it is evident that the taking of one subject instead of another will not produce any improvement in ENTER output unless the student is relatively better at the new subject in comparison to other students. Nevertheless a possible consequence of a student taking a subject is that it might affect the 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 outcomes in Physics or another Mathematics?

The early nineteenth century economist David Ricardo postulated the 'famous theory of comparative advantage'. (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, 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 calibrated subject outcomes, separately and in combination, was indicated. This section attempts to do that by a consideration of calibrated subject data for physics and two levels of mathematics for groups of students of similar general ability as measured by the QCS.

Three issues were considered, all pertaining to two levels of Maths and Physics and interrelationships between them:

(a) Possible influence of taking rigorous maths (Maths C) on outcomes for another maths (Maths B) .
(b) Possible influence of taking rigorous maths(Maths C) on outcomes for Physics.
(c) Comparative performance of males and females.

The results of the analysis were that the taking of Maths C produced a significantly improved result in both Maths B and Physics, the improvement in Maths B being greater than the improvement in Physics. The ENTER consequences of those improvements will vary but will be most noticeable for students near to and somewhat above the mean. For many students the improvement would be enough to permit entry to a Tertiary course that would otherwise be out of reach.

Consequences of subject selection.
(b) Opinions of students in Year 12 Maths C.

Year 12 Maths C students in five schools completed a short questionnaire to ascertain what it is like to take Maths C and to comment on any wider implications.
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 analysis.

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 attached thesis Appendix 3 parts A and C). 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 - and sometimes earthiness - 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 the attached thesis Appendix 3 part D (q.v.).

Another part of the survey examined student reasons for their subject selection. The results show that the 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 the findings of earlier researchers who commented that '*overall senior students appeared to act in a mature, calculating manner'*. If the year 10 students were aware of the ENTER advantages that exist if the combination of rigorous maths and physics is taken then it is possible that 'mature calculation' would encourage a rise in participation.

Consequences of subject selection
(c) Opinions of students in Year 10

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. Relevant outcomes of that survey are that:

(a) The students are indeed trying to be calculating.
(b) They claim to receive little advice at to whether or not to take any Physics or Maths C or Chemistry but also claim that they have 'heard it is hard'. In the absence of data they are clearly working on rumour.
(c) 30% of students stated that they did not really know what Maths C is and 23% stated they did not know what Physics is.
(d) They have no idea at all that there are significant ENTER advantages in the concurrent study of Maths C/Maths B/Physics.

A lack of knowledge about the subjects reduces the student's ability to make informed, calculating decisions.

Earlier it was 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. That problem is compounded by 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 ENTER implications. They are indubitably working on rumour. Most, if not all, of those problems are likely to exist in the other States. To imagine otherwise would be a triumph of hope over reason.

Male performance in Mathematics and the Physical Sciences.
(a) Male performance at ENTER.

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 . 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). 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) To what extent these remarks are based on dubious analysis such as the Equity Programs Unit material referred to earlier is unknown. Nevertheless the fact is that it is a currently fashionable received wisdom, a '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).

The analysis presented here is for Queensland. However, unless it is to be assumed that students are fundamentally different from State to State, the general thrust of the analysis outcomes will be true for all States.

The version of ENTER in Queensland is the Overall Position (OP). It ranks the students into 25 bands. Hence the 'middle' is at the band 12/band 13 interface. An examination of the OP data is somewhat complicated by the substantial difference in participation rates between females and males. (15000 to 12000). 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. 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. So relatively poor male performance is near to and somewhat above the mean, the same band groupings where it has been shown that students are most advantaged by the concurrent study of Physics/Chemistry/Maths C/Maths B.

Male performance in Mathematics and the Physical Sciences.
(b) Male performance in Physics.

As was noted earlier, students who take Maths C perform significantly better in both maths B and Physics than students *of similar general ability* who do not take Maths C.

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. (That was the crude system used by the Equity Programs Unit, an approach that if applied to the results for French would 'show' that males are much better at it than females!) 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.

Two rather different methods are shown in chapter 5 of the attached thesis (q.v.) Both approaches produced similar results that can be summarised as follows:

An examination of the analysis for the years 1992 - 2001 sheds some light on the two fashionable questions/assumptions: are the males doing notably poorly in physics and are they getting progressively worse? The responses have to be that (a) males are definitely 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.

Male performance in Mathematics and the Physical Sciences.
(c) Male performance in Maths.

For Maths C the position is radically different from that for Physics. For every year the females' are performing slightly better than males of similar general ability. 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, albeit slight, 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 another Matters et al finding, 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 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.

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 Maths B analysis shows two beyond reasonable doubt: firstly there is no evidence whatsoever to support the claim that the females are outperforming the males, and, secondly, the females are obviously not 'catching up'. The importance of the Maths B analysis in the female/male debate is hard to overestimate. Maths B is not 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 and Physics. In particular most of the

students will be in region of the OP distribution (5 to 15) in which relatively poor male performance has already been identified.
That relatively poor OP performance in the region near to and somewhat above the mean can only happen if males are performing relatively poorly in the subjects that they are taking. However there is no doubt that males are performing as well as females in the combination Physics/Chemistry/Maths C/Maths B. Bearing in mind that, for the males, Ricardian comparative advantage in subject selection *only requires parity* with the females, it is clear that the subject combination is a comparative advantage for the males.

In comparative advantage terms males are advantaged in subject and hence OP (ENTER) 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.

We know that a very large percentage of students, predominantly male, across Australia have 'dropped out' of' the most rigorous maths and Physics. Hence those males are not taking a subject combination at which they are at a comparative advantage. Inevitably many of them must therefore be taking subject combinations at which there are at a comparative *dis*advantage. Poor things, they try to be 'calculating', hard headed, but they simply do not have the tools to make wise decisions. Worse still, if material such as has emanated from the Equity Program has penetrated the school(s) - as it is intended to do - then the males will be actively discouraged from taking the maths/physical science combination. 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 Studies Authority techniques that produce the ENTER 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 ENTER 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. The consequences would be improved ENTER results for some of those students and a concurrent increase in participation levels in rigorous maths and physics at secondary level and hence an increased pool of adequately qualified students from which the relevant tertiary departments can draw.

Minimal suggestions for remediation.

All governments and political parties would do well to change their focus and their thinking away from their pre-occupation with Year 12 retention rates, tertiary enrolment numbers and funding for the various school types. They need to 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 State governments emphasise to their Studies Authority the importance of setting up a system of genuinely validating student outcomes for all subjects at Year 10 exit. The governments 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 billions spent annually on education at the year 8/9/10 levels.

The Authorities need 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). That extraordinary comment is justified. There is a tendency, a deliberate policy, to remove, or at least grossly degrade, the use of mathematics in physics. Such a move has the potential to move physics back to a pre

Newtonian, non-numerate study. There is a huge increase in the level of English comprehension even in mathematics. As one education analyst put it in reference to a *maths* assessment 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'.*

Although it is not of direct relevance to this Inquiry, the Committee members should recognise that the over emphasis on verbal skills, together with a concurrent de-emphasis on mathematics will adversely effect males from lower socio-economic backgrounds who are relatively poorer at literacy than numeracy. There is a very major social justice issue here.

There is an urgent need to ensure that all syllabi at all levels provide a reasonably full description, list, of content/ideas etc that *must* be studied. (Some syllabi are hopelessly deficient, e.g. Physics trial syllabus Qld).

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. 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 ENTER 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.

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).

Note. Attached documents.

(a) PhD thesis.

The contents of this document are listed on Roman numbered pages x to xiii. In essence Chapter 1 is just a sad story of declining participation, Chapter 2 deals with the importance of lower secondary schooling and includes a summary of the survey of school Principals opinions. Chapter 3 examines the condition of mathematics (particularly algebra) and numerical science and points to the inevitable discontinuity at the end of Year 10. Chapters 4 and 5 are analyses of the effect of the taking of rigorous maths/physics on final ENTER results and demonstrate that males are comparatively advantaged if they take those subjects. Chapter 6 is a summary. The Appendices 2 part B and 3 part C are of interest in that they are 'straight from the horses mouth' comments by Principals and students.

(b) ***Practical Wickedness: a series of essays on 'Education today'.***

These easy to read but soundly based essays deal with a wide selection of issues in education today. The 'overview of essays' on pages 2 and 3 provides a summary of each of the essays, the majority of which are relevant to the Inquiry. The first essay, that starts on page 4, may be of interest in that it contains some comments made by the thesis reviewers.

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