WHY GIRLS, IN A SINGLE-SEX SCHOOL, STUDY MATHEMATICAL METHODS BUT NOT PHYSICS

Submitted by
JANE COYLE
B. App. Sc. (Mathematics) Royal Melbourne Institute of Technology,
Grad. Dip (Ed.) Australian Catholic University
Student No. 201110313

A research paper submitted in partial fulfilment
of the requirements for the degree
of Master of Education

School of Scientific and Developmental Studies
Faculty of Education
Deakin University
Burwood, Victoria 3125

November, 2006

Candidate's statement

DEAKIN UNIVERSITY
FACULTY OF EDUCATION

CANDIDATE'S STATEMENT

I certify that the Research Paper/Minor Thesis entitled:

WHY GIRLS, IN A SINGLE-SEX SCHOOL, STUDY MATHEMATICAL METHODS BUT NOT PHYSICS

and submitted for the degree of **Master of Education** is the result of my own work, except where otherwise acknowledged, and that this Research Paper (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Approval to conduct the study was granted by the Deakin University Ethics Committee through the Faculty of Education Ethics Subcommittee.

Signed ....

Date ....

Table of Contents

List of tables

List of figures

Abstract

This study sought to investigate the influences and reasons girls, from single-sex schools, have for their subject choices in physics and mathematics. This study aimed to find out why girls, who seem to be capable of studying physics, do not choose it. Unit 2 Mathematical Methods students from three girls schools catering for different socio-economic areas of Melbourne were asked open-ended questions in regard to their subject choice of Physics and Mathematical Methods. They were also asked who influenced their subject choice decisions. The selection of Mathematical Methods students was used as an indicator of mathematical interest and ability. It was assumed that students who have already shown themselves to be interested and capable in mathematics are likely candidates to study Physics. Selecting students from the single-sex environment was an attempt to identify issues other than that of gender imbalance in the classroom. The study also aimed to identify the state of physics uptake in Victoria with respect to female enrolments in the Victorian Certificate of Education (VCE) Physics courses. Data from the Victorian Curriculum and Assessment Authority (VCASA) for Units 2 & 4 Physics and Mathematical Methods enrolments were analysed with respect to gender for the 2000 – 2005 period.

From the surveys it was established that the majority of these girls found junior physics boring and did not see any future relevance in the study of physics. The findings also brought into question the purported benefits of the all-girl environment to challenge the gender gap in enrolments for stereotypically male subjects such as physics and mathematics. The VCAA data established that there is a distinct gender gap in enrolments for VCE Physics. The combination of these results paints a bleak picture for female participation in the study of Physics in Victoria. If female enrolments in physics are to be increased, greater efforts are needed to capture the imagination of these potential students and to open their minds to the opportunities that the study of physics has to offer.

Acknowledgments

I wish to acknowledge the support and guidance of my supervisor, Dr Peter Hubber, whose detailed annotations were of great assistance. I thank all my colleagues at Marian College for their words of encouragement and their understanding. I thank my husband Roger Lewis for his patience and critical eye. Lastly, I thank my children, Evelyn, Katie and Dominic who now will get their mum back!

Framing the Issue

Introduction

This study was the result of several years of observation and teaching of physics and mathematics in which this researcher had observed girls in junior mathematics classes show considerable interest and ability for physical, real world applications of their mathematics skills. Yet when it came time to make decisions about subjects at a senior level (years 11 and 12), although continuing to study a sophisticated level of mathematics, very few of these girls considered studying physics. Why do these girls not consider physics?

In this study, Mathematical Methods students from three, all girls-schools were surveyed in regard to their subject choices in Mathematical Methods and Physics. As mathematics and physics are often linked by similar content area and skills base (Gill, 1999) this study focused on students who had demonstrated an interest in mathematics. The selection of Mathematical Methods, which is an algebra and calculus based mathematics course offered as part of the Victorian Certificate of Education (VCE), was used as an indicator of mathematical ability and interest. This focus allowed the researcher to consider a group of students who could be expected to be capable of studying Physics. The link made between Physics and Mathematical Methods was examined using enrolment data from the Victorian Curriculum and Assessment Authority (VCAA) for the number of students enrolled in both subjects.

The lack of girls studying physics has been documented for many years (Cumming, 1997; IUPAP, 2005; Kelly, 1982; Parker, 2002). Concern for the decline in enrolments in the physical sciences (Parliament of Victoria, 2006; AUTC, 2005; Thomson, 2005) reilluminates this gender gap issue. To establish the state of enrolments in Victoria, this study used a preliminary analysis of available VCE data on enrolment trends in Mathematical Methods and Physics to identify if and by how much, females are underrepresented in Physics and Mathematical Methods. Data was also used to determine if the suggestion that overall numbers in Physics are falling could be supported by VCE data for the last five years.

This study aimed to determine what factors girls who study an advanced mathematics had for choosing and not choosing physics as part of their VCE studies. In determining these factors data was collected from responses to an open-ended questionnaire that sought reasons for female students' subject choices of Mathematical Methods and Physics. Data was sought from both Physics and Mathematical Methods students to identify what motivated these girls to choose Mathematical Methods yet for the majority, not to choose Physics. To get a better picture of the subjects chosen with Mathematical Methods, students were asked to list the other subjects they were studying. Students were asked to identify what they thought physics entailed, as a limited understanding of what the study of physics is has been suggested as one possible reason why students find little relevance or interest in physics and thus do not choose to study it (IUPAP, 2005; Norvilitis, Reid & Norvilitis, 2002; Parker, 2002; Stadler, Duit & Benke, 2000; Stokking, 2000; Williams, Stanisstreet, Spall, Boyes & Dickson, 2003). Students were also asked to identify whom, if any helped them or influenced their choices as several studies recognise the influence of family, peers and background as significant factors in the decision making of students with regard to subject choices (Cumming, 1997; Labudde, Herzog, Neuenschwander, Violi & Gerber, 2000; Lyons, 2005; Stokking, 2000).

This study was specifically limited to single-sex schools in an attempt to identify issues that relate to girls' interests and perceptions and to offset any gender issues in mixed gendered schools; such as students' concern of gender imbalance in the classroom. The philosophy of single-sex girls education includes breaking gender stereotypes in the belief that girls achieve better outcomes in a single sex environment (Kelly, 1982; Stage, Kreinberg, (parsons) & Becker, 1985; Watterston, 2001). It may be concluded that subjects that have been traditionally dominated by male enrolments such as physics and mathematics, would have a larger than average female uptake in a single-sex school. This study used data collected from VCAA, to compare average VCE enrolments in Mathematical Methods and Physics with the enrolments in these subjects at the three surveyed schools.

<u>Purpose, goal and outcomes</u>

The over-riding purpose of this investigation was to get a clearer understanding of the motivations behind girl's subject choices in physics. To achieve this, this study attempted to arrive at some understanding as to the state of physics enrolments in Victoria and how they differentiate with respect to gender and to investigate why girls who demonstrate an interest or ability in mathematics choose or do not choose to study physics. This study assumed that these girls, who choose to study an advanced mathematics, would be prime candidates to study physics, as their male counterparts do.

My research questions for this study may be given as:

Question 1.

What is the state of Physics enrolments in Victoria with respect to total VCE enrolments and differentiated by gender?

Question 2.

What factors do female Mathematical Methods students from single sex schools have for choosing or not choosing Physics as part of their VCE studies?

It is hoped that by gaining a better insight into the reasons girls have for their subject choice in physics and mathematics, strategies can be formulated to address these reasons with the result that more girls consider physics as a subject and career choice.

Literature review

Introduction

This chapter reviews some of the literature pertaining to this study. The review is divided into four sections: Mathematics and physics, Gender issues in science and mathematics, Subject choices and Single sex environment for girls. The first section, Mathematics and physics, explores the link between these two subjects, how they complement each other and to what extent the successful study of physics relies on mathematical ability. The second section, Gender issues in science and mathematics, examines the historical concern of male dominance, both in enrolments and success in the fields of science and mathematics. The third section, Subject choices, explores the motivations for students' subject choices in their post compulsory years at school. The final section, Single sex environment for girls, explores the issues pertaining to the single sex education of girls.

Mathematics and physics

In this study the attitudes of female mathematics students are investigated in regard to their subject choices of mathematics and physics. A student's selection of Mathematical Methods is used as an indicator of mathematical interest and ability. It is assumed that students who have already shown themselves to be interested and capable in mathematics are likely candidates to succeed in studying physics. This inference can be justified by looking at the close relationship mathematics has to physics.

Mathematics is the tool physicists use to explore the physical world. Sells (1975) in Stage, Kreinberg et al. (1985) identifies mathematics training in secondary schools as a 'critical filter' for women choosing to study science as undergraduates or graduates. In a study of a diagnostic mathematic and scientific reasoning test for first year undergraduates in South Africa, Saayman (1991) showed that students who achieved higher than 65% were more likely to pass their first year physics exam. Although several studies indicate that strong mathematical skills alone cannot be used to predict success in physics they all identify that a lack mathematical skill is a strong predictor for failure in physics (Hudson & Liberman, 1982; Hudson & McIntire, 1976; Norvilitis et al., 2002).

The VCE study design for Physics (2004) outlines the need to use mathematical modelling to investigate the physical phenomena under study. The second dot point in the aims for the course states:

> To understand the way knowledge is extended, organised and revised in physics, in particular the role of conceptual and mathematical models applied to physical phenomenon. (Victorian Curriculum Authority, 2004, p.7)

There is an expectation that students studying physics have some mathematical ability. Mathematical modelling, describing phenomena mathematically and/or performing mathematical calculations are mentioned at the start of every Unit of work description and at least 20 times throughout the document. The descriptor at the beginning of Unit 3 includes:

> Mathematical modelling, including calculations, as applied to all areas of study to organise data and make predictions (p. 25).

Lack of mathematics ability is often voiced as an underlying concern for Science and Engineering first year students. The Learning Outcomes and Curriculum Development in Physics report commissioned by the AUTC (2005) found that poor mathematical ability was a major concern for Australian tertiary physics departments. A quick Internet search using with the search terms ‘remedial mathematics in physics courses’ produces many university and college sites offering remedial mathematics courses for science and engineering undergraduates. This suggests that such institutions place importance on students having the necessary mathematics skill prior to entering their courses.

Intervention programs which were designed to attract girls to physical sciences, technology and engineering have focused on increasing mathematical skills (Stage et al., 1985). Quinn (1992) in Raw (1999) suggests that the mathematical nature of physics is a deterrent for prospective physics students. Gill (1999) identifies the areas of calculus, logarithms, trigonometry, complex number and algebraic manipulation as areas of greatest concern in regard to mathematical ability of first year physics undergraduates. Other than complex numbers, all of these particular areas of mathematics are covered in the VCE Mathematical Methods course.

It may be reasonable to state that the preferred undergraduate physics student entering first year would be one that has studied a combination of physics and mathematics. This is indeed the case for most Victorian universities. Mathematical Methods is stated as a prerequisite for seven out of nine physics courses identified by the Victorian Tertiary Admissions Council (2006). The two courses that did not have it as a prerequisite highly recommended it be studied. All of the university engineering courses had Mathematical Methods or Specialist Mathematics as a prerequisite.

The Parliament of Victoria in a recent inquiry into the Promotion of Mathematics and Science in Education (2006) linked the subjects of physics, chemistry and advanced mathematics as 'Enabling Sciences' (p. 5). This suggests that governing bodies believe that there is a link between mathematics and physics. This link in the study of physics and mathematics is also strongly supported by Thomson (2005) in her Longitudinal Surveys of Australian Youth report which examined the pathways from school to further education and work. In her examination of Yr 12 subject choices she identified subject clusters of which advanced mathematics-physical science was one. This cluster involved the triplet of advanced mathematics (a mathematics involving calculus), physics and chemistry. Thomson identified that these clusters formed coherent courses in which students were advantaged by studying similar concepts in each subject (p.1). Her research revealed that boys were far more likely to be represented in this group than girls and that the differentiating factor was physics. That is, boys studied all three of advanced mathematics, physics and chemistry where as girls tended to study the advanced mathematics and the chemistry but not the physics
(p. 12). The reasons for this gender difference have been the subject for much discussion and the following section examines these in detail.

<u>Gender issues in science and mathematics</u>

Gender issues in physical science and mathematics have generated much academic discussion in the last fifty years. One of the most prominent issues is the large difference in the uptake of physical sciences between boys and girls. This 'gender gap' is particularly significant in the study of physics where in 2005 girls made up less than a quarter of the physics cohort in the VCE (Victorian Curriculum and Assessment Authority, 2005). The 'gender gap' is a term also used to describe an historical difference in achievement between genders. The literature found the causes of such gender gaps to range from physical, cognitive differences between male and females, exclusive curriculum and social conditioning, which then leads to a diminishing of interest in the physical sciences and physics (Cox, 2004; Cumming, 1997; IUPAP, 2005; Norvilitis et al., 2002; Parker, 2002; Stadler et al., 2000; Stokking, 2000; Williams et al., 2003).

The question of difference in male and female cognitive ability for mathematics and science is discussed in several papers, with the main conclusion being that there is little or insignificant biological reasons for the gender differences in achievement in sciences (Jones, 1989; Kelly, 1982; Kelly, Whyte & Smail, 1984). Spatial ability is traditionally identified as a differentiating factor between male and female cognitive ability and yet studies suggest the difference is not enough to warrant the marked distinction in gender balance and performance (Harding & Sutoris, 1985; Kelly, 1982). If boys were more predisposed to mathematics then significant differences in ability would be expected from early stages. In Jones (1989) in which achievement scores on tests and teacher beliefs of ability were investigated, it was suggested that in their junior years (Grades 1, 2, & 3) boys and girls show little or no measurable difference in mathematical ability. Indeed when there was a slight difference, it determined that girls demonstrated slightly more ability. Although teachers rated boys slightly higher than girls in mathematics ability, this research found that the girls demonstrated a more positive attitude to mathematics (Jones, 1989, p. 2).

The difference in learning styles between boys and girls has also attributed to a gender gap in physics (AUTC, 2005; Stadler et al., 2000). From their study, Stadler, Duit and Benke (2000) suggest that boys and girls hold different notions of what it means to study physics. They suggest that boys are happy to find an internal coherence of physics; they look for concrete answers, readily use terminology and the traditional scientific framework, whereas girls tend to look for an external coherence; they do not believe they have grasped a concept until they can put it into a broader, (non-scientific language) context (p. 420). The result of this is that traditional methods of teaching physics may favour the male learning styles and undermine female students' confidence.

Interestingly several authors suggest that a significant gender gap in both ability and uptake does not develop until students move into their secondary years of schooling (Cole, 1997; Jones, 1989; McCullough, 2004). Kelly (1982) suggests that as stereotypes of male and female develop in children, their attitude to gender-related subjects also develops. By middle secondary, boys are more interested in the physical science and mathematics and girls are more interested in English and languages. In addition she identifies that by the time students are making their subject choices they are in the midst of puberty, and the pressures associated with this lead students to find comfort in conventional gender specific areas where they are not making decisions that conflict with their own self-image. Head (1980) continues this argument, suggesting that adolescents go through crisis (intensive questioning) and commitment (firm belief) in their struggle for 'ego-identity': it is the very conventionally male aspect of science that attracts boys and repels girls at this stage in their development.

There is a large body of evidence to support the argument that students see science and mathematics as male pursuits. Kahle's (1993) study of student perceptions of a scientist, which required students to sketch a picture of a scientist, clearly illustrates that both male and female students saw scientists as males (the Australian figures were over 90% of students). Kahle suggests that this male stereotype of scientists would deter female students' self-confidence and interest in science. Sjoberg (1990) continues this argument suggesting that science curriculum, which has often been gender exclusive, disadvantages girls. He suggests that although unintentional, science curriculum, particularly in the physical sciences, "builds on experiences that strongly favours boys" (Sjoberg, 1990, p. 31). Kelly (1982) also suggests that the masculine image of science discourages girls. This argument so far has identified science in general as masculine, but should perhaps be more specifically aimed. Researchers have found clear gender orientation within the sciences, between the physical (in particular physics) and biological sciences (Fullarton & Ainley, 2000; Lamb & Bell, 1999; Thomson, 2005).

McCullough (2004) identifies masculine characteristics of physics beyond the classroom. She suggests that the language used to describe the atomic bombs during the

Second World War (Fat Man and Little Boy) is indicative of a study that is innately masculine. Importantly, McCullough attributes this masculine culture as a result of male dominance in the field of physics rather than some cognitive difference that excludes females from its study: “Who the scientists are affects how science grows and what the science is” (McCullough, 2004, p. 22). In a study by Sjorberg (1988), in which students were asked to rate words describing physicists and biologists, both girls and boys saw biologists as caring, open and imaginative whereas physicists were described as selfish, closed, boring and in-artistic (Sjoberg & Imsen, 1988, in Sjoberg, 1990). Kelly considers the impersonal approach of physical sciences as a factor in discouraging girls. Her suggestion that physical science has an “apparent remoteness” (Kelly, 1982, p. 12) that girls do not relate to seems confirmed by Sjoberg’s results. The preference of girls toward what they perceive as more altruistic area of science is confirmed by enrolment figures for Biology in the VCE in which 68% of the cohort was represented by girls in 2005 (Victorian Curriculum and Assessment Authority, 2005). Sjoberg (1990) concludes that the image of the physicist in conjunction with female students’ interests would significantly influence their subject and career choices.

This result is further supported by the work of Jones and Kirk (1990) who studied the gender differences in interest of topics within a high school physics course. By gathering student responses to the prospect of learning about areas such as new technologies, how vacuum cleaners work, foetal heart-beat monitor and kinetic energy, Jones and Kirk identify clear trends between what interested girls and boys. They found the girls appeared to be far more interested in learning about medical-technology, biological and aesthetic aspects of physics while the boys were more interested in technical devises and how things worked (Jones & Kirk, 1990, p. 312). It would be expected that catering for student interest would be of importance when it comes time for students to make decisions on subject they wish to study in their non-compulsory years at school. However although some the research indicates that this is the case, others suggest interest alone has a smaller influence on student subject choices than once believed.

Subject choices and gender

The significance of interest on subject choice is identified in a longitudinal study on the choices made by girls when selecting mathematics and science by Walkington (1998). This study identified interests as a significant factor in girls' decision-making:

> The liking or disliking of Science and Mathematics work was a strong contributing factor to subject selection. The nature of the subject itself and the perceptions of a subject's relationship to the girl's interests provided interesting responses:
>
> "I'd like to do science - research - I'd like to save the world - to contribute to something" (p. 4).

This last statement from a student exemplifies the suggestion that girl's interest are altruistic and that they are more likely to consider subjects that they believe offer such opportunities (Smail, 1985).

Although the students may be interested in the physics this does not always lead to them considering it as a subject to study (Haussler & Hoffman, 2002). Confidence in ability is identified as a significant factor in subject choice, particularly for girls. Kelly (1982) suggests that while both girls and boys agree that physics and chemistry are difficult, boys will persevere with such subjects. Girls, she suggests, will choose subjects they perceive as easier. Jones (1989) documents the observation by several authors that girls attribute their success to hard work and their failure to lack of ability, while boys, on the contrary, attribute their success to ability and their failures to lack of effort. This difficulty for girls is interpreted as a lack of ability. Both Jorg, Veld et al. (1990, in Stokking, 2000) and Stokking (2000) identified perceived difficulty as a significant factor for girls choosing physics. Walkington (1998) reveals that girls' perception of their ability was of considerable import. He suggested that being sure they would do well was a significant influence in why girls chose a particular subject (p. 3). In a survey of Yr 10 students on subject choices, Williams et al. (2003) identified perceived difficulty as one major factor for not choosing physics. This is supported with similar findings by Cumming (1997), Walkington (1998), Parker (2002) and Lyons (2005). Cox, Leder and Forgasz (2004) investigations further this argument. Their examinations of why girls seemed to out perform boys in the physical sciences suggested that girls' average grades were higher than the boys because the cohort of girls who studied subjects such as Physics and Specialist Mathematics would not consider choosing the subject unless they were confident in doing very well (p. 44).

Clearly changing girls' perceptions of their ability may influence their subject choices and achievement. Intervention programs that build up student confidence have boosted numbers of girls studying physical science and engineering at the undergraduate level (Stage et al., 1985). Initiatives such as contextualising course content, addressing gender-exclusive language and strategies addressing the 'male only' perception (Carlone, 2004; Kelly, 1987; Kelly et al., 1984; Lewis & Davies, 1988; McCullough, 2004; Sjoberg, 1990) have been attempted in an effort to make physical science and mathematics 'girl friendly'. By changing the context of questions in a commonly used physics conceptual test, the Force Concept Inventory, McCullough (2004), illustrates that context will affect performance. Cox, Leder and Forgasz (2004) identified that the introduction of non examination Common Assessment Tasks (CATs) into the VCE study between 1994-1999 with open ended and written forms of assessment was advantageous to female students (p. 39). Smail (1985) identifies curriculum changes that focus on nurturing rather than analytical approaches enable girls to investigate science in a way that relates to themselves and their world. The introduction of study areas such as Medical Radiations in the VCE Physics course (Victorian Curriculum and Assessment Authority, 2004) is an attempt to address this.

Career choice is another factor identified as a main predictor for the choice of physics at secondary level (Stokking, 2000). The link between subject selection and career choice was identified in Hobbs' (1987) investigation of subject selection at Yr 10. He found that interest in gendered occupations lead to gendered subject choices, which would thus restrict subject choices of both boys and girls. Vanderkam (2005) illustrates the link between interest and careers choice, highlighting a study that investigated young scientists' career choices. Women in the survey said "they viewed pure math and physics careers as isolating and not so helpful to society" (Vanderkam, 2005). Sjoberg (1990), in his study of Norwegian school students' job priorities, identified that girls gave higher importance to interpersonal aspects of occupations, whereas boys identified salary and being the boss as important factors for career choice. Studies investigating the general drop in student numbers in physics courses suggest that students believe physics is irrelevant (Lyons, 2005; Stokking, 2000; Williams et al., 2003). Clearly the perception that students have of physics as a science is entwined with their perceptions of physics as career.

With the many interventions and curriculum changes that have been implemented in the last 20 years, the numbers of girls taking up physics at secondary and tertiary remains constant (AUTC report into Tertiary Physics learning, 2005; Cox et al., 2004; Cumming, 1997; Malone, deLaeter & Dekkers, 1993; Sharma & Armi-Stoks, 2002). Cumming (1994) suggests that the many school interventions now being employed have little impact. She proposes that it is the strong socialising influences such as parental background and expectations, peer pressures and social stereotypes that are the major influences in students' choices (p. 3). Similar findings were made by Lyons (2003). Using a 'multiple worlds' framework of the social backgrounds of students, Lyons identified that social interactions of family and peers were strong influences in post-compulsory subject choices. In particular, students choosing physics had families which were strongly supportive by positive relationships (social capital), had strong emphasis of the strategic value of education and/or had members who were advocating/supporting an interest in science (pp. 20-21). He suggested that students with these backgrounds were able to overcome the perceptions of difficulty and irrelevance of physics.

In the final section of this review the use of girls-only education is examined to address some of the issues of gender stereotyping in schools. In this study, the sample is only taken from the single-sex environment in an attempt to identify issues other than that of gender dominance in the classroom. Some of the literature pertaining to girls in a single sex environment is examined below.

<u>Single sex environment for girls</u>

A single sex environment for education is often suggested as one way of addressing gender differences in subjects that have traditionally been the domain of one particular sex (Kelly, 1982; Stage et al., 1985; Watterston, 2001). In particular, girls-only classes for mathematics and physics are increasingly used to address the gender imbalance in these areas (Haussler & Hoffman, 2002; Salomone, 2003; Stage et al., 1985; Streitmatter, 1999). Salomone (2003) suggests that the single-sex setting enables girls to have greater confidence and overcome historic gender bias:

> It appears that girls in particular derive academic and psychosocial benefits from single-sex programs. The literature is replete with evidence pointing in that direction. All-girls settings seem to provide girls a certain comfort level that helps them to develop greater self-confidence and broader interests, especially as they approach adolescence. Research has found that single-sex schools and classes promote less-gender-polarized attitudes toward certain subjects – maths and science in the case for girls. (p. 239)

Kelly (1982) identifies that there is a higher proportion of girls studying physical sciences and mathematics in girls schools than in comparable co-educational settings. She suggests that it is easier to challenge male stereotypes in such an environment, particularly as a higher proportion of staff in these areas are women.

Tertiary intervention programs designed to encourage and improve achievement of girls in physical sciences and engineering, often use a single-sex setting (Smail, 1987; Stage et al., 1985). A mixed-sex acceleration program at Johns Hopkins University was split into single-sex programs when observations and interviews revealed that the formal, competitive and theoretical conditions "diminished the girls' success in the co-educational class" (Stage et al., 1985, p. 122). It is also suggested that class composition in a co-educational environment can be a limiting factor for choosing physics. In Walkington's (1998) study some girls did not eventually choose physics "for fear of being the only girls in the class" (p. 7).

The above literature suggests that an all girls environment should be conducive to a higher uptake of physics. Part of this study will be to look at just how successful three girls' school have been in this.

Summary

Mathematics and physics have a clear link. Both the VCE and university physics courses require a degree of mathematical ability. They are often taken as a triple with chemistry and are considered 'enabling sciences'. If we are to boost numbers of students taking physics in school and at university, those who have a predisposition for mathematics are likely candidates. Historically mathematics and physical sciences have shared similar gender issues. The latest data on enrolments seem to suggest that mathematics and chemistry have made significant inroads into the ‘gender gap’, but physics has not.

The gender gap for physical sciences and in particular physics has had much discussion and investigation. The body of literature identifies and/or dismisses several reasons and influences as to why girls do not see the study of physics as appealing or relevant;

- There is no significant difference in cognitive ability due to gender
- Despite the first point there is significant gender variations in the uptake and achievement in the physical sciences
- Gender variations can be attributed to social concepts that the physical sciences are stereotyped as masculine and are dominated by male professionals
- Gender variations can be attributed to social concepts that the physical sciences do not offer careers which are altruistic
- Gender variations can be attributed the girls perception of their ability and that physics is difficult
- Intervention programs have been successful at a micro level.

Physics is considered by many students as irrelevant and boring and that these concepts are preserved even after considerable intervention strategies.

Single sex education is spouted as a way of addressing the gender gap for mathematics and the physical sciences. The question this study hopes to address is that with all these advantages of a single sex education, why are so few girls from these schools considering physics? Particularly considering that the same historical gender bias in mathematics appears to have been largely overcome.

Methodology

Introduction

This chapter outlines the methods used to address the research questions. This study involved a mixed research approach with the collection of qualitative data through a survey questionnaire and quantitative data through the analysis of Victorian Certificate of Education (VCE) enrolment data with respect to gender and year, available from the Victorian Curriculum and Assessment Authority (VCAA). The following sections outline the methodology used in this mixed research study, the sample and its justification for this study and details as to the qualitative instruments and quantitative analysis used.

Mixed Research

Mixed research methods involve the use of both qualitative and quantitative data collection and analysis. Mixed approaches in educational research have developed through the dissatisfaction with purely qualitative or quantitative approaches to fully describe the social interactions in education (Johnson & Onwuegbuzie, 2004; Rao & Woolcock, 2002). Proponents of mixed approaches suggest that by integrating both methods of research, the criticisms and limitations of each method to describe the human condition can be overcome (Johnson & Christensen, 2004; Sharp & Frechtling, 1997). Sharp and Frechtling (2004) describe a trade off between the breadth that a quantitative technique can yield and the depth that a qualitative technique would provide (p. 3). Both approaches have strengths and limitations; the former offers broadly generalisable information that may oversimplify a complex situation, the latter delivers real insight into a particular situation that may not be relevant beyond that circumstance. Johnson and Christensen (2004) liken the combination of both approaches as the overlapping of two hole ridden nets, the result giving a hole free approach (p. 9).

At this point one could feel that mixed method approaches are the saviour for all educational research problems. However, as with most research approaches, if they are not clearly tailored to address the research question the result can be a disjointed study in which the holes of each research method are not covered (Johnson & Onwuegbuzie, 2004). Other concerns include the lack of research into mixed method studies that results in researchers struggling to know how the methods can be combined and under what circumstances (Rao & Woolcock, 2002). In addition, the size of a mixed method study may be too large for a single researcher and such a researcher needs to be confident in several paradigms (Johnson & Onwuegbuzie, 2004).

Johnson and Christensen (2004) identify two major types of mixed research, *Mixed model research* and *Mixed method research.* The former is described as studies that mix both qualitative and quantitative research approaches within a single stage of a study. The separate paradigms are used to generate and investigate one set of data (p. 9). The latter is described as studies that use a quantitative paradigm for one phase of a study and a qualitative paradigm in a different phase. The separate paradigms generate and investigate different sets of data that are then combined to draw conclusions (p. 8). In this study both types of mixed research are applied.

Mixed model approach

A mixed model approach was used for this study as qualitative data was generated through open ended survey questions, coded using categories identified from the students' responses and then quantified to identify the frequency of each category. The qualitative method focused on identifying, documenting and interpreting the views and ideas of Yr 11 Mathematical Methods students through open ended survey questions in regard to their reasons for subject choices in Mathematical Methods and Physics, what they interpreted physics to be and who they felt influenced them in their subject choice decisions. The survey questions are discussed in detail in the final section of this chapter.

An interpretive perspectives (Blanche & Durrheim, 1999; Connole, 1993) approach was used to interpret the data. Wiseman (1990) describes the interpretive approach as one in which the researcher searches for and interprets a situation using the interpretations of those being studied (p. 105). This study involved using the students' own words to code the data into categories that were identified in their responses to the questions.

The student's responses to the questionnaire provided the initial text for interpretation. The coding of data to determine categories was open to interpretation by this researcher, which may have limited her ability to determine the meaning that the students were trying to relay. The researcher is aware that preconceived ideas about this research topic will shape any response to the text (Campbell-Evans, 1992). From anecdotal observations over 15 years of teaching mathematics and physics in single sex and coeducation settings, this researcher has developed several ideas as to the reasons girls have for not choosing physics.

- Girls believe physics is hard and difficult to excel in.
- Girls are not really sure what physics is.
- If girls decide a subject (such as physics) is boring it is very difficult to motivate them.

In an attempt to address any possible bias in interpretation, examples of the students' responses were frequently used in the interpretation of the data to illustrate the types of responses that were allocated to each category.

Once the responses were coded the frequency distribution for each category was determined. This enabled the data to be quantified so that particular, recurring reasons given by the students could be identified.

In addition it is also important to note that after spending the last six years teaching in a single–sex environment and being the product of such an environment herself, this researcher has always assumed that the single sex environment offers advantages to girls' success in academic studies, that they are more likely to challenge gender stereotypes and as a result would have higher enrolments in subjects like physics. It remained to be seen if the results from this study would challenge this assumption.

Mixed method approach

A mixed method approach was used for this study as in addition to the qualitative data collected through the open-ended survey questions, quantitative data on the enrolments for Unit 2 Physics and Mathematical Methods in the three surveyed schools was compared with enrolment data obtained from the VCAA. The VCE data was analysed with respect to gender for total VCE enrolments in these subjects. Quantitative analysis was also done on the available enrolment data for VCE Physics with respect to those who also studied Mathematical Methods over the last five years to justify the link made in sampling Mathematical Methods students for this study. Enrolments in Unit 4 VCE Physics and Mathematical Methods with respect to gender were used to illustrate any gender gap within these enrolments. Enrolments in Unit 4 VCE Physics and Mathematical Methods with respect to year were used to verify if downward trends in physics and mathematics enrolments identified in much of the literature are apparent in VCE enrolments for the last five years.

The mixing of approaches both in model and method enabled this study to look at the subject choices of these female Mathematical Methods students from their own perspectives and also to consider how their choices contribute to a broader picture of enrolment trends in Mathematical Methods and Physics.

<u>VCE data</u>

One premise used in the study was that students who study Mathematical Methods are likely candidates to study Physics. This was based on this researcher's understanding of the similarities of the two courses, having taught both for many years, observations that many schools mandated or highly recommended the study of Physics be accompanied by Mathematical Methods and the experience that it was rare for a year 11 Physics students not also to be studying Mathematical Methods. Enrolment data from VCAA over the last five years was used to test this premise by comparing the number of students who studied both Unit 2 Physics and Mathematical Methods against the overall enrolment in Unit 2 Physics for any year.

Victorian Certificate of Education enrolment data was used to determine how significant the gender gap and falling enrolments in Physics and Mathematical Methods have been over the last five years. Finding the percentage of Unit 4 Physics and Mathematical Methods students against the total Unit 4 VCE cohort over the 2001 to 2005 period was used to verify if enrolments are falling for these subjects in Victoria. The total VCE cohort was determined using the number of student eligible to complete VCE in that year. Enrolment data for Unit 4 Physics and Mathematical Methods was analysed by comparing enrolments by gender against total enrolments for each subject cohort. A second gender comparison was also undertaken to take into account that girls outnumber boys in the total VCE cohort. In this comparison enrolment data for Unit 4 Physics and Mathematical Methods was analysed by comparing enrolments against total enrolment for the VCE cohort by gender.

Enrolment data for Unit 2 Mathematical Methods and Physics was used to determine percentages for the state averages in enrolments of these subjects so that they could be compared to the percentage enrolments of these subjects at the three surveyed schools. Initially the state percentage average was sought by finding the percentage of female enrolments in Unit 2 Mathematical Methods and Physics against total Unit 2 cohort over the 2000 to 2005 period. However on later consideration it was decided that this result did not reflect the fact that the enrolment numbers had dropped over the six-year period. As an alternative, the school cohorts were compared to the VCE data from the previous year. The total Unit 2 state cohort was determined by the combined the number of female enrolments in Unit 2 English and English as a Second Language (ESL).

<u>The sample</u>

The survey was given to Yr 11 Mathematical Methods students from three single-sex girls' schools; School A, a girls Catholic secondary school in a medium to low socio-economic area, had a total enrolment of approximately 800 girls and 102 enrolled in Yr 11. School B, a girls Catholic secondary school in medium to high socio-economic area, had a total enrolment of approximately 1000 and 170 enrolled in Yr 11. School C, a Grammar school in a high socio-economic area had a total enrolment of approximately 1100 girls and boys over three campuses. The senior school (Yrs 7 – 12) offered single sex girls' education and had 100 enrolled in Yr 11. The schools were chosen to represents a range of socio-economic backgrounds.

<u>The survey</u>

This study asked Unit 2 Mathematical Methods students about their subject choices in that subject and in Unit 2 Physics. As so many students who study Unit Physics also study Mathematical Methods, it seemed reasonable to suggest that if we are to boost physics numbers and female representation, students who choose Mathematical Methods are prime candidates. The following section details the reasoning behind each survey question.

Question 1. Explain your reasons for choosing Mathematical Methods

Before asking the students about their choices in physics, it was felt that it would help to understand the students' choice of Mathematical Methods. This enabled data to be collected for a subject that the girls had chosen, rather than physics which most of them had not chosen. As the study of Physics and Mathematical Methods is often taken concurrently, this question enabled the researcher to see what motivations these students had for their choice in Mathematical Methods and how this differed to their motivations in not choosing physics. The data was coded post hoc into categories as the frequency of some responses became apparent.

Question 2. Do you know what physics is all about?

A limited understanding of what the study of physics entails has been suggested as one possible reason why students find little relevance or interest in physics and thus do not choose to study it (IUPAP, 2005; Norvilitis et al., 2002; Parker, 2002; Stadler et al., 2000; Stokking, 2000; Williams et al., 2003). The data was coded firstly into six categories that the students identified which represented the students' breadth of understanding: general descriptions of broad concepts areas (i.e. motion, light), one or two specific concepts (i.e. speed and forces), several concepts (more than two), maths/numbers, how things work, no idea. Maths/number was added after it appeared on several responses.

During the preliminary analysis of the students' responses it was noted that students answered this question in different ways. Some used language that was quite forthright while other responses used quite hesitant language. It was decided that as part of the analysis note would be taken of this language use as well as what the students thought physics was as it gave an indication of how confident the students were in their perceptions of physics. The data was also coded using the students' responses into three groups to indicate the confidence of response: not sure/not really, know a little/some idea and I know/ it is.

Question 3. Explain your reasons for choosing/not choosing physics.

This question is at the heart of this study; to find why girls who are mathematically capable, are not choosing physics. The survey respondents were asked to give as much detail as possible. The data was coded into categories as they became apparent in the reading of the responses.

Question 4. Is physics what you expected?

For those students' studying physics this question once again addressed the proposition that many students do not really know what physics is. The data from this question gave insight into how the student expectations of physics compared to the reality of studying physics. Data for this question was not coded due to too few responses.

Question 5. Who, if any, helped/influenced you with your choices?

Many studies recognise the influence of family, peers and background as significant factors in the decision making of students with regard to subject choices (Cumming (1997, Lyons, 2005, Stokking, 2000). Lyons (2005) in his study into the puzzle of falling enrolments in physics and chemistry courses suggested that the combination of interactions of family and school on student decision making were significant in their choices. Cumming (1997) also suggested that strong socialising influences had significant impact on the vocational choices of girls (p 3). Although students may not be conscious of all the social factors at play, it seemed significant to identify whom the students turned to for advice. Thus students were asked to identify who helped and influence their choices. The data was coded into categories as they became apparent in the reading of the responses.

Results and Discussion

Introduction

The first section of this chapter analyses the most recent enrolment data available from the Victorian Curriculum and Assessment Authority (VCAA). It identifies the link between Mathematical Methods and Physics and illustrates the gender gap as well as the trend of declining enrolments in both Physics and Mathematical Methods.

The second section of this chapter analyses responses of Mathematical Methods students from three all-girls schools, to open ended questions in regard to subject choices of Physics and Mathematical Methods and subject choice decisions.

Trends in VCE enrolments

Below is a table with the enrolment data for students who study both Yr 11 Physics and Mathematical Methods (including the CAS stream) from 2000 - 2005. The percentages are calculated with respect to the total Unit 2 Physics cohort (differentiated by gender).

Unit 2 Physics						
Year	Boys	% Boys	Girls	% Girls	Unit 2	% Total Unit 2 Physics
2000	6908	89.9	2727	91.9	9635	90.4
2001	6932	90.9	2675	92.9	9607	91.4
2002	7280	90.2	2568	89.9	9848	90.1
2003	7143	88.5	2446	89.4	9589	88.7
2004	6846	92.6	2394	93.6	9240	92.9
2005	6630	92.1	2271	93.3	8901	92.4
					Average	**91.0**

Table 1. Unit 2 Physics enrolments that also study Mathematical Methods by gender for 2000-2005

This data supports the premise that in Victoria the majority of students studying Physics also study Mathematical Methods. This is not evidence of the physics ability or quality of these students, but it supports the assumption that students and schools link these subjects together. The questioning of Mathematical Methods students in regard to their subject choices and in particular to Physics, seems reasonable as clearly the students who choose Physics generally have chosen Mathematical Methods as well.

To get a clear understanding of the trends in current enrolments of Physics and Mathematical Methods a preliminary analysis of data available on the VCAA web site is given below. Detailed tables for this data can be found in Appendix 1.

The first analysis, shown in figure 1, was to identify the trend in the Physics Unit 4 enrolments over the last five years.

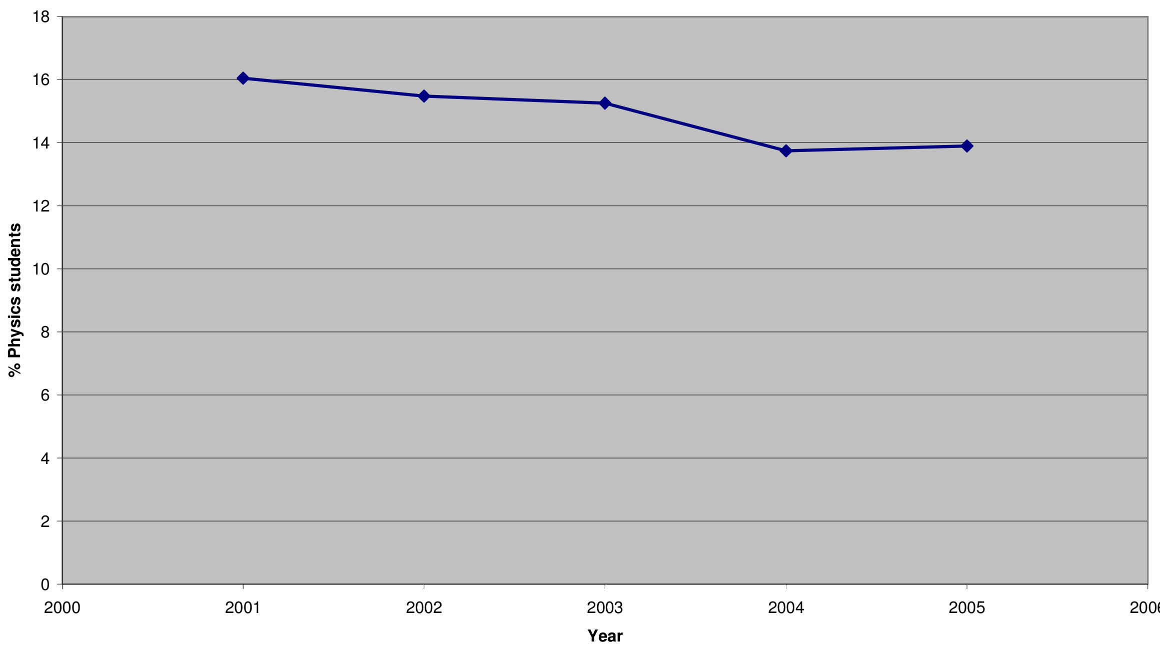

Figure 1. Unit 4 Physics enrolments as a percentage of students eligible to complete VCE, 2001-2005

The percentage of students studying physics dropped from 16.0% in 2001 to 13.7% in 2004 and rose slightly to 13.9% in 2005. This data supports the suggestion that physics enrolments are falling.

The second analysis was to identify the trend in the Mathematical Methods Unit 4 enrolments over the last five years and is shown in figure 2.

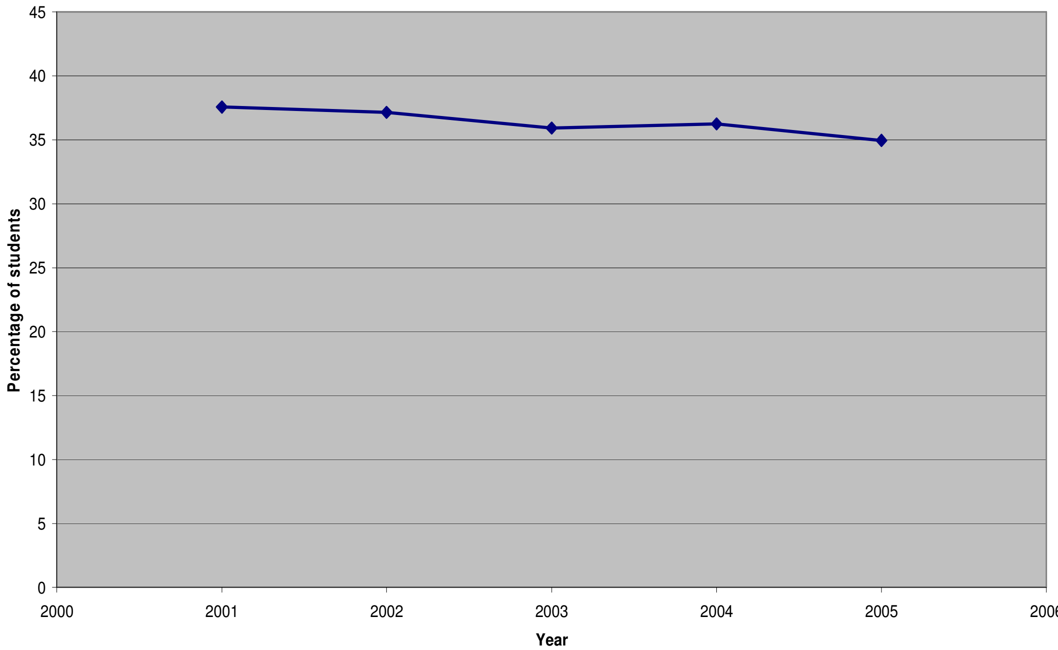

Figure 2. Unit 4 Mathematical Methods enrolments as a percentage of students eligible to complete VCE, 2001-2005

Mathematical Methods has also experienced a down turn over the last fives years, dropping from 37.6% to 35.0% of students eligible to complete VCE. Interestingly in the 2003-2004 period, where Physics experienced a fall, Methods experienced a slight rise.

Figures 3 and 4 illustrate the percentage of male to females with respect to the total Physics and Mathematical Methods cohorts.

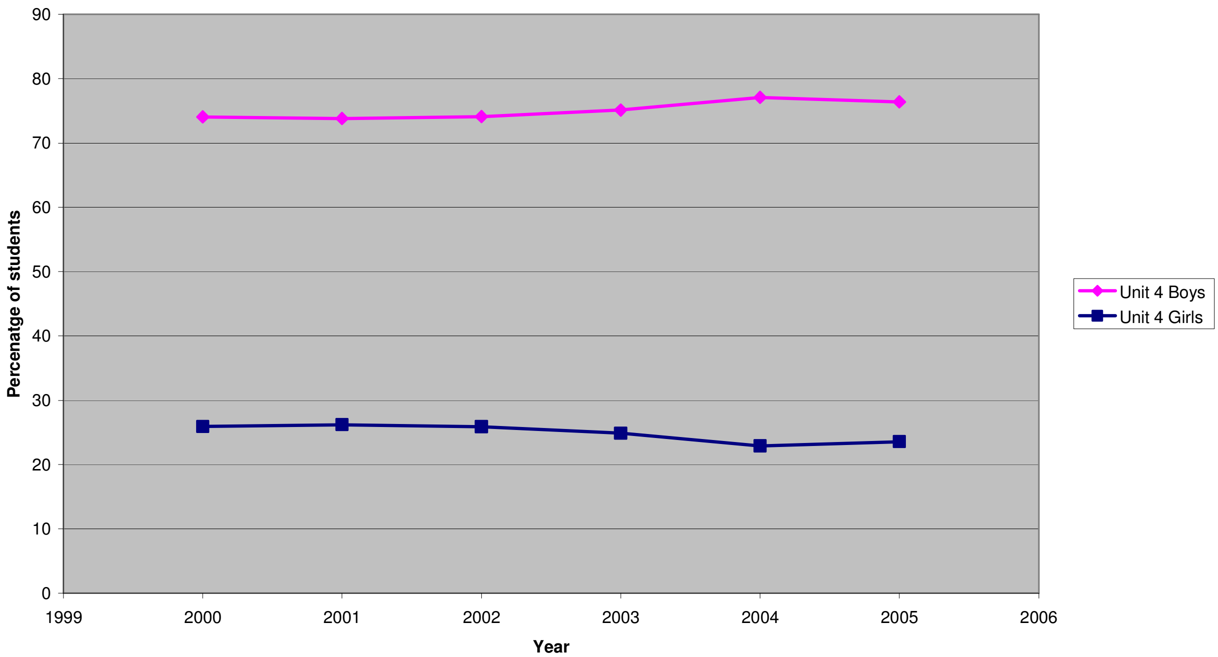

Figure 3. Unit 4 Physics enrolments by gender as a percentage of the Unit 4 Physics cohort, 2000-2005

Within the Physics cohort boys outnumber girls considerable. Interestingly, the 2003-2004 saw an increase in the gender gap.

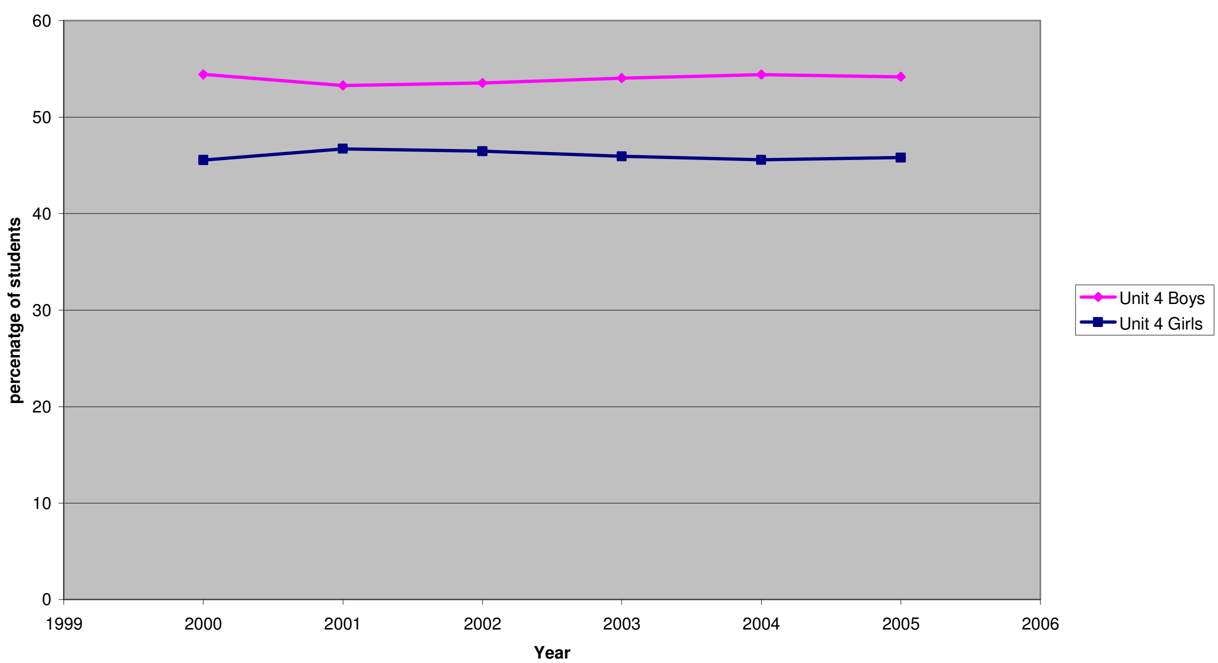

Figure 4. Unit 4 Mathematical Methods enrolments by gender as a percentage of the Unit 4 MM cohort, 2000-2005

Within the Mathematical Methods cohort boys still outnumber girls but the ratio is much closer. However both these graphs do not give the full picture, as they do not take into account the overall enrolments in the VCE in which girls out number boys.

The next analysis, figures 5 and 6, identifies the enrolment trends of Unit 4 Physics for males and females.

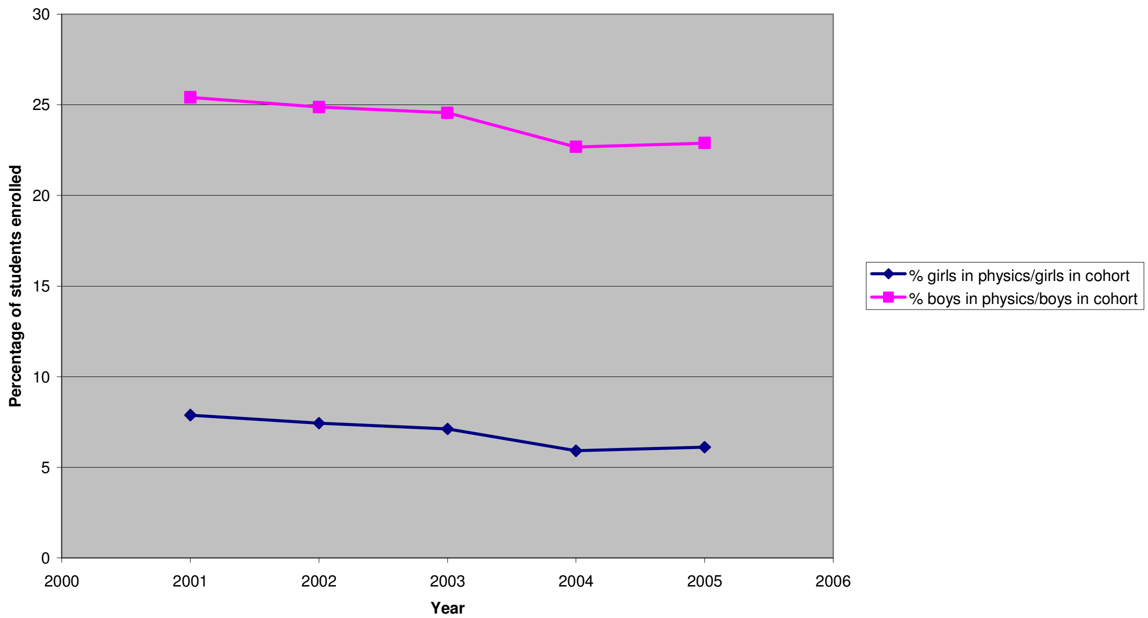

Figure 5. Unit 4 physics enrolments by as a percentage of students eligible to complete VCE by gender, 2001-2005

The trend for males and females follows the over all trend for physics enrolments (*Figure 1*).

For males enrolments drop from 25.4% to 22.9 % of males eligible to complete VCE

For females enrolments drop from 7.9% to 6.1 % of females eligible to complete VCE

This graph also clearly highlights the significant gender gap in physics enrolments.

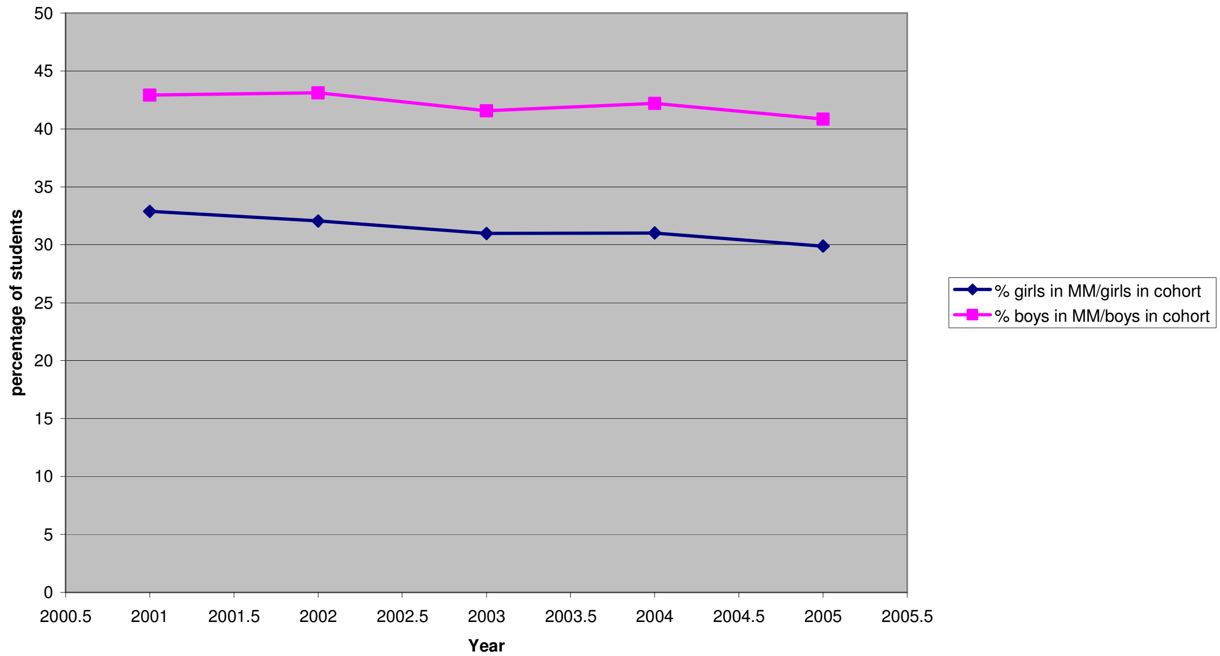

Figure 6. Unit 4 Mathematical Methods enrolments by as a percentage of students eligible to complete VCE by gender, 2001-2005

Once again the gender split follows the overall Methods cohort trend *(Figure 2)*. The gender difference is still smaller than physics but more pronounced as it takes into account that more girls were enrolled in the VCE over the 2001-2005 period.

This data summarises trends in Victoria for the VCE Unit 4 Physics and Mathematical Methods over the last five years. This data is only a preliminary analysis and has not been tested to determine if these fluctuations are part of some greater trend. They do, however, clearly illustrate the large gender gap in VCE Physics and to a lesser degree they support the proposition that numbers in the 'enabling sciences' (AUTC, 2005, Parliament of Victoria, 2006) such as physics and advanced mathematics are dropping.

The next table illustrates the VCE Unit 2 Mathematical Methods and Physics enrolment data for the three schools in this project and the state data for 2005. School A represented a girls' Catholic school in a middle to low socio-economic area. School B represented a girls' Catholic school in a middle to high socio-economic and School C represented a private girl's school in a high socio-economic area.

	Girls in Unit 2 Physics	Girls in unit 2 Methods	Female cohort enrolled	% Physics	% Methods
School A	5	24	102	4.9	23.5
School B	4	63	170	2.4	37.1
School C	8	38	100	8.0	38.0
State -*2005*	2435	11240	30460	8.0	36.9

Table 2. Comparison of enrolments in Physics and Mathematical Methods for the three surveyed schools and state average over the 2001-2005 period.

All three of these schools had physics enrolments on or lower than the state average. This I found surprising, as I had assumed that all-girls schools were more likely to challenge gender stereotypes and as a result would have higher enrolments in subjects like physics. Interestingly, only two of the three had marginally higher than state average enrolments in Mathematical Methods. School B had a policy that those studying Mathematical Methods were also expected to study General Mathematics. Again this data should be treated warily as it is for one year and numbers can fluctuate considerably, but it still remains that none of these three different girls schools which catered to a range of socio-economic areas had enrolments in Unit 2 Physics in 2006 that were higher than state averages of the previous year.

The following table gives the breakdown of subjects taken with Mathematical Methods for the students from the three surveyed schools.

Subject	%
English*	100
RE/philosophy*	80
2nd Maths*	62
Chemistry	62
LOTE	59
Biology	51
History	18
Psychology	17
PE	17
Legal Studies	15
H&HD	14
Vis Comm	13
Physics	9
Studio Arts	9
Accounting	7
Literature	7
Music	6
Economics	5
IT	5
International Studies	5
Textiles	4
Multi media (VET)	2
Politics	1
Design & Tech	1
Hospitality	1
Theatre Studies	1

Table 3. Subjects taken with Mathematical Methods for survey respondents from the three surveyed schools.* these subjects were compulsory in some of the schools.

As mention earlier, each school had different policies in regard to subject selection that is reflected in table 3. Two schools were Catholic and most students from these schools were expected to study Religious Education. One school required students studying Mathematical Methods to study a second mathematics. Chemistry was the most frequent subject taken with Mathematical Methods that did not have some form of mandate tied to it, closely followed by LOTE (Language other than English) and then Biology.

The Mathematics and Chemistry are two of the three enabling sciences given priority by the Parliament of Victoria in a recent inquiry into the Promotion of Mathematics and Science in Education (2006). The third science, Physics is identified by Thomson in her (2005) Longitudinal Surveys of Australian Youth report, which examined the pathways from school to further education, as a major gender differentiator. This data supports

Thomson's finding that girls tend to enrol in Chemistry and Advanced Mathematics, but not Physics.

In the next section I look at the responses to the open-ended survey questions. It is hoped that if particular reasons for girls subject choices in Mathematics and Physics can be identified, this may be useful in identifying ways to better promote physics to girls.

What the girls wrote – survey responses

In the following section analyses the coded data for the responses to the open ended questions posed in the survey questionnaire.

Response to Question 1. Explain your reasons for choosing Mathematical Methods

Table 4 lists the reasons the girls gave for their subject choices and the percentage of girls who identified with those reasons. Reasons varied considerably however there were several reasons that were common to all three schools surveyed.

Reason for MM	**%School A (n=12)**	**%School B (n=47)**	**%School C (n=35)**	**%Overall (n=94)**
Enjoyed/like maths	58	36	17	32
Relation recommended	8	9	6	7
Not too easy not too hard/am capable	8	17	9	13
Prerequisite	92	55	80	69
Good at maths	33	28	17	24
Challenging	25	40	20	31
Extra credit/ENTER score	8	13	6	10
Leaves options open	17	38	11	26
Helps with other subjects	8	6	6	6
Interested in Maths	8	2	0	2
Understand it	8	0	3	2
Could change to General/Further if too hard	8	2	0	2
Don't have to remember long facts	0	2	0	1
Peer/other pressure	0	2	6	3
Teacher/school recommended	0	15	17	14
The class will be motivated and capable	0	2	0	1
Practical applications	0	2	0	1
Value	0	0	11	4
Timetable constraints	0	0	3	1
Improve logic/skills	0	0	14	5
no essays/writing	0	0	3	1

Table 4. Reasons for choosing Mathematical Methods by girls from the three surveyed schools.

Mathematical Methods being a prerequisite for many courses at tertiary level was a significant reason for choosing it with these students. For all three schools in the survey this was the most frequent reason given and was often the first reason listed. Many of the responses reflected that the students had a clear goal of entering tertiary education and that Mathematical Methods was a prerequisite for many courses. This can be seen in the following student comments:

> Because it is a prerequisite and I need it to get into the courses I want – *School A*
> I was unsure of what I wanted to study once I've finished high school and I know that many of the courses require Methods as a prerequisite. – *School B*
> Maths Methods is a prerequisite for some university courses I am interested in. It leaves my options open" – *School C*
> I Personally do not like studying mathematics, I only study it because it is a prerequisite and I need it….if methods wasn't a prerequisite I wouldn't do it - *School A*

Leaving options open was mention by many respondents, particularly in school B. This was often coupled with statements about university prerequisites. For example,

> It gives me options for year 12 and further years – *School B*
> It is a prerequisite for many courses in Uni and because I'm not sure what I want to do, I thought to keep my options open – *School B*
> I believed that if I study Methods, it would leave more options open – *School A*

Many students, particularly in school A and B sighted their enjoyment of mathematics as a reason for choosing to study Mathematical Methods. This was also often coupled with statements that they were good at mathematics. For example,

> I love maths. I've had a passion for it since I was young. I'm good at it. I achieve good marks
> - *School A*
> I enjoy maths, I am good at maths, I understand maths. – *School B*
> I like maths and was doing well and understanding the topics last year and enjoyed doing it – *School B*

Interestingly being challenged was also a significant factor in the girls' choice of Mathematical Methods, particularly in School B. For example,

> I wanted to challenge myself (I thought general maths would be a little easy). – *School B*
> I also chose it because I wanted a challenge, though Specialist seemed hard and General maths much easier so choosing Methods would be alright and intermediate. – *School B*
> I though I might enjoy the challenge – *School C*
> Challenging, can gain satisfaction after completing/understanding the work – *School A*

Being capable was mentioned by several students as was the belief that the ENTER score for Mathematical Methods may be subjected to standardising up. In two schools (B & C), teacher recommendation was also given as a reason for studying Mathematical Methods.

Response to Question 2. Do you know what physics is all about?

Table 5 summarises the responses this to question; analysing both what the students believed physics to be and the language they used to make their response.

What is physics about?	**%School A (n=12)**	**%School B (n=47)**	**%School C (n=35)**	**%Overall (n=94)**
General descriptions eg Physical movement	17	4	0	4
One or two specific concepts	33	60	49	52
Several concepts	50	6	3	11
Maths/numbers	25	13	46	27
How things work	8	17	11	14
no idea	8	9	17	12
not sure/not really	33	26	9	20
know a little/some idea	42	9	3	11
I know/It is	25	57	71	59

Table 5. Responses to question: "What is physics about?" by girls from the three surveyed school analysed by depth of understanding and confidence in response.

In this analysis a significant difference between School A and the other two schools emerged. Where as Schools B and C had a significant number of forthright responses, School A's responses were spread over the three categories, as demonstrated by the following responses:

> Not really, I believe it's got something to do with light and electronics?! – *School A*
> I don't really know exactly what physics is about. However, I know it includes Einstein's theory of relativity, how light and sound travels and different types of forces etc. – *School A*
> Velocity, how things work, mechanics??? – *School A*

> Physics is about a range of things, from light, motion, energy to Newton's Laws. It is a science based on physical movement – *School A*

Although many were hesitant in their language, School A's students showed a broader understanding of what physics is in comparison to School B and C; where they generally identified one or two concepts, usually about motion. For example,

> Physics is the study of speed and velocity etc – *School B*
> Movement, speed, velocity etc. I remember something about Newton's Law – *School B*
> The way things work, velocity, machine workings, displacement etc. – *School B*
> Yes, its like energy and forces and motion and Newton's Law and stuff like that – *School C*
> Working out problems related to motion and energy, its pretty mathematical – *School C*

The link to mathematics was made by students from all schools, however, considering this survey asked questions of Mathematical Methods students about Physics choices, it is not inconceivable that the students made this link because of the survey sampling method. However its significance may be better identified in the next question form the survey.

Response to Question 3. Explain your reasons for choosing/not choosing physics.
The next question on the survey asked the students to explain their choices in physics. Due to the small number of students studying Unit 2 Physics in the three schools, the number of students who responded that were studying Unit 2 physics was very low. At School A no Unit 2 Physics students chose to respond, in School B there were two responses and at School C, six. Their data is included in the second table in this section.

Although the response from physics students was disappointing, those not studying physics gave many reasons as to their choices (Table 6). Again, some significant trends appeared in the girl's responses. The most frequent reason given was that physics did not interest the girls and that it was boring. For example,

> I don't really know a lot about physics, but it doesn't seem to be a subject that interests me – *School C*
> Because it seems really boring and pointless and a lot of work. I prefer to do subjects that relates more to real life and people – *School B*

> I found physics quite tedious and boring, but found other forms of science more interesting – *School A*

That students find physics boring is supported by much of the literature (Jones & Kirk, 1990; Sjoberg, 1990; Walkington, 1998). In particular, many studies suggest that girls find physics impersonal suggesting that girls to not see physics as altruistic (Jones & Kirk, 1990; Kelly, 1982; Sjoberg, 1990; Smail, 1985; Smail, 1987). The second statement above supports this.

Reasons for not doing physics	**% School A (n=12)**	**% School B (n=45)**	**% School C (n=29)**	**% Overall (n=86)**
Don't need it for UNI/prerequisite	25	29	14	23
Couldn't fit it in (limited number of subjects)	25	29	28	28
Didn't find it interesting /boring	58	64	41	56
Too difficult	25	27	24	26
Not worth doing/not scaled much vs. difficulty	17	0	0	2
Too much maths/calculations	8	0	17	7
Couldn't cope with too many maths subjects	17	7	3	7
Too much work	0	7	7	6
Won't enjoy it/disliked it	8	29	21	23
Not as important with options	8	4	0	3
Didn't consider it	8	2	0	2
Dislike science	8	9	10	9
Not beneficial for future	17	7	7	8
Not many chose it	0	2	0	1
Didn't understand	0	11	0	6
Wasn't good at it	0	16	3	9
A boyish subject	0	4	0	2
Teacher	0	2	0	1
Didn't want too many sciences	0	7	10	7
Wasn't promoted/didn't know what VCE Phys was about	0	2	0	1
Prefer other subjects	0	16	14	15

Table 6. Responses to question: "Explain your reason for not choosing Physics" by girls from the three surveyed schools.

Interest and finding it boring also links to the girls' expectations of physics (Kelly et al., 1984). That they would not like the subject or disliked what physics they had already had done also rated highly. For example,

> I had a preview of Physics on Year 10. We covered topics like light, energy, force, Newton's laws and I found I didn't really like them and wasn't so fascinated- *School A*
>
> I did not like it in Year 10 so I did not study it in Yr 11– *School C*

> Did not enjoy learning about forces – *School B*

There were many responses that suggested that timetabling or a limit on the number of subject a student could take was a factor in not choosing physics. For example,

> I chose not to do physics, as I did not have a chance to do it as I could only do 6 subjects. It was my 7th subject – *School A*
> They wouldn't let me because of the subject blocks, otherwise I would be doing it – *School C*
> I didn't have enough spaces to do physics – *School B*
> I chose not to study physics as I simply did not have enough space in my timetable – *School B*
> Because ESL and Physics in the same block. I can't choose two in one block. Overseas students have to choose ESL – *School C*

Responses such as these were never given as the sole reason for not choosing physics and were usually coupled with comments about other subjects being more interesting. For example,

> There were other subjects that appealed to me more" - *School C*

Timetabling issues change from school to school and generally involve arranging subjects to best suit the majority of the cohort. If a subject is not very popular, as was the case with physics in these three girls school, multiple classes are not available and thus students do not have as much variation in their timetable. This factor may not be experienced in a co-educational or boy's school were several physics classes may be offered.

The belief that physics is difficult was mentioned frequently in surveys from all three schools, as demonstrated in the following comments:

> I didn't know what it is, it sounds hard – *School B*
> Not many other girls chose the subject (I think about four girls) so that made it seem like a hard and challenging subject b/c not many girls chose it – *School B*
> I heard it was difficult so I wanted to choose subjects I knew I could do well in – *School C*

> It sounded extremely hard and I didn't believe I had the determination of heart to do such a subject – *School A*
>
> Physics is also portrayed as a difficult subject - *School C*

The perception that physics is difficult is identified as a factor for influencing girls' choices in much of the literature (Cumming, 1997; Lyons, 2005; Stokking, 2000; Williams et al., 2003). The perceived difficulty of physics has also been identified as a particular problem for girls who tend to devalue their ability (Kelly, 1982; Stokking, 2000; Walkington, 1998). This results in girls believing they must be very good to attempt a subject like physics. Some responses reflected this:

> I had a scary experience in year 8 when I received a medium for a physics test – *School B*
>
> I am not good at physics although I received reasonable marks last year in the topics containing physics – *School B*
>
> I am not smart enough to do physics – *School C*

The mathematical nature was also significant in the girls' responses; particularly if concern about the mathematical nature and doing a lot of 'mathematical' subjects is considered together. For example,

> I wouldn't be able to cope doing another maths related subject – *School A*

Interestingly, School B, that insisted all girls study a second mathematics with Mathematical Methods, had no girls using the difficulty in or dislike of mathematics as reason for not doing physics. This school's students also identified the challenge of Mathematical Methods as an important factor in choosing that subject. They did have students who felt the workload of three 'mathematics type' subjects would be too great. For example,

> I also thought that Methods and General were enough maths to be doing, and enough homework
>
> – *School B*

The fact that physics was not a prerequisite or needed for the courses the girls were interested in was also a significant reason for not choosing it. For example,

> I don't need Physics for my university courses – *School A*
>
> It is not a prerequisite for anything I am interested in – *School B*
>
> I didn't need it as a prerequisite – *School C*

Clearly students were not interested in physics related career paths, or did not know what these may be. Studies investigating the general drop in student numbers in physics courses suggest that students believe physics is irrelevant (Lyons, 2005; Stokking, 2000; Williams et al., 2003). Jamie McKenzie (McKenzie, 2006) claims that today's students 'game the system', that is, they make decisions based only on one goal, such as getting a place at university; interest and understanding are secondary. The emphasis in the girls' responses in regards to prerequisites for both Mathematical Methods and Physics would seem to support this notion. The emphasis of prerequisites is also apparent for the girls who did choose physics.

The girls who did study physics gave the following reasons for their choices.

Reasons for doing physics	**%School A (n=0)**	**%School B (n=2)**	**%School C (n=6)**	**%Overall (n=8)**
Enjoyed it	0	100	33	50
Wanted a challenge	0	50	17	25
Was interested in it	0	100	33	50
Prerequisite/recommended for UNI	0	50	100	88
Can do well/easy	0	50	33	38
Advantage of being a woman, not a many woman	0	0	17	13
relative did it	0	0	17	13
small class	0	0	17	13

Table 7. Responses to question: "Explain your reason for choosing Physics" by girls from the three surveyed schools.

Although this is a very small sample all but one girl gave the reason of physics being a prerequisite. It seems clear that in these three schools, university prerequisites are one of the most important factors in the subject choices of Mathematics Methods and Physics.

Response to Question 4. Is physics what you expected?

The question of whether these girls were enjoying physics now they were studying it was not summarised into a table due to too few responses. Of the four girls who did respond in detail three stated that physics was not what they expected, as can be seen below:

> I expected it to be much drier and only involve movement – there is actually a lot more prac. work and nuclear physics was a really good change – *School C*
> It is not what I expected, I thought it would be about distance and motion etc. I find we do learn interesting things, especially the unit on nuclear science - *School C*
> No, it isn't as hard, but it is challenging. It is a bit boring but I still enjoy it - *School B*

The one girl who did find physics was what she expected had a very detailed idea of what physics was. The last section of the survey looked at who, if any, had helped the girls make their subject choices.

Response to Question 5. Who, if any, helped/influenced you with your choices?
Below is a table of the individuals the girls from this study identified as of help in the decisions of subject choice for yr 11.

Who helped in decision making	**School A (n=12)**	**School B (n=47)**	**School C (n=35)**	**Overall (n=94)**
Parents	42	57	54	54
Siblings/other relatives	8	19	11	15
Teachers	33	34	43	37
Careers counsellor	8	34	37	32
Peers	17	32	26	28
Tutor	8	0	0	1
No-one	25	6	11	11

Table 8. Responses to question: "Who, if any, helped/influenced you with your choices?" by girls from the three surveyed schools

In all three schools, the students identified advice from their parents most often, when identifying who assisted in their decisions about subject choices for yr 11. For example,

> My parents helped me work out what pre-requisite subjects I need for my uni course – *School B*
> My parents helping me with deciding on the career path I wanted to follow – *School A*
> They [parents] helped me decide what subjects I need to take – *School C*

The next significant individuals mentioned were teachers and the Careers Councillor. Teachers were often identified in helping a student identify her strengths, what a subject entailed and how a subject related to a chosen career path, Careers Counsellors advised about career options and course prerequisites. For example,

> Teachers they tried to help me by discussing the importance of these subjects to the career I wanted – *School C*
>
> My class teacher gave me an idea of what I was good at and what I could do well in – *School A*
>
> Teachers helped me choose out of physics and biology. Their reason for telling me this was because physics is a good prerequisite and hard to pick up – *School B*
>
> The careers counsellor helped a lot with advice about prerequisites – *School B*
>
> Career's counsellor advised about prerequisites - helped me with selecting subjects to maximise my VCE score, what I enjoyed and prerequisites for my chosen course - physics was never mentioned – *School B*
>
> Careers Counsellor – helped me decide what I wanted to do in the future and therefore what the prerequisites were – *School C*

Several of the students who indicated no one helped them mentioned prerequisites or maximising their chances of getting into university. For example,

> My subject choices were based on receiving the best ENTER score I can and leaving my options open so that I can get into any university course I wanted – *School A*
>
> I chose subjects because I wanted to do them as they were the best choices for university – *School C*
>
> I just looked at the prerequisites of the courses I want to do in Uni. I had a pretty good idea with what courses I would like to do so this influenced my subject selection – *School B*

The frequent mention of prerequisites suggests that many students have ambitions for further education. Several students stated siblings also had an influence in their decision-making. For example,

> My brother helped me since he has experience and did similar subjects to what I'm doing – *School A*
>
> Sister – did it [physics] and found it interesting – *School C*

Considering both parent and sibling influence, for many students the influence of family was significant. The last group that students believed to have some influence on their decision was peers. For example,

> They [peers] helped me figure out the 'pros' and 'cons' of the subjects I was considering – *School A*
> Other students saying that physics was really hard in VCE – *School B*
> I hate sciences, but a girl (who entered Harvard) motivated me. She did all sciences and maths, so I decided to choose one science and two maths – *School C*

It is difficult to ascertain the size of impact these individuals and groups would have in influencing these students' decisions about subject choices. Many respondents emphasised that although they turned to these various sources for advice the final decisions were their own. Although students believe they are making independent choices, social influences will shape those decisions. Cumming (1997), Lyons (2005) and Walkington (1998) all suggest that the interaction of social influences such as home background, parent's expectations and peer influences have a significant influence on a students understanding and appreciation of vocational opportunities. The frequent mention of prerequisites suggests that many of the girls have some idea of their vocational pathway. If we are to influence girls to consider physics and careers that lead from physics, clearly we need to show these students the value of such a vocation early on in their school career.

<u>Summary</u>

In this section I have presented data obtained from the Victorian Curriculum and Assessment Authority (VCAA) that shows the majority of students who study Physics also study Mathematical Methods. The VCAA data has also illustrated the falling numbers of VCE Physics and Mathematical Methods enrolments over the last five years and the significant gap in Physics enrolments between male and females students.

The enrolments in Mathematical Methods at the three schools surveyed were either marginally higher or below the state average and for Physics all the enrolments for these all-girls schools were on or below the state average. This challenges the belief that all-girls schools are able to break down stereotypes in gender specific subject areas (Kelly, 1982; Stage et al., 1985; Watterston, 2001). This cannot be generalised for every girls school, as the samples in this study were small, however for these three all-girls schools, in a range of different socio-economic areas, the numbers of students attempting physics were disappointingly low.

Girls in these three schools more frequently chose to study Chemistry with Mathematical Methods than any other subject. Languages other than English (LOTE) closely followed this. Chemistry and advanced mathematics are two of a three-subject cluster (advanced mathematics, chemistry and physics) that Thompson (2005) identified as having the best pathway to higher education (around four in five students entering tertiary courses, (p.30)). Thompson found the participation in this subject cluster was gender biased toward male students with the differentiator being the study of physics (p.12). The subject choice of Mathematical Methods and Chemistry but not Physics, in the three schools in this study supports Thompson's findings.

Being a prerequisite for a tertiary course was a significant factor for girls choosing Mathematical Methods and Physics. Interest, enjoyment and the challenge of the subject were also often given as reasons for studying Mathematical Methods. That it is boring was a significant factor for girls not choosing physics. Not being able to fit Physics into their timetable, believing it to be difficult, that they wouldn't like it and that it was not a prerequisite for the courses they wished to pursue were also often given as reasons for not studying physics. The students had high expectations of going on to further education and many had clear ideas on which vocation pathway they wished to follow.

Many of the students seemed quite confident in their knowledge of what physics was. However, this turned out to be quite a limited idea of physics related mainly to the study of motion. This limited understanding of what physics is may be linked back to so many students finding physics boring, but from this study it can only be speculated. A significant number linked physics to mathematics, both when being asked what they thought physics was about and as a reason for not studying it. The link shown in this study may not be valid, as some respondents may have been influenced by the survey method of asking mathematics students about physics.

The students identified their parents and family as significant in helping them formulate their subject choices. Students also often identified peers and advice from teachers and the careers counsellor. This is consistent with findings by Cumming (1997), Lyons (2005) and Walkington (1998) that suggest that the interaction of social influences play a significant role in a student's decision. The advice sought was often in regard to prerequisite subjects for courses of interest.

Conclusions and recommendations

In reference to my first research question: What is the state of Physics enrolments in Victoria with respect to total VCE enrolments and differentiated by gender? This study examined VCE enrolment data for Mathematical Methods and Physics over the 2000 – 2005 period. This data revealed that the state of Physics enrolments in the VCE are of concern. There is a large gender gap with 23% of boys and only 6% of girl attempting Unit 4 Physics in 2005. The total enrolments in Unit 4 Physics over the 2000 - 2005 period dropped by 2%. The VCE data supported the linking of Mathematical Methods with Physics as over the 2000- 2005 period on average 91% of students studied Physics with Mathematical Methods.

In reference to my second research question: What factors do female Mathematical Methods students from single sex schools have for choosing or not choosing Physics as part of their VCE studies? This study found that the factors that female Mathematical Methods students from single sex schools had for choosing or not choosing Physics as part of their VCE studies were many. Of the 21 factors identified by the students in this study, five were most significant. Fifty six percent of the girls surveyed found physics boring or uninteresting. Twenty eight percent could not fit physics into their subject selections, either due to other subjects having a higher priority or timetable issues preventing them from studying it. Twenty six percent believed physics to be too difficult and 23% believed they would not enjoy physics if they were to study it. Twenty three percent also stated that they did not need physics as a prerequisite. Being a prerequisite for a tertiary course was a significant factor for the subject choice of Physics and Mathematical Methods.

A majority of students in this study had quite a limited understanding of what physics is about and yet many were quite confident in this understanding. Students who illustrated a broader understanding of physics appeared less confident in their understanding. In several contexts, students linked physics with mathematics.

Students in this study turned to their parents for help in their subject choice decisions. Suggestions from teachers, careers counsellors and peers were also quite significant for these students. Much of this advice related to career and tertiary options.

The single sex environment for these girls did not appear to challenge the stereotypes that are reflected in the gender gap of enrolments in Physics and Mathematical Methods. Enrolment data from the three schools revealed that none of these schools had higher than average enrolments in Physics and only one of the three had marginally higher (1%) enrolments in Mathematical Methods.

Looking to the future

The majority of girls surveyed in this study believed that physics offered little future relevance and had limited perceptions of what physics is about. The emphasis of so many respondents on prerequisites and future options suggests many students are making decisions about vocational pathways at the same time that they are choosing their VCE subjects. The dropping numbers of students studying physics could be addressed by increasing the female participation in VCE Physics. However, this seems unlikely unless greater efforts are taken to capture the imagination of these students and to open their minds to the opportunities that the study of physics has to offer.

If more girls are to be attracted to the study of physics ways to appeal to their interests early in their school careers must be found. Junior science teachers must be encouraged to make links between the physics content they teach and the applications of these in vocational areas. Senior physics teachers need to work with the junior science teachers to strengthen their confidence in the physics topic areas and to promote physics explicitly in the junior science courses. Senior physics teachers may also have to approach careers counsellors in the school to make them more aware of the possible career paths that physics leads to.

For girls studying science and mathematics, the single-sex environment has created confidence and improved outcomes (Haussler & Hoffman, 2002; Salomone, 2003; Stage et al., 1985; Streitmatter, 1999). Yet in the three schools surveyed none had made inroads into enrolment numbers of the stereotypically gendered subject of Physics or Mathematical Methods. Small enrolment numbers can mean that there are few physics specialist in a school resulting in non-physics specialists taking up the brunt of the junior science load. Small numbers in enrolments also exacerbate obstacles such as timetabling. The all-girl environment may inadvertently be creating hurdles for female participation in physics rather than promoting it.

Girls' schools cannot be complacent in the belief that the very fact they are a single-sex school is enough to break down gender stereotypes. Schools and teachers need to be proactively working to illustrate the significant contribution that physics continues to make to our society and the rewarding careers physics can lead to.

Appendices

<u>Appendix A – VCE enrolment data</u>

Physics students break down 2000 - 2005

	Unit 2					Unit 4				
Year	Boys	Unit 2 Boys	Girls	Unit 2 Girls	Unit 2	Boys	Unit 4 Boys	Girls	Unit 4 Girls	Unit 4
2000	7686	72.14192	2968	27.85808	10654	5580	74.0642421	1954	25.9357579	7534
2001	7628	72.59922	2879	27.40078	10507	5558	73.80161997	1973	26.19838003	7531
2002	8073	73.86769	2856	26.13231	10929	5527	74.11827813	1930	25.88172187	7457
2003	8075	74.69935	2735	25.30065	10810	5764	75.14013818	1907	24.85986182	7671
2004	7391	74.29634	2557	25.70366	9948	5270	77.10314557	1565	22.89685443	6835
2005	7201	74.73018	2435	25.26982	9636	5232	76.4130276	1615	23.5869724	6847
Average	7675.667		2738.333							

Mathematical Methods student breakdown 2000 - 2005

	Unit 2					Unit 4				
Year	Boys	Unit 2 Boys	Girls	Unit 2 Girls	Unit 2	Boys	Unit 4 Boys	Girls	Unit 4 Girls	Unit 4 MM
2000	12471	51.44165	11772	48.55835	24243	9310	54.43489446	7793	45.56510554	17103
2001	12759	52.05418	11752	47.94582	24511	9393	53.2875702	8234	46.7124298	17627
2002	12935	52.20567	11842	47.79433	24777	9586	53.54110813	8318	46.45889187	17904
2003	13077	52.6831	11745	47.3169	24822	9762	54.05614929	8297	45.94385071	18059
2004	12557	51.97434	11603	48.02566	24160	9810	54.41233568	8219	45.58766432	18029
2005	12400	52.45347	11240	47.54653	23640	9335	54.1850476	7893	45.8149524	17228
Average			11659							
		Please note from 2002 Mathematical Methods and Mathematical Methods CAS are combined								

Comparison of numbers

Year	Physics	MM	SM	All	Females	Males	% girls	% girls in physics/girls in cohort	% girls in MM/girls in cohort	% boys in physics/boys in cohort	% boys in MM/boys in cohort	% Physics cohort/VCE cohort	% Methods cohort/VCE cohort
				Eligible for SC									
2001	7531	17627	5923	46924	25042	21882	53.37	7.88	32.88	25.40	42.93	16.05	37.56
2002	7457	17904	6094	48180	25947	22233	53.85	7.44	32.06	24.86	43.12	15.48	37.16
2003	7671	18059	6237	50276	26794	23482	53.29	7.12	30.97	24.55	41.57	15.26	35.92
2004	6835	18029	6162	49741	26498	23243	53.27	5.91	31.02	22.67	42.21	13.74	36.25
2005	6847	17228	5627	49273	26413	22860	53.61	6.11	29.88	22.89	40.84	13.90	34.96

Composite Unit 2 English numbers

Year	Boys	Girls	Total
2001	28386	30201	58587
2002	29139	30375	59514
2003	29525	30602	60127
2004	28884	30392	59276
2005	28490	30460	58950
Average	28884.8	30406	59290.8

Students studying Physics with Methods												
Unit 2							**Unit 4**					
Year	**Boys**	**% Boys**	**Girls**	**% Girls**	**Unit 2**	**%Total Unit 2 Physics**	**Boys**	**Unit 4 Boys**	**Girls**	**Unit 4 Girls**	**Unit 4**	**%Total Unit 4 Physics**
2000	6908	89.9	2727	91.9	9635	90.4	4613	82.6702509	1648	84.3398158	6261	83.1032652
2001	6932	90.9	2675	92.9	9607	91.4	4645	83.5732278	1666	84.4399392	6311	83.8002921
2002	7280	90.2	2568	89.9	9848	90.1	4658	84.2771847	1600	82.9015544	6258	83.9211479
2003	7143	88.5	2446	89.4	9589	88.7	4797	83.2234559	1587	83.2197168	6384	83.2225264
2004	6846	92.6	2394	93.6	9240	92.9	4414	83.7571157	1337	85.4313099	5751	84.1404535
2005	6630	92.1	2271	93.3	8901	92.4	4361	83.3524465	1363	84.3962848	5724	83.5986563
					Average	**91.0**					**Average**	**83.6310569**

References

2006, *Inquiry into the Promotion of Mathematics and Science Education,* in *Education and Training Committee,* Parliament of Victoria, Melbourne.

AUTC 2005, *Learning Outcomes and Curriculum Development in Physics - A report on tertiary physics learning and teaching in Australia*, School of Physics and Materials Engineering, Monash University.

Authority, V. C. 2004, *Physics: Victorian Certificate of Education Study Design*, Victorian Curriculum Authority, Melbourne.

Blanche, M. T. & Durrheim, K. 1999, 'Histories on the present: Social science research in context', in Durrheim, K. (Ed.) *Research in Practice: Applied Methods for the Social Sciences*, Universtity of Capetown, Capetown, pp. pp. 1-16.

Campbell-Evans, G. 1992, 'Seek first to understand and then to be understood: A qualitative research approach', *Issues In Educational Research,* vol. 2, no. 1, pp. 25-33.

Carlone, H. B. 2004, 'The Cultural Production of Science in Reform-based Physics: Girls Access, Participation and Resistance', *Journal of Research in Science Teaching,* vol. 41, no. 4, pp. 392-414.

Cole, N. 1997, *The ETS Gender study*, Educational Testing Service, Princeton, New Jersey.

Connole, H. 1993, 'The research enterprise', in H.Connele, B. S., R Wiseman (Ed.) *Study Guide: Issues and Methods in Research*, University of South Australia, Underdale, pp. pp. 17-42.

Cox, P. 2004, *A fair and equal education for all? Is egalitarianism alive and well in schools?,* AARE Conference, Melbourne, Victoria,

Cox, P. J., Leder, G. C. & Forgasz, H. J. 2004, 'Victorian Certificate of Education: Mathematics, science and gender', *Australian Journal of Education,* vol. 48, no. 1, pp. 27 - 46.

Cumming, J. J. 1997, 'Attracting girls and women students to non-traditional areas', *Queensland Journal of Educational Research,* vol. 13. <http://education.curtain.edu.au/lier/qjer_13/cumming.html>

Fullarton, S. & Ainley, J. 2000, *Subject Choice by Students in Year 12 in Australian Secondary Schools (LSAY Research Report Number 15)*, Australian Council for Educational Research.

Gill, P. 1999, 'The physics/maths problem again', *Physics Education,* vol. 34, no. 2, pp. pp. 83 - 87.

Harding, J. & Sutoris, M. 1985, 'An object relations account of the differential involvement of boys and girls in science and technology', in Kelly, A. (Ed.) *Science for Girls?*, Open University Press, Milton Keynes.

Haussler, P. & Hoffman, L. 2002, 'An intervention Study to Enhance Girls' Interest, Self-concept and Achievement in Physics Classes', *Journal of Research in Science Teaching,* vol. 39, no. 9, pp. 870-888.

Head, J. 1980, 'A model to link personality characteristics to a preference for science', in Kelly, A. (Ed.) *Science for Girls?*, Open University Press, Milton Keynes.

Hobbs, T. 1987, *Senior Secondary subject selection by boys and girls*, Department of Education, Queensland.

Hudson, H. T. & Liberman, D. 1982, 'The combined effect of mathematical skills and formal operational reasoning on student performance in the general physics course', *American journal of Physics,* vol. 50, no. 12, pp. 1117 - 1119.

Hudson, H. T. & McIntire, W. R. 1976, 'Correlation between mathematical skills and success in physics', *American journal of Physics,* vol. 45, no. 5, pp. 470 - 471.

IUPAP 2005, *Women Physicists: Progress?*, International Union of Pure and Applied Physics, 12.

Johnson, B. & Christensen, L. 2004, *Educational research: Quantitative, qualitative and mixed approaches (2nd edition)*, Pearson Education, Boston, MA.

Johnson, B. & Onwuegbuzie, A. J. 2004, 'Mixed Method Research: A Research Paradigm Whose Time Has Come', *Educational Researcher,* vol. 33, no. 7, pp. 14-26.

Jones, A. T. & Kirk, C. M. 1990, 'Gender differences in students' interests in applications of school physics', *Physics Education,* vol. 25, no. 6, pp. 308-313.

Jones, J. 1989, *Achievement and aspirations in mathematics and science in two school systems,* A.A.R.E. Conference, University of Adelaide,

Jorg, T., Veld, M. i. t., Th., W. & Verwey, P. 1990, *Oorzaken van de geringe populariteit van het vak natuurkunde als examenvak bij meisjes in het Mavo en Havo*, Cdû, Utrech.

Kahle, J. B. 1993, 'Images of Scientists: Gender Isssues in Science Classrooms', in Fraser, B. J. (Ed.) *Research Implications for Science and Mathematics*, Curtin University of Technology, Perth, Western Australia, pp. 20-25.

Kelly, A. 1982, 'Why girls don't do science', in Kelly, A. (Ed.) *Science for Girls?*, Open University Press, Milton Keynes, pp. 12 - 17.

Kelly, A. 1987, 'Introduction - Science for Girls', in Kelly, A. (Ed.) *Science for Girls*, Open University Press, Milton Keynes, pp. 1-10.

Kelly, A., Whyte, J. & Smail, B. 1984, 'Girls into science and technology: final report', in Kelly, A. (Ed.) *Science for Girls*, Open University Press, Milton Keynes.

Labudde, P., Herzog, W., Neuenschwander, M. P., Violi, E. & Gerber, C. 2000, 'Girls and physics: teaching and learning strategies tested by classroom interventions in grade 11', *International Journal of Science Education,* vol. 22, no. 2, pp. 143 - 157.

Lamb, S. & Bell, K. 1999, *Curriculum and careers: the education and labour market consequences of Year 12 subject choices (LSAY Research report Number 12)*, Australian Council for Educational Research.

Lewis, S. & Davies, A. 1988, *Girls And Maths And Science Teaching project - Gender Equity in Mathematics and Science*, Curriculum Development Centre, Woden, ACT.

Lyons, T. 2005, 'The Puzzle of Falling Enrolments in Physics and Chemistry Courses: Putting Some Pieces Together', *Research in Science Education,* vol.

Malone, J. A., deLaeter, J. R. & Dekkers, J. 1993, 'Secondary science and mathematics enrolment trends', in Fraser, B. J. (Ed.) *Research implications for science and mathematics teachers*, Curtain University of Technology, Perth.

McCullough, L. 2004, 'Gender, Context and Physics Assessment', *Journal of International Women's Studies,* vol. Vol 5, no. #4, pp. pp. 20 - 30.

McKenzie, J. 2006, *Extended Inquiry,* Extended Inquiry - Melbourne 2006, From Now On, Melbourne, <http://www.fno.org>

Norvilitis, J. M., Reid, H. M. & Norvilitis, B. M. 2002, 'Success in Everyday Physics: The Role of Personality and Academic Variables', *Journal of research in science teaching,* vol. 39, no. 5, pp. 394 - 409.

Parker, K. 2002, 'Men are not from Mars', *Physics Education,* vol. 37, no. 1, pp. 12-17.

Quinn, J. 1992, *A/AS Level Students' Attitudes to Physics*, Institute of Physics, London.

Rao, V. & Woolcock, M. 2002, 'Integrating Qualitative and Quantitative Approaches in Program Evaluation', Development Research Group, The World Bank.

Raw, A. J. 1999, 'Developing A-level physics students' mathematics skills - a way forward', *Physics Education,* vol. 34, no. 5, pp. 306 - 310.

Saayman, R. 1991, 'A diagnostic of mathematics and scientific reasoning ability of first-year physics undergraduates', *Physics Education,* vol. 26, no. 6, pp. 359 -366.

Salomone, R. C. 2003, *Same, Different, Equal - Rethinking Single Sex Schooling*, Yale University Press, New Haven.

Sells, L. 1975, *Sex, Ethnic and Field Differences in Doctoral Outcomes,* Thesis, PhD Dissertation, University of California, Berkeley.
Sharma, M. D. & Armi-Stoks, G. D. Australian Women in Physics', <http://www.aip.org.au/women/austwip.html> (March)
Sharp, L. & Frechtling, J. 1997, 'Introducing This Handbook', in Sharp, L. (Ed.) *User-Friendly Handbook for Mixed Method Evaluation*, Directorate for Education and Human Resources, pp. 1-8. <http://www.ehr.nsf.gov/EHR/REC/pubs/NSF97-153/START.htm>
Sjoberg, S. 1990, 'Gender equality in science classroom', in Fraser, B. J. (Ed.) *Research Implications for Science and Mathematics Teachers*, Curtain University of Technology, Perth.
Sjoberg, S. & Imsen, G. 1988, 'Gender and science education.' in Fensham, P. (Ed.) *Development and dilemmas in science education*, Falmer Press, London.
Smail, B. 1985, 'Organizing the curriculum to fit girls' ineterests', in Kelly, A. (Ed.) *Science for Girls?*, Open University Press, Milton Keynes, pp. 80 - 88.
Smail, B. 1987, 'Encouraging girls to give physics a second chance', in Kelly, A. (Ed.) *Science for Girls?*, Open University Press, Milton Keynes.
Stadler, H., Duit, R. & Benke, G. 2000, 'Do boys and girls understand physics differently?' *Physics Education,* vol. 35, no. 6, pp. 417- 422.
Stage, E. K., Kreinberg, N., (parsons), J. E. & Becker, J. R. 1985, 'Increasing the participation and achievement of girls and women in mathematics, sciences and engineering', in Kelly, A. (Ed.) *Science for Girls*, Open University Press, Milton Keyes, pp. 119 - 133.
Stokking, K. M. 2000, 'Predicting the choice of physics in secondary education', *International Journal of Science Education,* vol. 22, no. 12, pp. 1261 - 1283.
Streitmatter, J. L. 1999, *For Girls ONLY*, State University of New York Press, Albany, New York.
Thomson, S. 2005, *Pathways from School to Further Education or Work: Examining the Consequences of Year 12 Course Choices (LSAY Research Report Number 42)*, Australian Council of Educational Research.
Vanderkam, L. April 11, 2005, 'What math gender gap?' <http://usatoday.com/news/opoinion/2005-04-11-girls-math-forum_x.htm>
Victorian Curriculum and Assessment Authority, V. 2004, *Physics: Victorian Certificate of Education Study Design*, Victorian Curriculum Authority, Melbourne.
Victorian Curriculum and Assessment Authority, V. July 17, 2006, 'VCE Statistical Information', <http://www.vcaa.vic.edu.au> (September)
Victorian Tertiary Admission Centre, V. Course Search: Major search', <http://www.vtac.edu.au/courses/searchmajors.html> (September)
Walkington, J. 1998, 'Girls selecting mathematics and science: Making choices and having expectations', *Queensland Journal of Educational Research,* vol. Vol 14.
Watterston, B. 2001, *Practices and Policies on Single Sex Classes within Co-educational Schools,* Australian Association for research in Education Annual Conference, AARE, Fremantle, <http://www.aare.edu.au/01pap/wat01270.htm>
Williams, C., Stanisstreet, M., Spall, K., Boyes, E. & Dickson, D. 2003, 'Why aren't secondary students interested in physics?' *Physics Education,* vol. 38, no. 4, pp. 324-329.
Wisemen, R. 1990, 'The interpretive approach', in Wiseman, R. (Ed.) *Research Methodology 1: Issues and Methods in Research*, Deakin University, Geelong, pp. 103-177.