How might the development of pedagogic strategies enhance sports science students' attainment of statistical literacy in Higher Education?

Thesis presented to Kingston University (in collaboration with University of Surrey and University of Surrey, Roehampton) in partial fulfilment of the requirements for the degree of Doctor of Education.

Beverley J. Hale

Submitted July 2010

Abstract

The reluctance of Sports Science students to engage with Statistics[1] has been widely documented in the higher education sector. This research project employed a mixed methodology to explore the complex interaction between motivation, learning and student achievement to inform the development of statistical pedagogies through evidence based practice.

Data for 336 students were collated from student records. Descriptive statistics explored the impact of gender, degree programme, previous Mathematics qualification and UCAS tariff points on marks in Statistics examinations. Inferential statistical tests (ANOVA, ANCOVA and *t*-tests) evaluated the mean differences within each factor and the interactions between them. Additionally, Statistics marks were compared to those of other compulsory modules. Regression models identified the comparative contribution of quantitative factors to Statistics and Dissertation marks. Unstructured and semi-structured interviews were conducted with twelve participants to understand the students' perspectives while they were studying a level five Statistics module.

A synthesis of quantitative and qualitative findings revealed mathematical experiences to be the only factor to influence achievement in Statistics. Students perceived Statistics as a branch of Mathematics and expressed insufficient confidence to engage with statistical activities, which in turn led to poor examination results, particularly at level five. Interview responses revealed the examinations to be inadequate indicators of statistical literacy. Recommendations were made to develop statistical thinking in response to Sports Science problems. This approach would enable students to have space for necessary reflection and to appreciate better the vital role of Statistics in all areas of Sports Science. Assessment through project work was commended as beneficial, both as a vehicle for learning and to promote motivation for deeper engagement with Statistics.

[1] To enable the reader to distinguish between statistics as a subject discipline and statistics used to describe the analyses undertaken in the project, all subject disciplines are denoted in 'title' case.

The ambiguous identity of Statistics was exposed as the cause of interview participants' anxiety about Statistics. Further research was advocated to establish the characteristics that set Statistics apart from Mathematics and to develop innovative approaches to assessment. Professional development to improve the Sports Science/Statistics interface and challenge the boundaries of modular degree structures was a critical recommendation for future development.

Contents

List of Tables

List of Figures

Acknowledgements

Sincere thanks must go to Doctor Penny Bidgood and Professor Keith Grieves for their supportive, constructive supervision of this thesis.

I am grateful to my students for the module evaluations and verbal feedback which prompted me to undertake this work, and to those whose data were analysed in the quantitative sections of this project. The twelve students who participated in interviews deserve a separate, if anonymous, mention. The interviews would not have been completed without their altruistic generosity with their time.

Thanks must also go to my colleagues and to my friend Sue, who read draft chapters, or provided a listening ear when necessary. Especial thanks to Dudley and John, for relieving me of some teaching and administrative work for a semester so that I could give greater attention to this research project.

Finally, my family deserve a mention. Thank you to Philip, Michael and Naomi for putting up with lax domestic arrangements and occasional panic, and to my parents, John and Jean, who have always been there for me with quiet support.

I am grateful to you all.

Statement of Objectives

This research project aimed to evaluate factors thought to be influential in the development of pedagogic strategies to enhance students' attainment of statistical literacy.

Quantitative and qualitative methods were used to address the following objectives as a means to investigate the research aim:

- Evaluation of Statistics module marks compared to those of other compulsory modules.
- Investigation of the influence of gender, degree programme and previous academic achievement on students' ability to succeed in Statistics modules.
- Interpretation of students' experiences of learning Statistics, including the ability to relate statistical literacy to Sports Science contexts.
- Conclusions and recommendations to inform evidence-based professional practices.

Chapter One

Introduction

1.1 The contested application of Statistics

Towards the end of the nineteenth century Statistics[1] was hailed as "the most important science in the whole world for upon it depends the practical application of every other science and of every art; the one science essential to all political and social administration, all education..."; a quotation widely attributed to Florence Nightingale, 1820-1910, (for example, Ridgway, McCusker and Nicholson 2004). H.G. Wells (1865) foresaw the reliance on quantitative data that is a facet of modern society, and claimed that "Statistical thinking will one day be as necessary a qualification for efficient citizenship as the ability to read and write"[2]. Nearly one hundred and fifty years later a review of Statistics teaching in United Kingdom (UK) universities identified a decline in the number of Statistics lecturers; a trend which appeared likely to continue (Barnett, 2007). Over a period of ten years as an applied Statistics lecturer at a university in the UK, the researcher had observed students' antipathy towards Statistics, an attitude widely documented in educational literature. Although Statistics had become a core component of many degree programmes, it was not perceived as the vital life-skill envisaged by H.G.Wells. Rather, it was regarded as a difficult and unnecessary departure from activity in the dominant discipline of a degree programme.

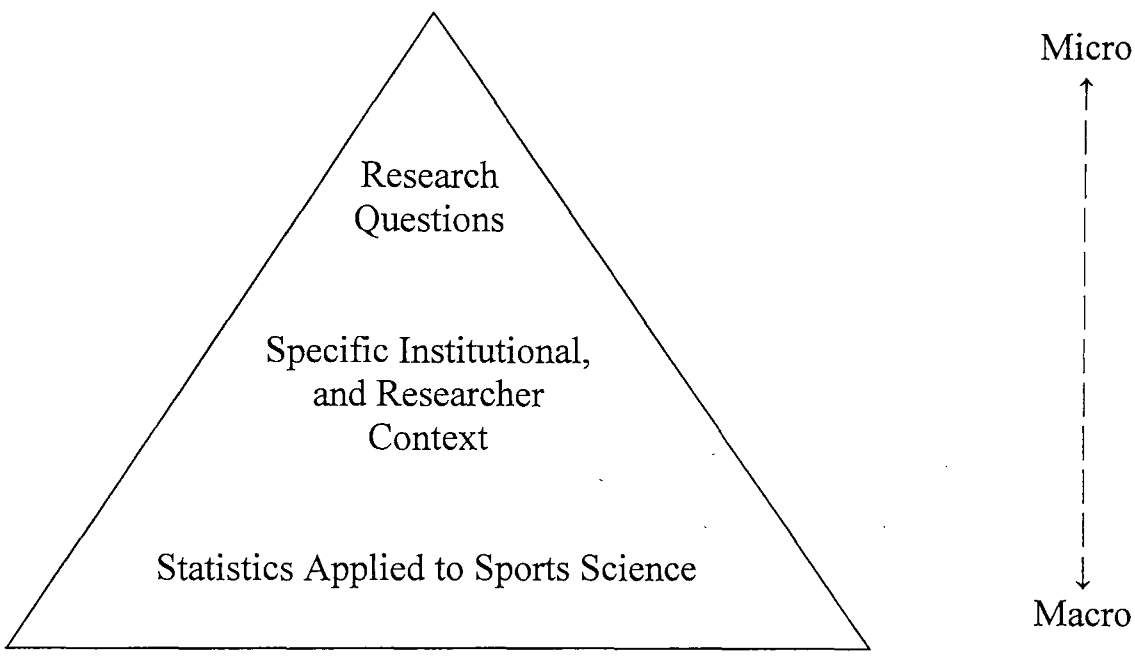
Many Sports Science students demonstrated a resistance to Statistics, often manifested by a reluctance to engage with statistical learning. Students' module evaluation comments such as: "Why do we have to do Statistics? It has no relevance to a Sports Science Degree." (First year Sport and Exercise Science student, 2004), and "I don't see that this has anything to do with my degree, which is Sports Therapy" (First year Sports Therapy student evaluation, 2005), were representative

[1] Throughout this project subject disciplines, module and programme titles, are indicated in upper case 'title' presentation.
[2] Both the quotation attributed to Florence Nightingale and that of H.G.Wells are widely documented in Statistics books and publications but the researcher was unable to trace the original material. Ridgway, McCusker and Nicholson (2004) is an example of these publications.

of students' opinions between 2003-2006. There was a need to evaluate the extent and effect of antipathy towards Statistics in order to inform statistical pedagogic development in the particular university setting.

This chapter follows the structure indicated in figure 1.1. It provides a rationale for this research project and locates specific research questions in the university context. The contribution to published literature in the field of statistical pedagogies, and to Sports Science in particular, is clarified. The final section outlines the structure of the project.

Figure 1.1 The location of this research project at macro and micro levels



1.2 Rationale for this research project

Previous research that evaluated Sports Science students' statistical learning has been dominated by questionnaire methods of data collection. Analysis with quantitative procedures enabled the relationship between assessment outcomes and psychological states to be determined (Chatzisarantis and Williams, 2006; Lane, Dale and Horrell 2006, Lane, Hall and Lane, 2004; Lane *et al.* 2003; Lane, Hall and Lane, 2002). Only one research paper was identified that allowed Sports Science students to voice their experiences without the constraint of a closed response structure. Lane, Devonport and Horrell (2004) asked students who had completed dissertations to evaluate the relevance of Statistics to specific degree programmes. Research was overdue that investigated the pedagogic strategies and learning experiences that made, and continue to make, Statistics problematic for Sports Science students.

This project investigated students' experience of learning Statistics in a specific university setting. Interviews were conducted with twelve students *during* the Statistics component of a level five[3] Research Methods module. Additionally, marks from examinations were analysed to determine whether gender, degree programme and previous academic qualifications (UCAS tariff points and highest qualification in Mathematics) affected success in Statistics. These factors were identified from literature or through the researcher's empirical observations. The research project aimed to evaluate critically the impact of pedagogic practice and developing knowledge on 'statistical literacy' *before* students undertook an individual research project. If pedagogic practices were to address some of the negative psychological states that had been documented, it was vital to understand the students' perspectives more clearly *while* they were studying Statistics rather than after they had graduated (Chatzisarantis and Williams, 2006; Lane, Hall and Lane, 2004; Lane *et al.,* 2003). The concept of statistical literacy is developed in Chapter Two and employed to evaluate learning in Sports Science settings in Chapters Four to Seven.

Students' module evaluations between 2003 and 2005 explicitly highlighted how statistical computer software had subsumed statistical activity. Comments such as 'I don't like the computer sessions', or 'It is beneficial to learn a new computer application', far outweighed any feedback referring to 'Statistics'. Tabachnick and Fidell (1996) identified conceptual understanding as central to the development of critical, evaluative and innovative thinking through statistical knowledge. Statistics can contribute to the development of what Warhurst (2001) and Barnett (1997) describe as a 'critical thinker', through a conceptual approach to statistical learning and teaching. The challenge of enabling Sports Science students to develop applicatory and interpretive, reflexive approaches to Statistics motivated the researcher to undertake this project.

---

[3] UK universities refer to full time first year through to third year undergraduate study as levels four five and six. A part time student could be in their second year of registration with a particular university but still be completing level four modules.

Robson (2002) and Carr and Kemmis (1986) claimed 'insider' research to be essential practice in circumstances where change and development are a primary consideration. Clarke and Erickson (2003) argued that without 'inquisitiveness' about how one's students learn, teaching practice becomes 'perfunctory and routinized' (p5). This project focused on the researcher's professional setting; a Statistics lecturer employed within a Sport, Exercise and Health Department. A mixed methodology was adopted that incorporated a quantitative investigation of students' assessment marks, linked with interviews that encouraged students to use their own words to describe the learning experiences on a particular module. The mixed methodology allowed the situated context of the researcher to provide a further dimension to the interpretation documented in Chapter Six and to position the findings of the research project amid the existing body of published quantitative research related to Statistics in Sports Science settings. Contextualisation is vital to statistical reasoning (delMas, 2004), yet is missing from experimental and questionnaire research in the field of Statistics for Sports Sciences. The interpretation of experiences of the contributing participants is an important ingredient of this research project.

The core questions addressed through quantitative data collated from student records were:

1. Does attainment in Statistics differ from attainment in other compulsory modules of students' degree programmes?
2. Do factors such as gender or previous academic achievement, especially in Mathematics, affect marks for Statistics examinations?
3. Is there evidence to suggest that choice of degree programme impacts on marks for Statistics examinations?

Qualitative methods complemented the quantitative investigation through the exploration of potential reasons for particular results. Interviews sought to clarify:

4. How previous experiences with Mathematics affected Sports Science students' perceptions of Statistics;

5. The nature of the evolving relationship between statistical literacy and the developing professional knowledge of Sports Science students, as they progressed from level four to level five;
6. Students' experiences of learning Statistics within a specific level five compulsory module.

The quantitative research questions and qualitative explorations provided evidence to evaluate the overarching research question:

How might the development of pedagogic strategies enhance Sports Science students' attainment of statistical literacy in Higher Education?

Following a review of published literature (evaluated in Chapter Two) factors thought to impinge on statistical learning were identified. Chapter Three documents the methodological decisions necessary to examine the core questions effectively. Quantitative findings in Chapters Four and Five influenced the content of both unstructured and semi-structured interviews that are interpreted in Chapter Six. A synthesis of quantitative and qualitative findings provided evidence of the influence of pedagogic practices on achievement *and* potential reasons for these effects. These findings were drawn together to reach overarching conclusions, presented in Chapter Seven, that inform the practice of the professional Statistics educator in higher education. The research project therefore included a pedagogic perspective hitherto absent from studies of Statistics in Sports Science settings.

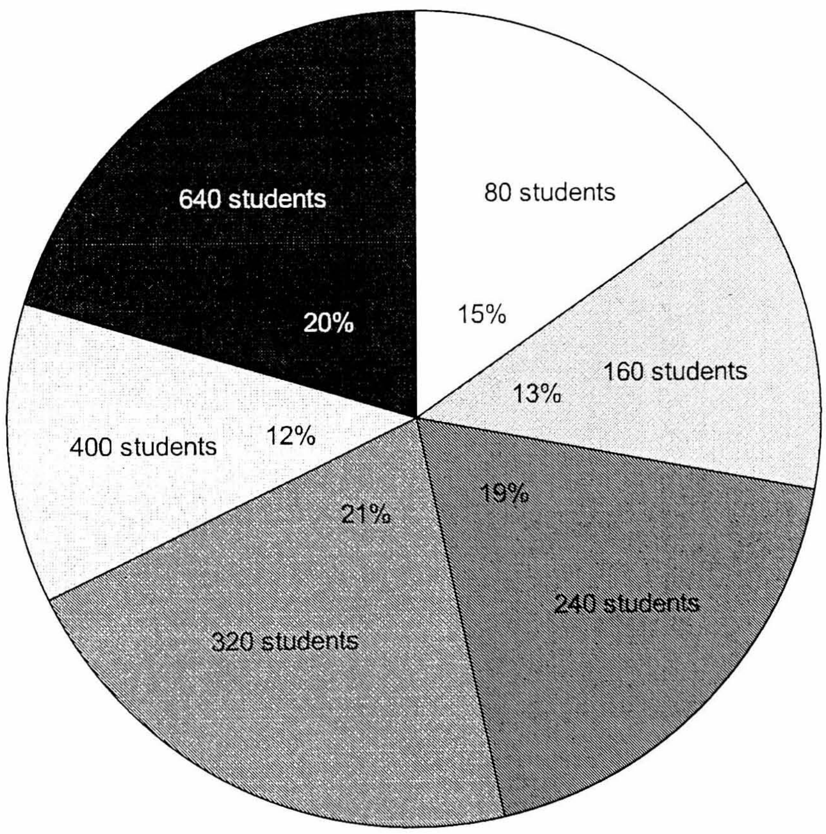
1.3 The institutional context

Data were collected from students at a particular university, one of 103 higher education institutions (HEI) offering 779 Sports Science related programmes through the University Central Admissions Service (UCAS, 2008). The university[4] was a small institution in the south of England that had gained university status early in the twenty-first century. Over the data collection period, of 2003-2006, it had an annual intake of approximately 120 students per year for Sports Science degree

[4] The particular setting is referred to as 'the university'.

programmes. Figure 1.2 shows that this was in the lowest 30% of universities for size of intake, although the diagram represents the whole Biological Sciences subject group because segregated data for the Sports Science sub-group were not available (Higher Education Statistics Agency [HESA], 2007). In common with other universities offering similar degree programmes, less than ten percent of each cohort was mature students. Few students with disabilities applied for Sports Science programmes, apart from those with dyslexia, and over the period for which data were analysed the university had approximately 4% of students from ethnic minority backgrounds, a figure marginally above that for the geographic locality (HESA, 2007; Gough and Gaine, 2002).

Figure 1.2 2005-2006 Maximum Student cohort sizes for Biological Science subjects in UK universities (HESA, 2007)



Reay, David and Ball (2005) investigated the effects of a mass higher education system on students' choices and options as they contemplated higher education. They identified a "complex institutional hierarchy… in which universities are classified and judged by both the applicants themselves and wider society in accordance with their proportion of working class and ethnic minority intakes" (p.163). The university context for this research project fitted the profile identified by Reay, David and Ball (2005) as a likely choice for working class, first-generation students who are more likely to opt for post 1992 universities close to home. The students included in this project revealed considerable cultural and experiential diversity despite the apparently homogeneous, predominantly eighteen to twenty-one year old, white, able bodied cohort profile of the programmes. The diversity of students provided rich data that enabled the researcher to frame pedagogic recommendations that might, in part, inform practice in other institutional and educational contexts because there are many similarities between the Statistics elements of Sports Science degree programmes (a comparative table of some of these can be found in appendix *i*). Similar difficulties have been documented in many other subject disciplines (for example Gigerenzer *et al.*, 2008; DeCesare, 2007; Murtonen, 2005a).

In 2006 the university offered modular degrees in a variety of subject areas grouped into six departments. The university year was split into two semesters during each of which full time students were required to study four modules. For every successfully completed module a student was awarded fifteen credits and therefore accrued 120 credits per year. A Bachelor of Science (B.Sc.(Hons.)) degree was awarded once a student had gained a total of 360 credits; 120 at each of level four, five and six. Modules entitled Research Methods and Statistics One, at level four, and Research Methods and Statistics Two, at level five, were compulsory for four undergraduate B.Sc.(Hons.) degree programmes in the Sports Science suite.

The Sport, Exercise and Health Sciences department was the only science-based department in the university and the only one to employ a Statistics specialist, the researcher, to lead the Research Methods and Statistics provision. A further 1.2 full time equivalent lecturers contributed to Research Methods or Statistics modules and this teaching load was shared by three different individuals, either on fractional or associate lecturer appointments. The researcher's background was in Mathematics and Statistics. The fractional appointments at the time of data collection were sports specialists with an interest in Statistics (a Sports Physiologist and a Sports Biomechanist). The associate lecturer was experienced in Psychology and qualitative research methods.

External examiners for the Sports Science degree programmes commented on low assessment marks in Research Methods and Statistics modules. In 2003-2004 the chief external examiner reported that there was "an uncharacteristic number of fails in Research Methods". The external examiner for Sports Physiology added that in dissertations students did not "distinguish between the singular datum and plural data, did not report testing of underlying assumptions for statistical analyses and finally, used an unrealistic number of significant figures to report results". These were a series of specific criticisms which highlighted students' inability to transfer the statistical content of stand-alone Research Methods and Statistics modules to the disciplinary research setting. The following year the same external examiner stated that "Research Methods modules now seem to have this cachet [of the lowest marks] but this simply reflects a national pattern. These modules have appropriate content and assessment". The external examiners' feedback positioned the Statistics provision at the university in the wider setting of universities offering Sports Science degree courses.

Statistics formed a separate section of both Research Methods and Statistics modules, and occupied two thirds of the available face-to-face module teaching time at level four and level five. At both levels, Statistics was assessed by examination and the mark aggregated with that for Research Methods to provide an overall module grade. This research project focused on the Statistics sections of each module only. For ease of reference these sections are identified as Statistics One and Statistics Two. Through detailed investigation of existing pedagogic and assessment strategies in the Sport, Exercise and Health Science department this research provided information to aid the development of innovative learning opportunities and assessments.

1.4 Statistics in Sports Science settings

Research Methods and Statistics modules were included in UK Sports Science related degree programmes to fulfil the Quality Assurance Agency (QAA) benchmarking criteria that, "Where a programme title contains the word 'science' then it should, among other things, enable students to

- demonstrate an understanding of the philosophical basis of scientific paradigms
- demonstrate evidence of competence in the scientific methods of enquiry, interpretation and analysis of relevant data and appropriate technologies"

(QAA benchmark statements, 2008, p.16)

These criteria did not place constraints on how the 'understanding' and 'competence' should be facilitated. The researcher was aware that the stand-alone Research Methods and Statistics modules contained in many Sports Science degree programmes (appendix *i*) were developed in response to more prescriptive stipulations of earlier regulations. The 2008 benchmark criteria presented an opportunity to change radically the learning situations through which students develop statistical literacy.

Many universities offer degree programmes that require students to carry out research using quantitative methods that develop and enhance knowledge. Statistical knowledge is often provided through a 'service course' and students can have problems seeing the relevance of Statistics to their particular discipline (Learning and Teaching Support Network for Mathematics, Statistics and Operational Research [LTSN,MSOR], 2001). A service course delivered to a particular group of students, for example Sports Science students, needs to have explicit disciplinary links in order to sustain interest (Murphy, 2008; Davies, 2006; Graham, 2006; Garfield, 1995). Perceptions of irrelevance can be exacerbated if students' experience with Mathematics predisposes them to disengage from Statistics. In these circumstances, problems may be encountered with student motivation and the maintenance of statistical rigour (Chatzisarantis and Williams, 2006; Hencken, 2005). This research project explored the interplay between motivation, learning and student achievement to inform future development of statistical pedagogies and evidence based practice.

As early as 1986, Brogan and Kutner contended that stand-alone modules taught by statisticians caused students to lack confidence in lecturers' abilities to identify with issues specific to the dominant discipline. Hencken (2005) claimed the content could also be too technical for Sports Science students. Paradoxically, employing academics with a professional knowledge of Sports Science and an interest in Statistics to teach students did not alleviate the problems. In such circumstances issues of professional knowledge and competence arose, because interest did not always equate with proficiency (Hencken, 2005).

Yilmaz (1996) identified widespread issues with Statistics where it is taught as a non-dominant, support subject applied to a range of dominant disciplines. Many academics and students categorised Statistics as scientific, underpinned by mathematical methods, a Mode 1 interpretation of knowledge (D'Andrea and Gosling, 2005). A reductionist, 'cook-book' approach to teaching can develop from this interpretation, and marginalise underlying statistical concepts. Students taught this way might apply a set of rules that lead to an appropriate statistical procedure, yet have little or no understanding of the results obtained or ability to relate findings to the research context. This is a superficial approach to learning that raises many educational issues (Birkhead, 2009). Statistics cannot exist in isolation – it is part of the trans-disciplinary research environment discussed by Nowotny, Scott and Gibbons (2005). Statistics applied to multidisciplinary Sports Science degree programmes requires interpretation and reflexivity in professional settings, characteristics attributed to Mode 2 knowledge (Nowotny, Scott and Gibbons, 2003; Gibbons *et al*, 1994). Statistical thinking transcends statistical literacy as students progress from passive consumption of statistical material to active researchers able to interpret their results and findings. 'Deep' learning encouraged by this Mode 2 interpretation of statistical knowledge better facilitates the statistical reasoning and thinking necessary for students to be able to think critically and be evaluative and innovative (Ramsden, 2003; Warhurst, 2001).

An investigation of the provision of Statistics degree programmes in UK universities concluded that "By 2010 we predict a decline of between 7% and 22% in Statistics staff in the Mathematical Sciences." (Smith and Staetsky, 2007, p.42). There is likely to be a shortage of trained statisticians and increased pressure for university tutors from other disciplines to teach Statistics within their own fields. Without statisticians to provide professional development, disciplinary misconceptions about statistical techniques are more likely to proliferate.

1.5 The structure of this project

Chapter Two considers the body of literature relating to statistical learning in higher education. The chapter engages with the range of competencies and skills that characterise statistical literacy, reasoning and thinking and relates them to the Sports Science setting. A critical evaluation of published statistical pedagogic research in Sports Science revealed a psychological focus that highlighted the need for educational research such as that presented in this research project. Conceptualisations of learning and pedagogic models appropriate to this research project are evaluated. Motivators and barriers to learning Statistics are discussed critically, with particular reference to the role of assessment.

Chapter Three examines the complementary nature of qualitative and quantitative paradigms in educational contexts. It defends the selection of a mixed methodology for this research project. The chapter summarises the methods employed by previous published research in the field of Statistics education which revealed infrequent use of qualitative interpretations of data. A rationale is provided for the choice of methods for exploring the key research aims, to inform and enhance the professional practice of Statistics educators by addressing the overarching research question, "How might the development of pedagogic strategies enhance Sports Science students' attainment of statistical literacy in Higher Education?" A discussion of ethical issues raised by the research project is included.

Chapter Four is the first of two chapters documenting the analysis of quantitative data. It focuses on descriptive statistics to explore and summarise data from the sample of students registered for Sports Science degree programmes in June 2006. The characteristics of that sample are presented, and achievement in Statistics is compared to that in other compulsory modules. The potential effects of gender, highest Mathematics qualification, UCAS tariff points and degree programme on statistical achievement are examined, as are the potential interactions of these factors.

Finally, the relationship between achievement in Statistics and Dissertation marks is explored.

Chapter Five extends the descriptive analysis from Chapter Four. The sample of Sports Science students from June 2006 is taken as a representative sample of students who are accepted onto the suite of Sports Science degree programmes at the university. Initially, the chapter evaluates whether the place of Statistics marks identified in Chapter Four is generalisable to future cohorts of students. Inferential hypothesis tests and statistical regression models explore the potential effects of entry profiles and degree route choices on students' achievement in Statistics examinations. In turn the impact of statistical literacy - as demonstrated by Statistics marks - on Dissertation marks is evaluated.

Findings from Chapters Four and Five informed the choice of interview topics to elicit the qualitative data interpreted in Chapter Six. Pen-portraits of interview participants as well as a thematic analysis of the researcher's key areas of interest present an interpretation of data that is both inductive and deductive. The chapter contains an overview of the participants' entry profiles and achievement in Statistics One and Statistics Two. An individual perspective is presented through pen-portraits which is followed by a thematic analysis which compares and contrasts students' opinions about core questions 4-6 (see section 1.2).

Chapter Seven integrates the findings from Chapters Four, Five and Six to draw conclusions that inform the professional practice of the Statistics educator and highlight areas for future research. Qualitative and quantitative perspectives verify the trustworthiness of the conclusions reached. The limitations of this research project are identified. The chapter concludes with a presentation of the key findings of the project and makes some recommendations for evidence-based professional practice and future research.

Chapter Two

Review of Literature

2.1 Introduction

This chapter opens with a critical analysis of statistical literacy, reasoning and thinking and explores the disparity between definitions of these concepts. A perspective that informs this research project is presented as a method of characterising different levels of competence with Statistics. The published literature about Statistics in the Sports Science domain is evaluated. The perspectives of learning styles, surface and deep approaches to learning, and alienation and engagement are assessed for utility within this project to explore and evaluate learning. The pedagogic strategies that were employed in the Statistics Two module, and form a part of the semi-structured interviews explained in Chapter Three, are evaluated critically in section 2.5. The overarching importance of assessment, and potential barriers to learning Statistics are explored in the final sections of the chapter.

2.2 Statistical literacy, reasoning and thinking

Schield (1999) perceived 'traditional Statistics' as a deductive, positivistic mechanism through which to reach a conclusion. Sports Science developed from the natural and biological sciences, which encouraged this interpretation of Statistics in response to the quantitative experimental or quasi-experimental approach to research evident in published literature (for example in *The Journal of Sports Sciences*). The professional experiences of the researcher found the most prevalent interpretation of Statistics applied to Sports Science to emphasise the mathematical connection at the expense of situated interpretation. Teaching was driven by statistical procedures rather than by data analysis requirements. Similar situations were evident in other institutions known to the researcher. An alternative perspective is characterised by statistical literacy, which originated in the United States of America in the mid 1990s. Wallman (1993) identified statistical literacy as, "the ability to understand and critically evaluate statistical results that permeate our daily lives – coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions" (p.1).

In the late 1990s and early 2000s statistical literacy was a contestable entity, not easily defined. Schield's (1999) perception of statistical literacy was of an inductive process which employed Statistics to provide evidence for decision making. He concluded that, "statistical literacy is more about questions than answers. It doesn't have many answers, but it should help one to make better questions and thereby make better judgements and decisions" (p.1). This stochastic perspective can be unsettling for students, who have a deterministic interpretation of Statistics and expect it to provide definitive answers.

Gal (2002) claimed adults' statistical literacy to be, "two interrelated components, primarily (a) people's ability to *interpret and critically evaluate* statistical information, data-related arguments, or stochastic phenomena, which they may encounter in diverse contexts, and when relevant (b) their ability to *discuss or communicate* their reactions to such statistical information" (p.2, emphasis in original). This conceptualisation of statistical literacy was explicitly applied to adults, who were differentiated from students, because they read Statistics produced by others rather than generate Statistics through the analysis of empirical data. Increasingly students are expected to read academic research literature that requires them to 'consume' rather than produce statistical information, but it was claimed that the shared language of a subject discipline is less varied than that found in public circulation. Sports Science is a multidisciplinary subject that requires students to read academic research papers from a variety of subject disciplines such as Psychology, Physiology, Medicine and Biology. Consequently, Gal's classification of adult statistical literacy may be applicable to Sports Science students.

Gal's (2002) model of statistical literacy, table 2.1, included both Mode 1 and Mode 2 interpretations of knowledge because specific procedural knowledge is critically applied and evaluated in context (Nowotny, Scott and Gibbons, 2003; Gibbons *et al*, 1994). Schield's (1999) critical questioning is clearly evident in the model. The contribution of context and the need for personal involvement through the engagement of one's own beliefs and critical stance, juxtaposed with mathematical elements are of particular importance for this project. There is clear evidence from published research in Sports Science settings that students perceive Statistics as a branch of Mathematics (see section 2.3). The implications of the relationship between the two disciplines are evaluated critically in section 2.7.3.

Table 2.1 A model of adult statistical literacy, adapted from Gal (2002) to show how Mode 1 and Mode 2 knowledge contribute to statistical literacy

Knowledge Elements	**Dispositional Elements**
Literacy skills – Mode 1 Statistical knowledge – Mode 1 Mathematical knowledge – Mode 1 Context knowledge – Mode 1 and Mode 2 Critical questions – Predominantly Mode 2 ↘	Beliefs and Attitudes - Mode 2 Critical stance – Mode 2 ↙
Statistical	**Literacy**

Gal's (2002) paper was one of the first to present possible components of statistical literacy and subsequent research has extended and adapted his model. A vital message from his work is that statistical literacy is not 'factual' knowledge enabling manipulation of data following mathematical rules, but a tightly interrelated set of 'elements', that cannot be fragmented and taught in isolation. The complexity of statistical literacy makes it cognitively demanding.

Researchers who have investigated statistical literacy in specific educational settings identified the importance of basic computation and the interpretation of empirical reality (Gigerenzer, *et al.*, 2008; Murphy, 2008; Vere-Jones, 1995; Bessant, 1992). These skills resonate with some of the elements of the model in table 2.1. It is clear from the work of these authors that statistical literacy does not have a single definition and that interpretational and contextual differences complicate its use as a description of learning. Rumsey (2002) criticised statistical literacy as "too broad" because it was not consistently defined throughout published literature. She discarded 'statistical literacy' in favour of 'statistical competence' to describe "the basic knowledge that underlies statistical reasoning and thinking" (p. 3). She added 'statistical citizenship' to encompass Wallman's (1993) definition of an ability to understand and interpret Statistics and to appreciate its value to personal and professional decision-making.

A significant body of research that investigated statistical literacy was guided by the International Research Forum on Statistical Reasoning, Thinking and Literacy (SRTL), a small biennial forum in conference format which had its inception in 1999. Garfield and Ben-Zvi (2007) claimed that statistical literacy was a prerequisite for 'statistical reasoning' and 'statistical thinking' but provided a more complex definition than Rumsey's (2002) 'statistical competence' and 'statistical citizenship'. The model of statistical literacy developed by Gal (2002) and the "increased awareness of students' inability to think or reason statistically, despite good performance in statistics courses" (p.5), led Ben-Zvi and Garfield (2004b) to conceptualise a model driven by data analysis and understanding rather than through separate procedures.

Pfannkuch and Wild (2004) saw the integration of statistical and contextual knowledge as crucial to 'statistical thinking'. Students who perceived Statistics as a branch of Mathematics were found to focus on computational details and numeric solutions. Such skills form a part of statistical literacy, but do not enable the meaningful interpretation of results. It was *situated* decision making that Pfannkuch and Wild (2004) claimed to evidence statistical thinking. Sports Science students who can conduct statistical analyses and report results and conclusions often cannot apply the conclusions to the specific research context. An inability to think statistically constrains further development of their work. delMas (2004) asserted that statistical thinking enabled one to select appropriate analyses and methods, but to explain *why* results occur and justify subsequent conclusions required 'statistical reasoning'. A synthesis of knowledge about the particular statistical analysis with the limitations of research design and data collection, securely situated in the specific context and evaluated critically are vital ingredients of statistical reasoning. The Sports Science student who does not reason statistically will not realise the importance of sample selection and research design on the findings from a particular statistical analysis.

Despite diverse interpretations in the literature, there was recognition of the variety of cognitive demands associated with statistical activity. A common thread included in this section was the importance of critical interpretation and informed decision-making as essential ingredients of statistical literacy (Murphy, 2008; Gal, 2002; Schield, 1999; Wallman, 1993), and the hierarchical nature of statistical competence characterised by statistical thinking and reasoning (Garfield and Ben-Zvi, 2007; delMas, 2004; Pfannkuch and Wild, 2004). The utility of statistical literacy, thinking and reasoning to this project was as conceptualisations of statistical learning that enabled the exploration of students' understanding and development.

Following Wallman (1993) and Gal (2002), the researcher defined *statistical literacy* as the skills needed to understand data presented in Sports Science research. The ability to organise data through tabulation and graphs, descriptive summaries, familiarity with statistical terminology, and simple probability, contribute to a student's statistical literacy. These skills need to be taught explicitly to most Sports Science students. *Statistical thinking* was visualised as a broader concept that encompassed issues surrounding statistical activity, such as the choice of research design and associated analytical procedures. Statistical thinking is necessary for a student to critique and evaluate research papers, as well as to design appropriate undergraduate research projects independently. *Statistical reasoning* was interpreted to include the capability to conduct a statistical procedure with understanding and employ that understanding to interpret and evaluate the results obtained. An appreciation of the effect of research decisions on the conclusions that can be drawn would require skills of statistical reasoning. These distinctions draw on the research of Pfannkuch and Wild (2004) and delMas (2004) and closely resemble those made by Ben-Zvi and Garfield (2004b) and sustained over a period of time (Garfield and Ben-Zvi, 2007).

Cultural and subject discipline differences are a contributory factor of context knowledge; therefore, further research into statistical literacy is not only vital in 'Various Functional Environments' as Gal suggested in 2002, but also in different cultural settings. The paucity of significant research from the UK needed to be addressed. At the time when this project was proposed (2006) conceptualisations of statistical literacy, thinking and reasoning were under-researched in Sports Science settings. Pedagogies developed with particular attention to these concepts should enhance students' engagement in the excitement of solving quantitative problems.

2.3 Statistical literacy in Sports Science settings

Prior to 2007, studies of Statistics in Sports Science settings reflected the dominant research perspective of Sports Psychology and focused on motivation and self-efficacy. Motivation was perceived as an incentive to involve oneself in statistical activity. The stimulus to undertake statistical work was acknowledged as unlikely to come from within the individual, intrinsic motivation, so research focussed on ways of making statistics more appealing to students through extrinsic motivators. Self-efficacy is defined as the 'beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments' (Bandura, 1997, p.3). Parajes (1996) claimed that belief in personal capability can be more effective than academic ability in generating a positive attitude towards subjects that students perceive to be difficult. This is an important consideration for Statistics because of its association with Mathematics, a subject that few Sports Science students pursue beyond compulsory schooling. However, high self-efficacy does not necessarily equate with motivation to undertake statistical work, and it will not enable students to increase their statistical literacy unless they invest time in the subject.

Chatzisarantis and Williams (2006) explored how to develop Sports Science students' motivation to learn Statistics. The authors adopted a confidence interval perspective to the teaching of statistical inference to see if it would increase student motivation over more traditional probability-based methods (Schmidt, 1996). The experimental group, taught by 'Schmidt's method', did not demonstrate different patterns of change in motivation from a control group, who attended another university where a more traditional teaching approach was maintained. For both groups intrinsic motivations decreased over time while extrinsic motivations increased; a directional change counter to that thought desirable for learning by Ryan and Deci (2000a). Later research by Newstead and Hoskins (2003) contested the value of intrinsic motivation in academic contexts (section 2.7.1). Written feedback, collected from the experimental group in Chatzisarantis and Williams's (2006) study, indicated that students felt their *understanding* had improved, although this did not increase enjoyment or perception of competence. The quantitative bias to data collection and analysis assumed that 'Schmidt's method' *should* improve motivation although this was neither investigated nor evidenced. Additionally, the cultural, situational and pedagogic differences between the two institutions included in the study would have affected students' learning experiences and impinged on the research findings. The authors missed an explicative opportunity by making minimal use of qualitative feedback which could have enriched the findings. The crucial value of the learners' perspective was emphasised by its omission from Chatzisarantis and Williams's (2006) research, a circumstance which influenced the choice of a mixed methodology for this project.

A considerable number of studies have explored Statistics in a particular Sports Science context (Lane, Dale and Horrell, 2006; Lane, Hall, and Lane, 2004; Lane, Devonport and Horrell, 2004; Lane, *et al.,* 2003; Lane, Hall and Lane, 2002). The studies explored the effects of self-efficacy on statistical learning. Lane and Lane (2001) developed and validated a self-efficacy questionnaire which was later adapted to relate specifically to Statistics modules within Sports degree programmes (Lane, Hall and Lane, 2002). Further studies used the developed instrument to investigate Sports Science students' self-efficacy to complete Dissertation or Statistics assessments (Lane, Hall, and Lane, 2004; Lane, Devonport and Horrell, 2004; Lane, *et al.,* 2003). An important finding from these studies was that Sports Science students had little self-efficacy in Statistics.

Quantitative analyses identified significant relationships between self-efficacy and academic performance, which Lane *et al.* (2003) and Lane, Hall and Lane (2004) interpreted to indicate causality. Improving students' self-efficacy was recommended as a strategy to increase motivation to learn Statistics. However, attention to other aspects of learning may improve academic performance and result in a simultaneous increase in self-efficacy. Self-efficacy alone will not encourage a student to learn Statistics. It could have the opposite effect because students who have strong belief in their statistical ability may marginalise the subject in favour of more appealing study in the same way that those with low statistical self-efficacy might procrastinate. A more critical issue is *how* students can be motivated to engage with Statistics and potentially improve statistical literacy, thinking and reasoning regardless of their perceived self-efficacy.

In a departure from the customary quantitative perspective, Lane, Devonport and Horrell (2004) included both quantitative and qualitative methods in a study that explored students' "self-efficacy to use research methods skills" (p.25). The authors did not attempt to integrate findings, but treated their work as two separate studies. Qualitative data were collected from two focus groups: the first with four female level six students, who had completed their dissertations, and the second with six postgraduate Masters students, two male and four female. Findings revealed research methods as relevant, but difficult. Lack of motivation was attributed to an inability to "engage with it in a meaningful way" (Lane, Devonport and Horrell, 2004, p.33). Of vital importance to this project is that Lane, Devonport and Horrell's (2004) conclusions were drawn from a sample of students where 60% of the sample was sufficiently committed to continue to postgraduate study. Pedagogic strategies to facilitate a wider population of Sports Science undergraduates to improved statistical literacy required the interpretation of learning experiences of students at levels four and/or five in the context of achievement in assessments, and in terms of professional life skills.

With the exception of one study, the research reviewed in this section employed quantitative methods to assess the specific impact of self-efficacy on statistical learning. The importance of this attribute is not to be underestimated, but strategies to improve statistical pedagogies need to consider the "complex interaction between aims and objectives, subject matter, thinking processes, learner, teaching methods, teacher and assessment" (Holmes, 2000, p.11), crucial to the development of statistical literacy. Lane *et al.*'s work (2002; 2003; 2004a; 2004b) provided a significant foundation from which to explore different perspectives on Statistics in Sports Science settings. The authors concluded that there was clear necessity to explore more effective ways of teaching; they applied the descriptor 'user friendly', but their research did not extend to pedagogic theories and practices.

2.4 Conceptualisations of learning

An examination of how students develop statistical literacy required a clear articulation of the ways in which learning could be conceptualised. The following sub-sections critically evaluate three alternative models with particular attention to their utility for this project.

2.4.1 Learning styles

Many conceptualisations of learning style are evident in the literature. While all the authors who attempted to measure learning style used a questionnaire to gather data, *what* they measured was inconsistent. Some questionnaires aimed to indicate genetic intelligence or personal attributes (For example, Gregorc, 1977 as cited in Coffield, *et al.* 2004), others quantified alterable learning characteristics (Kolb, 1999; Herrmann, 1989, as cited in Snee 1993; Honey and Mumford, 1982). A third group of inventories identified 'types' of learning such as deep, surface, strategic or apathetic (for example, Entwistle, 2000 and 1981). The description of learning differed depending on the inventory used, and the purpose of identifying specific styles was unclear. Therefore, the selection of an appropriate questionnaire for a particular purpose appeared arbitrary. Additional difficulties arise from the validity of self-report inventories of this nature, where responses may conform to what the respondent feels is socially acceptable and where the Hawthorne effect leads to heightened awareness, and possible alteration to, the phenomenon under investigation (Parsons, 1974). The learning style that is identified from psychometric questionnaires is likely to evaluate learners' *impressions* of their behaviour rather than their *actual* behaviour (Mitchell, 1994).

Further difficulties with learning styles as conceptualisations of learning were documented by Coffield, *et al.* (2004). They revealed a, "widespread disagreement about the advice that should be offered to teachers … should the style of teaching be consonant with the style of learning or not?" (p.140). 'Consonance' between teaching and learning style is hard to facilitate as learners may need to operate outside their customary study habits in less familiar disciplines such as Statistics (Altman and Bland, 1991). The notion of learning 'style' is less helpful in the context of teaching applied Statistics than an awareness of student diversity. Conceptualisations that focus on what students learn and why they do so are more directly relevant to experiences with statistical literacy.

2.4.2 Deep and surface approaches to learning

The development of statistical reasoning and thinking from an earlier position of statistical literacy could be perceived as a move from surface learning to deep learning, so there was utility in the evaluation of the meanings attached to deep and surface learning in existing pedagogic literature. These concepts were developed from Marton and Säljö's (1976) approaches to learning which "incorporated both what students do (strategy) and why they do it (intention)" (Case and Marshall, 2004, p 606). Motivated students who strive for conceptual understanding through the active synthesis of knowledge and experience demonstrate traits attributed to deep learning. Surface approaches include task related knowledge recall, through memorisation, that requires little thoughtful reflection and no reflexive decision-making (Ramsden, 2003). Biggs and Tang (2007) identified a "genuine preference, and an ability, for working conceptually" (p.25) as necessary for deep learning. However, students may demonstrate these characteristics in some areas of study while not in others (Biggs and Tang, 2007; Ramsden, 2003; Prosser and Trigwell, 1999). This is a crucial point as many students adopt a different approach to learning Statistics from the strategies that they use to learn about aspects of Sports Science.

Descriptions of deep and surface approaches to learning provided in the literature referred to discrete and opposing characteristics to emphasise the difference between them (for example, Biggs and Tang, 2007; Ramsden, 2003; Chalmers and Fuller, 1996). These explanations promoted a narrow construct that caused deep and surface learning to be considered in a dichotomous manner (Haggis, 2002; Malcolm and Zukas, 2001). For example, it was suggested that western countries view memorisation as a disengaged, surface activity, but if memory is used as a strategy to facilitate deep understanding, then surface approaches may not be as undesirable as they initially appear (Webb, 1997). This perspective had considerable implications for this project as there was evidence that many Sports Science students memorised statistical algorithms, but that some of them later developed a conceptual understanding.

Haggis (2003) rejected deep and surface approaches to learning because of the imprecise references to 'meaning' and 'understanding'. She questioned whether deep and surface learning should be perceived from a tutor's or learner's perspective. Cowan (2006), opposing Haggis, contended there to be an, "important difference between deep and surface learning – two terms whose meaning is, I hope, almost self-evident" (p.193). Over a period of four to five years Case developed an increasingly complex perspective on approaches to learning as a continuum from surface to deep (Marshall and Case, 2005; Case and Marshall, 2004; Case and Gunstone, 2003). Marshall and Case (2005) acknowledged the effect of situation and context on learning, but cautioned against discarding the deep and surface framework. They argued that there had been an "inevitable degree of conceptual slippage... 'deep approaches to learning' [had] become 'deep learning' and,...ultimately metamorphosed into 'deep learners'" (Marshall and Case, 2005, p.258). The authors concluded that the approaches to learning "theory on its own does not provide a sufficiently rich description of student learning in higher education" (Marshall and Case, 2005, p.263). Clearly, authors' interpretations of deep and surface were not as self-evident and consistent as Cowan (2006) claimed.

If statistical literacy is to be developed to include conceptual understanding sufficient to support decision making, it is vital to provide pedagogic strategies to support students to learn to think statistically. Surface and deep categorisations provided a means to distinguish between a mechanistic application of statistical algorithms to data that fit specific patterns, and the careful selection of appropriate analyses to investigate complex problems. The movement from algorithmic application to a reasoned statistical argument is not categorical, but is more akin to the continuum of surface to deep learning proposed by Marshall and Case (2005) Case and Marshall (2004) and Case and Gunstone (2003). This project applied surface and deep to different aspects of statistical learning but in conjunction with concepts of alienation and engagement to reach a more textured description of the quality of learning.

2.4.3 Alienation and engagement

Alienation can be described as a disconnection from the activity, environment, or experience in which one is participating. Engagement explains a connected involvement in a situation; "a dynamic and constantly reconstructed relationship" (Bryson and Hands, 2007, p.352). Mann (2001) considered there to be seven theoretical perspectives of alienation that contribute to students' disengagement from learning. These were developed through an interpretation of Seeman's (1959) 'meanings' of alienation. Particularly pertinent to this project are the perspectives of alienation relating to the focus on utility, skills and competencies, the student as an outsider, and the distancing of learners from their own identity as they fit into a prescribed, 'saleable' course with distinct quantifiable assessments. The following paragraphs exemplify how these perspectives can be applied to Sports Science students' alienation from Statistics.

Mann (2001) explained the experience of the new entrant to university as similar to being "an outsider in a foreign land". The culture, practices and language can all be exclusive. Mann (2001) postulated that increased expectation that school pupils would progress to university left students feeling, "estranged from the meaningful personal purpose in engaging in higher education, and from an intrinsic pursuit of knowledge, understanding or justice" (p.9). Haggis (2003) evidenced the expectation that student learners should behave like academics and contested "the appropriateness and realism... in a higher education system that is now aiming to prepare 50% of the age cohort for the world of work" (p.97). Although global recession and changes to higher education policy during 2009 are likely to alter the demographic characteristics of future undergraduate students, the language and codes of practice of HEIs will continue to form a barrier for students who are not studying traditional academic subjects in red-brick universities (Blair, 2009).

Alienation through estrangement can be further exacerbated by a failure to understand the order and possible logic of new areas of study. Students may find the teaching disjointed and chaotic (Mann, 2001). Learners who do not understand how a teaching session is organised are unable to sift important material from incidental information. This point is particularly relevant to this project as it is conceivable that *most* Sports Science students feel like outsiders in the Statistics classroom. In these circumstances memorisation of a procedure presents itself as a viable alternative to understanding, but does not prepare students to apply analytical skills learned in stand-alone Statistics modules to data collected in laboratory settings.

The diversity and 'situatedness' of the learner, whereby individuals' behaviour is constrained by their position within a group, can be a cause of alienation (Lave and Wenger, 1991). Sports Science students required to learn Statistics at level four may feel a disconnection from their anticipated experience. They may not engage with Statistics because of a perceived lack of relevance to their future professional role and exhibit, "alienation as a strategy for self-preservation" (Mann, 2001, p.15). Sports Science is multidisciplinary and therefore has an intermingling of diverse communities of practice, a situation that demands careful reflection and management (Wenger, 1998). Applied Statistics is a discipline on the periphery of the multiplicity of communities that contribute to Sports Science. Students receive mixed messages from tutors within specific subject domains, who use different statistical terminology to explain the same procedures. These inconsistencies can encourage insecurity, raise anxiety, lower perceived self-efficacy and cause students to become alienated from Statistics in favour of safer, more consistently presented parts of Sports Science. As the values of respected tutors are subconsciously absorbed as part of the students' experiences, they have a crucial influence on the development of students' attitudes towards Statistics (Becher and Trowler, 2001). Previous work that discussed the contested role of the academic statistician in Sports Science settings revealed the importance of these influences in the university where data were collected for this project (Hale, 2004). There was a clear need to negotiate the meaning of Statistics within the wider community. Wenger (1998) recommended the deployment of the shared practice of a community as a firm foundation for productive peripheral learning. For situated professional development such as this, he identified the need for the catalyst for change to be recognised as a legitimate 'core' member of the community. The full-time statistician employed by the School of Sport, Exercise and Health Sciences (the researcher) had enhanced the visibility of Statistics and provided a focus for statistical activity such that the time was apposite for an investigation of students' experiences of Statistics.

Case (2008) identified entry into higher education, fitting into the academic environment and remaining a part of it by meeting expectations and assessment demands, as critical points at which alienation might occur. Most academic attention is focussed on the last of these three, and there is much evidence to suggest that students' learning is guided by a preoccupation with grades and outcomes (Biggs and Tang, 2007; Ramsden, 2003; Prosser and Trigwell, 1999; Chalmers and Fuller, 1996). Students feel pressurised to do well in Statistics and prioritise outcome above learning. In these circumstances careful preparation of assessment *for* learning, as opposed to assessment *of* learning is essential to improve statistical literacy (see section 2.6).

The conceptualisation of engagement as the opposite to alienation ignores the situated nature of the 'connectedness' that the term implies. Bryson (2009) provided a broader explanation that "Engagement is a concept which encompasses the perceptions, expectations and experience of *being* a student and the *construction* of being a student in HE. Engagement underpins learning and is the glue that binds it together – both located in *being* and *becoming"* (slide 8). This perspective elucidates how individuals can apply themselves to being students of Sports Science, yet not embrace the whole programme of modules on offer. In this way the students reinforce their perceptions of what it is to be a sports scientist, but do not become competent in all elements of skill and knowledge. Selective engagement that compromises the fully rounded professional is evident in Coaching Science and Sports Therapy students' accounts of their learning experiences, interpreted in Chapter Six.

There is richly-textured overlay between deep/surface and alienation/engagement conceptualisations of learning. Deep approaches are more likely to result from student engagement, while surface approaches "could be described as expressing an alienation from the subject and process of study itself" (Mann, 2001, p.7). Core questions of this project aimed to assess whether pedagogic practices enabled Sports Science students to develop effective skills of statistical literacy. The identification of potential alienation, and the reasons for it, from students' accounts of their learning experiences was crucial to the evaluation and enhancement of statistical pedagogies at the university.

2.5 Statistical pedagogies

Holmes (2000) claimed that students learn best from *doing* Statistics rather than *hearing* about it. In 2002 tutors at the university made the decision to discontinue Statistics lectures and integrate statistical theory and practical experience within a computer-based laboratory session. Discussion and guided discovery involved students in making meaning and constructing knowledge, the *constructivist* model, with the teacher as expert guide (Carnell and Lodge, 2002). Constructivism in this context was more than the experiential approach to learning detailed by Kolb (1984). "From a constructivist perspective, teachers should take into account what students know and what they can do, how students can negotiate meaning and build consensus by interacting with one another and with artefacts, and how students can put their knowledge to the test and receive feedback on its adequacy." (Mvududu, 2005, p.49). Specific information about an individual student's prior knowledge is less important than the opportunity for everyone to develop towards a deeper understanding. Sports Science students have far less experiential homogeneity in statistical literacy than in the dominant subject disciplines; a constructivist model can embrace that diversity. However, it is important to acknowledge that experiences and beliefs may cause students to miss the intended learning outcome (Mvududu, 2005). In disciplines such as Statistics great care is needed to provide activities which promote and maintain student engagement and enable the development of statistical literacy and thinking.

The teacher needs to devise experiences that, through careful attention to method, provide meaningful experiences which meet the intended learning outcomes (Gregory, 2002). A constructivist model applied to experiential learning can be an effective method of developing statistical literacy if students have support to "draw out learning from the experience and in linking critical incidents in the experience to ideas and theories which shed light on them" (Beaty, 2003, p.136). Students at the university, in common with those of Murtonen and Merenluoto (2001), wanted to practise statistical computation through a series of example questions. It is essential for these tasks, and the outcomes from the constructivist classroom, to build to a coherent, integrated whole, otherwise learning will be compromised (Holmes, 2003). Students should have time for reflection and evaluation (Furedi, 2005; Dewey, 1966). Empirical evidence, in the form of students' module evaluations, suggested that these crucial ingredients were not recognised as part of the statistical pedagogies in the university.

Students whose data were included in this project experienced statistical pedagogies that were influenced by constructivist philosophy. Over a period of time staff and curriculum changes caused adjustments to teaching situations which in some instances led to an activity being structured to the extent that a transmission model of teaching was employed. Tutors perceived the traditional lecture style as a way of supporting students' lack of experience with, and anxiety about numeric work. There was evidence from the questions students asked in tutorials that the *transmission*, teacher centred, model of teaching fostered perceptions of poor competence. Demotivation and anxiety result from the quantification of taught content that students did not understand (Onwuegbuzie and Wilson, 2003). Additionally, the sessions were at too advanced a level for some students while not extending the knowledge of others. Ramsden (2003), Carnell and Lodge (2002), Jarvis (2002), and Deci and Ryan (1985) documented these effects from traditional lecture methods, a contributory factor to the decision to discontinue Statistics lectures two years before data were collected for this project. A critical evaluation of the effects of pedagogic practices on students' experiences of learning Statistics was overdue and of vital importance to the appraisal of statistical provision at the university.

2.6 Assessment for learning in Statistics

The importance of assessment to student learning is evident from the literature evaluated in most sections of this chapter. Section 2.4.3 highlighted the contribution of assessment to student alienation, and section 2.7.2 identifies Statistics examinations as a cause of heightened anxiety (Case, 2008; DeCesare 2007). Newstead and Hoskins (2003) and Race (1993) asserted that carefully constructed assessment can increase extrinsic motivation and enhance understanding in subjects where student interest is lacking (section 2.7.1).

If an assessment is perceived as difficult then alienation is likely. Anxiety can be reduced if students have a clear expectation of how to demonstrate statistical learning through assessment (Onwuegbuzie and Wilson, 2003). A danger inherent in raising students' awareness of what is expected in assignments is that learning may be limited to what students perceive they *need* to know. Holmes (2000) warned that "the aim of education is that students should be educated, not that they should be able to meet assessment criteria" (p.12). The information necessary to pass should therefore promote the skills required to meet the learning outcomes of the Statistics component of a degree course (Senn, 2007; Ramsden, 2003; Holmes, 2000; Chalmers and Fuller, 1996). Lane, Dale and Horrell (2006) found that, "Although statistics is commonly taught through contextually relevant examples, few students develop a deep learning of statistics. It is common for students to learn information required to pass the module/unit, with the tendency to forget this information once they have passed" (p. 297). In such circumstances, high marks may indicate an ability to answer assessment questions rather than quantify statistical literacy. Examinations are more likely to have these effects than project work and written assignments which encourage active involvement, because emotional engagement is necessary for students to gain high marks in coursework (Jarvis, Holford and Griffin, 2003). One of the core research questions of this project sought to position students' statistical achievement in the broader arena of compulsory modules in order to determine whether there was a trend towards lower marks in Statistics. The interpretation of findings included the potential effects of examinations because Statistics modules were assessed in this way over the 2003-2006 data collection period.

Statistics examination can assess learning outcomes in a mechanistic way that rewards good memory rather than understanding. There are two key issues here. Firstly, such assessments can lead students to "an unjustified sense of mastery" (Kelly, Sloane and Whittaker, 1997, p.6). Secondly, students who conceptualise the problem in a different way from the person who set the question may not be rewarded if their responses do not meet the predetermined marking criteria. In each of these cases marks do not reflect an individual's statistical literacy or reasoning capability. Investigative assignments that test statistical concepts rather than calculation-based problems, provide situations which extend learning rather than audit it. Race (1993) advised using assessments, "where learners *necessarily* develop desirable qualities *en route* to an assessed piece of work" (p.5, emphasis in original). Skills learned in this manner can be transferred to other parts of students' university courses and beyond (Jolliffe, 2007 and 1997; Garfield, 1995). The demands of such assignments resonate with the skills developed through constructivist pedagogies, although Garfield and Ben-Zvi's (2007) review of literature did not find evidence that a particular approach to teaching significantly improved assessment marks.

It is evident that great care is needed when setting assessments. The desire to succeed should promote statistical literacy that is sufficient to facilitate the competent completion of a dissertation and extend to later professional activity. An important consideration for this project was that pedagogic strategies and assessment procedures should be complementary and fulfil Senn's (2007) and Holmes's (2000) aim of educating students for a future professional role.

2.7 Barriers to learning Statistics

2.7.1 Lack of motivation

Most of the literature that explored Statistics in Sports Science contexts emphasised the importance of motivation (Chatzisarantis and Williams, 2006; Lane, Devonport, Milton and Williams, 2003; Lane, Hall and Lane, 2004). This section focuses specifically on aspects of motivation that have utility for the interpretation of students' experiences of learning Statistics, one of the core research questions of this project. Motivation may also impact on how students' feelings about Statistics alter as they move from level four to level five, another key research question.

There is considerable evidence to suggest that students are motivated to learn if they have an interest in a subject (Graham, 2006; Cobb and Moore, 1997; Garfield, 1995). Cullingford and Crowther (2005) interviewed students studying engineering at university, or intending to do so after leaving school. The authors found greater student motivation to understand mathematical processes if there was a perception of relevant application. A similar situation was identified with Statistics. Students' motivation was hampered by the lack of an apparent link to their choice of degree programme and the perception that the subject is difficult (Murtonen, 2005b).

Chatzisarantis and Williams (2006) sought unsuccessfully to increase students' intrinsic motivation to engage with Statistics by presenting material through methods that they thought students would find more accessible. Newstead and Hoskins (2003) postulated that lack of intrinsic motivation may not be detrimental to academic success if a student uses an approach to study that compensates for its absence. "The real question concerning nonintrinsically motivated practices is how individuals acquire the motivation to carry them out and how this motivation affects ongoing persistence, behavioural quality and well-being" (Ryan and Deci, 2000a, p.71). There is evidence that assessment and setting manageable targets increase motivation, but not necessarily *intrinsic* motivation (Newstead and Hoskins, 2003; Merricks, 2002; Race, 1993).

Haggis and Pouget (2002) and Haggis (2004) found motivational differences between young students at the lower end of entry requirements and mature students. Mature students were motivated by enthusiasm for learning or occupational aspirations (Haggis, 2004), but interest was more important to younger students (Haggis and Pouget, 2002). The authors warned that, for younger students, "teaching that does not succeed in making the link between new content and students' existing views of the world risks perpetuating the cycle of lack of interest, lack of motivation, lack of understanding and... poor results" (Haggis and Pouget, 2002, p.332). This finding resonates with theories promulgated by Davies (2006) and Jarvis, Holford and Griffin (2003) about the need for students' involvement in their learning.

These perspectives are relevant for this project as the majority of interview participants were either mature students or young students with entry profiles at the lower end of the acceptable criteria, similar to those investigated by Haggis (2004) and Haggis and Pouget (2002). Students did not immediately appreciate Statistics as interesting or relevant to Sports Science. Consequently, intrinsic motivation towards statistical literacy was unlikely. The evaluation of students' experiences of learning was a key component of this project because evidence of motivational change provided vital indicators for the evaluation and enhancement of pedagogic strategies.

2.7.2 Statistics anxiety

Onwuegbuzie and Wilson (2003) claimed prior experiences with Statistics or Mathematics to be a situational antecedent to statistical anxiety, but postulated that the effects may have decreased since the early 1990s as computer software relieved the computational burden. The relationship between Mathematics and Statistics is the subject of the next section. Sports Science students rarely continue with Mathematics beyond GCSE, which may make them feel inadequately prepared for Statistics. Anxiety over failure is inextricably linked with assessment and feelings of inadequacy (Orton, 2004; Onwuegbuzie and Wilson, 2003).

Students who are anxious may attempt to memorise information because anxiety inhibits deep learning (Onwuegbuzie and Wilson, 2003). However, because anxiety can also inhibit memory, reducing, or constructively harnessing fear is important for productive study. Wilson (1999), cited in Onwuegbuzie and Wilson (2003), suggested supportive group work to be a method of reducing statistics anxiety. A safe, cooperative learning environment of this nature also benefits intrinsic motivation and reduces the likelihood of alienation (Ryan and Deci, 2000a and 2000b). Use of humour, real-world examples and the strategic choice of assessment may alleviate anxiety (Murphy, 2008; Davies, 2006; Onwuegbuzie and Wilson 2003). Murtonen and Lehtinen (2003) advised careful investigation of the specific properties of data that make it 'real' to students. This project examined the nature of real data for Sports Science students through the interviews interpreted in Chapter Six.

Field (2009b) cautioned that humour *could* decrease anxiety and increase enjoyment, but not necessarily result in learning. He concluded that "we need to know more about how humour interacts with the personality of the lecturer...there is no substitute for teachers and writers finding their own voice" (Field, 2009b, p.213). Wilson (1999) and Snee (1993) found that tutors' interpersonal skills and subject enthusiasm were influential in deepening knowledge and reducing anxiety. These individual differences are important when evaluating the situated nature of learning. The impact of these characteristics could not be explored in this project because it was impossible to identify who taught each of the students whose data are analysed in Chapters Four, Five and Six. Students may have studied Statistics with as few as two tutors or as many as five over a two year period.

Onwuegbuzie (2004) found that low self-efficacy and anxiety led students to procrastinate over reading, computational tasks and assessment preparation in Statistics. When linked to an earlier study using similar self report methods to evaluate the role of self-perception on statistics anxiety, a picture emerged of students who have little statistics anxiety and less desire to procrastinate if they have high levels of perceived intellectual ability and scholastic competence (Onwuegbuzie, 2004 and 2000b). These relationships provided justification for this project to explore how pedagogical practices and experiences prior to university impacted on statistical learning and achievement.

Onwuegbuzie's (2004 and 2000b) explorations of statistical anxiety supported Lane *et al.*'s (2003) Lane, Devonport and Horrell's (2004) and Lane, Hall and Lane's (2004) conclusions that anxiety contributed to Sports Science students' reluctance to engage with statistical learning. Methods of assisting students to minimise statistical anxiety needed to be explored. However, DeCesare (2007) cautioned against overemphasising the importance of anxiety. He contended that an expectation that students underachieve because of statistics anxiety could become a self-fulfilling prophesy. This research project used a mixed methodology which generated measurable indicators of academic ability and mathematical competence as well as students' accounts of learning experiences. Through this approach it was possible to explore the interplay between measures thought to increase statistics anxiety, students' perceptions of the link between Statistics and Mathematics, confidence, motivation and Statistics marks.

2.7.3 The relationship between Statistics and Mathematics

A considerable body of literature addressed the tension between Mathematics and Statistics. Murphy (2008) argued that no amount of statistical computation would benefit students if they knew nothing of when or why they use it. Hencken (2005) agreed and advocated teaching that emphasised the purpose of the analysis and the interpretation of results in the research context. Carey (2006) cited several examples of statistical processes misapplied to psychological data. He explained how poor conceptual understanding of the mathematical underpinning of Statistics caused "obstruction of the progress of knowledge" (p.209). These papers and letters to professional journals demonstrated the controversy surrounding Statistics and its relationship to Mathematics. Murphy (2008), Carey (2006) and Hencken (2005) all identified the need for informed interpretation of results, but differed in their opinions of how it could be best achieved. Chatzisarantis and Williams (2006) claimed a practical perspective through use of 'real' situations and data to capture students' imaginations such that motivation to solve a problem should increase; a belief shared by Murphy (2008), Davies (2006), Graham (2006), Cobb and Moore (1997) and Garfield (1995). These perspectives raised questions about what should be included in courses to enable Sports Science students to develop statistical literacy. The researcher deployed data gathered in students' Physiology, Biomechanics and Psychology modules to enhance engagement with Statistics, yet she was prompted to investigate students' learning experience and assessment performance because empirical evidence signalled Statistics to be a discipline from which most students felt alienated.

Murtonen *et al.*, (2008) claimed that the similarity between Statistics and Mathematics discouraged student engagement and compromised the quality of learning that resulted from Statistics classes. Murtonen and Titterton (2004) concluded that students' *perception* that Statistics is a branch of Mathematics is sufficient to adversely affect their learning experiences. This finding suggested that students' expectations created a barrier to learning Statistics regardless of the teaching strategies employed. delMas (2004) identified the negative logic inherent in the procedure of falsification as an added obstacle to statistical understanding (Popper, 1983 and 1977). Garfield and Ben-Zvi's (2007) review of research on learning and teaching in Statistics found no evidence that a strong Mathematics background was advantageous. They concluded that "motivation, conscientiousness, and desire to learn may be better predictors" (p.14). These studies indicated that pedagogic strategies that motivated students to assume ownership of statistical work and complete it out of curiosity about the outcome were more likely to engage them than those focussed on specific statistical or methodological procedures.

Core questions of this project explored the impact of previous experiences in Mathematics both on examination performance and on students' feelings about learning Statistics. It was possible that students felt anxious about mathematical skill yet some benefitted because anxiety was positively harnessed, through skills of emotional intelligence, to increase the desire to do well *despite* a perceived weakness (Goleman, 2004; McBride and Maitland, 2002).

2.7.4 Potential gender effects

Halpern (2000) demonstrated how male and female students led very different lives, despite attending the same classes and completing related individual study. She acknowledged traditional cultural role-models contributed to this difference, but also claimed a gender distinction in cognitive ability. She focussed particularly on the first three of Gardner's (1993) seven intelligences, linguistic, logical-mathematical and spatial. The association of Statistics with Mathematics makes the contention of gender difference in logical-mathematical activities particularly pertinent to this project.

Schram (1996) found gender effects on statistical achievement to be related to the type of assessment that was undertaken. Findings from a meta-analysis of thirteen articles containing eighteen samples suggested that females achieved higher marks than males when Statistics was assessed through coursework, but the situation was reversed in examinations. Schram acknowledged teacher effect, different types of Statistics course, levels of experience with Mathematics and anxiety to be important, but was unable to include the effect of these in her analysis. As previously stated, tutor effect could not be addressed by this project, but an exploration of gender effect on Statistics examination marks that also included degree programme and prior Mathematics qualifications can be found in sections 4.4-4.7 and 5.3. Schram's (1996) research suggested the potential for higher achievement by male students at the university, but her meta-analysis was undertaken from literature published in the USA. There was evidence that female students out-performed their male counterparts in most areas of education in the UK during the first decade of the twenty-first century (Higher Education Policy Institute [HEPI], 2009). Therefore, Schram's findings may not be transferable to UK settings. Contradictory positions in the literature similar to those illustrated in this paragraph, together with the predominance of male students on most Sports Science courses, made the potential effect of gender an essential factor for investigation in this project.

2.8 Conclusions

The critical evaluation of published research in the field of Statistics education revealed an emergent body of literature that addressed statistical literacy, reasoning and thinking as separate but intertwined elements of statistical knowledge. There was inconsistency of definition of each of the three elements among contributing authors, but some evidence of an agreed hierarchical relationship. Through statistical literacy students should be able to handle data effectively and have sufficient statistical terminology to read research papers with understanding. Methods to facilitate improved statistical literacy for all undergraduate students were the central focus of this project.

The published literature suggested statistical thinking and reasoning to be dependent on statistical literacy. Students need to be able to think statistically in order to design and execute rigorous research projects independently. These skills are essential at levels seven and eight[1] where there is the expectation that students will evaluate critically both their own work and published papers. Opportunity should be provided to lay the foundations of statistical thinking and reasoning at undergraduate level, especially to avoid the likelihood of an algorithmic approach to learning statistical procedures.

'Deep' and 'surface' conceptualisations of learning, promulgated by Biggs and Tang (2007) and Ramsden (2003) among others, are influential in the evaluation of statistical learning within this project. A surface approach to Statistics relies on memorisation of the key stages of analysis procedures and their application. It limits the development of statistical literacy unless memory is used as a means to question and develop knowledge. Active engagement and curiosity promote the deep learning experiences vital for the foundations of statistical thinking and reasoning. Statistical

[1] UK universities define level seven as study for masters degrees and level eight as doctoral level.

knowledge and competency could be regarded as a continuum which begins with elementary statistical literacy, develops through statistical thinking and ultimately reaches a level of understanding that enables advanced statistical reasoning. The roles of alienation and engagement and their effects on depth of learning appear to be inextricably linked with students' ability to progress through this continuum.

The published research in the field of Sports Science placed motivation at the centre of statistical education, but did not explore its impact on learning. It is apparent from the literature in this chapter that motivation should affect the extent of a student's engagement with Statistics and in turn influence the depth of learning for the successful development of statistical literacy, thinking and reasoning. Awareness of the lack of intrinsic motivation is important for Statistics educators as they cannot assume student interest and ought to incorporate potential extrinsic motivators in their teaching strategies. Additionally, the diversity of published research about *how* to motivate students to learn Statistics revealed the problems inherent in generating interest and engagement. Clearly extrinsic motivation differs between individuals. Analysis and interpretation of interview data, not hitherto undertaken in Sports Science, provided insight into the complex challenge of motivating students to engage with Statistics (Chapter Six).

Pedagogic strategies pertinent to Statistics teaching in the university were the transmission/reception model and the constructivist model. Transmission modes of teaching were sometimes used as part of 'Statistics laboratories' although these were largely practical and required students to be actively involved in knowledge construction. The danger of students 'missing the point' of constructivist learning was emphasised by Mvududu (2005) and Holmes (2000). In a discipline where there is little student motivation to participate, constructivist strategies provide the opportunity to incorporate some degree of personalised learning as individuals' previous experiences can be accommodated. It is also possible that students' prior experiences and beliefs make it difficult for them to construct meaningful statistical knowledge. Evidence of situations that obstruct learning was sought through interviews. Students were asked to provide information about their experiences of each of the teaching methods encountered during the Statistics Two module.

Published literature attributed alienation from Statistics to a perception that the subject was a branch of Mathematics. Neither mathematical nor statistical logic is intuitive for many Sports Science students, and the latter has the added problem of negativity through Popperian falsification. In addition, alienation can result from a sense that one's self-identity is challenged. Gender issues permeate all levels of education in the UK and could be considered a confounding variable in the investigation of Statistics in Sports Science settings. The possibility of gender effects in this male-dominated discipline could not be ignored. This complex interplay of situational and educational factors influenced the choice of mixed methods detailed in Chapter Three.

Assessment issues were cited as influential in raised statistics anxiety, low self-efficacy and alienation (Case, 2008; Lane, Devonport and Horrell, 2004; Lane, Hall and Lane, 2004; Onwuegbuzie and Wilson, 2003; Lane *et al.*,2003). Newstead and Hoskins (2003) and Race (1993) highlighted the values of assessment procedures for increasing extrinsic motivation. These contradictory perspectives served to emphasise the important influence of assessment on learning. In addition, it is widely documented that students' preoccupation with marks and grades is central to learning. Clearly, the mode of assessment affects both *what* is learned and *how* it is learned. The quantitative methods employed in this project were reliant on Statistics examination results to illuminate the effects of gender, degree programme, and academic ability (as indicated by UCAS tariff points and Mathematics qualifications). The mixed methodology described in Chapter Three allowed qualitative and quantitative interpretations of the effect of Statistics examinations on learning to provide a fuller understanding than had previously been possible.

Chapter Three

Methodology and Method

3.1 Introduction

This chapter begins with a brief evaluation of the role of mixed methodologies in educational research. Subsequent sections justify the particular mixed methodology selected to investigate the research questions. The final part of the chapter discusses the ethical issues that arose from the choice of methods.

The boundaries between qualitative and quantitative methods have blurred, with mixed methodologies becoming more common in educational research. Brannen (2005) cited cross-cultural examples of quantitative and qualitative paradigms combining to inform both practical, real-world policy-making and professional practice, but cautioned that combined methodology should evolve from careful consideration of the aims of particular studies. Pring (2004) claimed a qualitative/quantitative distinction to limit informative educational research. He advocated mixed methodologies for effective exploration of the multifaceted nature of education to avoid a polarisation which "cannot capture the richness which is present" (Pring, 2000, p.248). During the twentieth century, policy-makers' evidence for change usually required numbers. The problem for managers was that quantitative data could identify the need for change, but without qualitative data, the detail to inform the nature of that change was inaccessible. Within the particular there are elements that can be generalised because of the norms of human behaviour or culture, which makes qualitative research a defensible method of capturing opinions and experiences to shape the direction of change (Pring, 2000). A design which drew on the paradigms of qualitative and quantitative methodologies was appropriate to 'capture the richness' of the statistical context under scrutiny in this research project.

Yin (2006) differentiated between research projects that *mixed* methods to produce a single study and those which employed *parallel* methods, often written as separate but complementary studies. An example of this could be seen with Lane, Devonport and Horrell's (2004) study of students' self-efficacy with research methods (section 2.3). Yin identified five procedures through which integration could occur in a mixed methodology, and claimed that, "the more that a single study integrates mixed methods across these five procedures, the more that mixed methods research, as opposed to multiple studies, is taking place" (Yin, 2006, p.42). The extent of the mix was not a key consideration for this project. It was vitally important that the methods were integrated in a manner that contributed significantly to the existing body of knowledge about statistical pedagogies, particularly for Sports Science students.

The mixed methodology detailed in this chapter was deemed the most appropriate combination of research methods to address the aim of this project. Research questions were constructed that addressed specific aspects of statistical learning and teaching in the Sports Science context. These questions were first stated in Chapter One, but are included in table 3.1 for ease of reference. The data that arose from the questions was evaluated to suggest how Statistics tutors might respond in the shaping of future learning experiences for Sports Science students in higher education, the main aim of this professional doctoral thesis.

Table 3.1 A reproduction of the research questions initially stated in Chapter One

Questions addressed through quantitative methods:

1. Does attainment in Statistics differ from attainment in other compulsory modules of students' degree programmes?
2. Do factors such as gender or previous academic achievement, especially in Mathematics, affect marks for Statistics examinations?
3. Is there evidence to suggest that degree programme impacts on marks for Statistics examinations?

Qualitative methods complemented the quantitative investigation through the exploration of potential reasons for particular results. Interviews sought to clarify:

4. How previous experiences with Mathematics affected Sports Science students' perceptions of Statistics;
5. The nature of the evolving relationship between statistical literacy and the developing professional knowledge of Sports Science students, as they progressed from level four to level five;
6. Students' experiences of learning Statistics within a specific level five compulsory module.

3.2 Rationale for mixed methodology

A study that employed quantitative and qualitative methods to investigate the student experience in a particular setting was overdue at the beginning of 2006, when this research project was proposed. Previous research through the use of questionnaires limited findings about student learning to the data gleaned from questions and constructs that had been predetermined by the researchers (for example Lane, Hall and Lane's (2002) Self-efficacy Towards Statistics Questionnaire). Although such data were valuable for an overview of a large sample of individuals they could not provide information about the multifaceted experiences of learning Statistics. An alternative approach was sought that would enable students to challenge the preconceptions of the researcher. A data collection method that allowed students to describe personal learning experiences in their own words was crucial. Perceptions of learning Statistics are better explained through interview than quantified by questionnaire, because rich, thick description of the particular is more illuminative of experience than cross-sectional attitudinal measurement (Atkinson and Delamont, 2005; Geertz, 1993).

The decision to adopt an interview approach to data collection enabled participants to present their own interpretations of their feelings. Unstructured interviews that required students to consider past experiences with Mathematics and Statistics were selected as a means of minimising the researcher bias, because the selection of memories could not be influenced by the questions posed. Perks (1992), writing for historians, stated that "deliberate misinformation about the past is very rare" (p.13), although he acknowledged that the way people perceived the past relied on memory and its accompanying actions of selection, suppression and unconscious reinterpretation. Data collected in this manner could be described as a mixture of fact and opinion, both vital ingredients of experience.

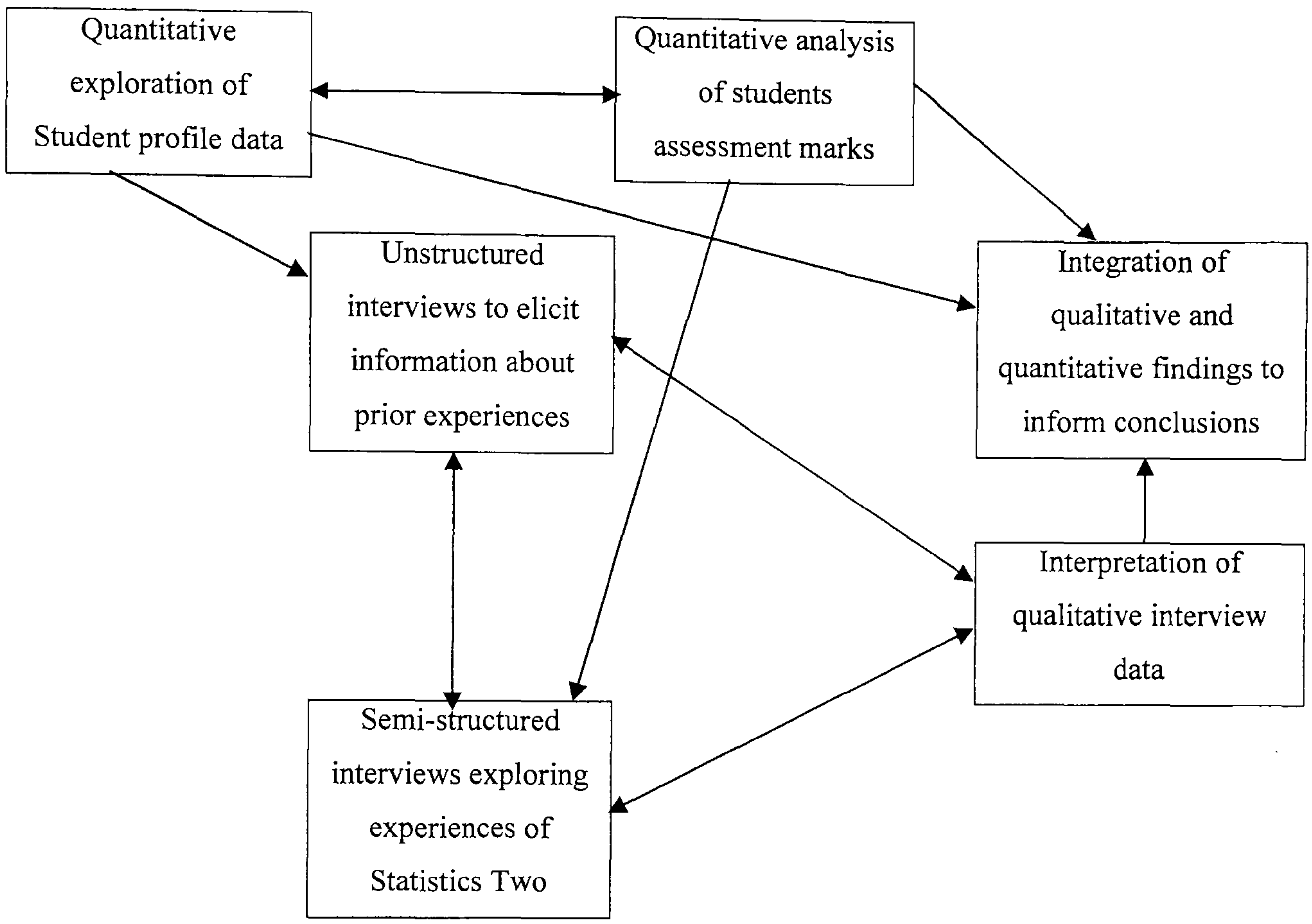
Previous encounters with Mathematics or Statistics are likely to influence students' experiences of learning Statistics at university (Murtonen, and Titterton, 2004). Quantitative assessment data were collected and analysed to evaluate the effects of factors that were thought to influence students' ability to achieve in Statistics. These variables were identified through a critical review of literature (Chapter Two sections

2.6, 2.7.3 and 2.7.4), and from observation and discussion with colleagues at the university, the lived experiences of the professional Statistics educator (this researcher). Quantitative analyses were used to investigate hypotheses developed from the research questions in table 3.1. These hypotheses were:

- Gender affects achievement in Statistics assessments at levels four and five, and in the dissertation;
- Level of Mathematics qualification attained prior to registration at university affects achievement in Statistics assessments at levels four and five, and in the dissertation;
- UCAS tariff point score at entry to university affects achievement in Statistics assessments at levels four and five, and in the dissertation;
- Degree programme affects achievement in Statistics assessments at levels four and five, and in the dissertation;
- There are some interaction effects between the factors in the previous hypotheses.

Second, semi-structured, interviews were undertaken to explore students' experiences during the Statistics Two module, which the quantitative analysis revealed as problematic. Therefore, results from the quantitative analysis informed the direction of the interviews and subsequent findings clarified results from quantitative analyses; the relationship between the methods was symbiotic. Figure 3.1 provides a diagrammatic overview of the mix of methods employed to research the questions raised in this research project.

Figure 3.1 An overview of the mixed methodology employed in this project (Arrows indicate how the methods informed further decisions)



3.3. Quantitative methods

Data pertaining to students' gender, qualifications on entry to university, degree programme and module results were accessed from a variety of institutional records. Computer software (Microsoft Excel© 2003) was used to collate the data into a spreadsheet. The Statistical Package for the Social Sciences, (SPSS), version 15.0 was employed to conduct quantitative analyses. The analysis fulfilled three main purposes: to *explore* the data for patterns and check the assumptions of the proposed statistical tests; to *test* sections of data for differences between groups; and to *model* potential relationships in the data. A glossary of statistical terms is included at the end of this document.

3.3.1 Descriptive statistics

Initially, data from all the Sports Science students registered at the university in June 2006 were explored using graphs and descriptive statistics. Tabulation of data by gender, degree route, and highest Mathematics qualification ascertained the distribution of students in factors thought to impinge on Statistics marks. Boxplots displayed the symmetry of the distribution of each subgroup of data. Although inadequate to identify the shape of the distribution, for example the bell-shaped normal distribution, these diagrams assisted with the identification of outliers in the data. Outliers at the upper end of a data set cause mean values to be inflated, while those at the lower end suppress the mean. Outliers make the mean less representative of the main body of data, so early identification of them was important. Bar charts were used to illustrate how Statistics marks compared to those from other compulsory modules at the same level. Comparisons were limited to compulsory modules to ensure consistency in the comparative groups. Summary descriptive statistics, in the form of means and standard deviations, were computed for each factor.

Universities base the conditional offers that they make to prospective students on A-level grade requirements or on UCAS tariff points calculated from A-level, BTec or other British post-16 qualifications. UCAS tariff points were therefore accepted as a valid measure of students' academic ability on entry to the university. However, academic ability did not necessarily equate to prior experience in the field of Sports Science or a related area. UCAS tariff points differed considerably between students and did not lend themselves to discrete grouping, so individual UCAS tariff point scores were correlated with achievement in Statistics One, Statistics Two and the Dissertation module, to investigate whether there was a relationship between the variables. Scatter diagrams and a Pearson's Product Moment Correlation Coefficient ascertained the pattern and strength of a relationship. Data were percentages (Statistics and Dissertation module marks) and points on a scale, from 80-500 (UCAS tariff points), which were deemed to include an acceptable range of ratio level data values for the correlation coefficient to be meaningful (Howell, 1997).

Through a variety of statistical summaries and graphs the impact of gender, degree programme, Mathematics qualification and UCAS points on Statistics and Dissertation marks were explored for the 2006 sample of Sports Science students. The interactions of all factors were considered at every stage of analysis. These procedures enabled the interpretation of the extent of any differences between groups and are documented in Chapter Four.

3.3.2 Inferential statistical tests

Inferential statistics were employed to extend the descriptive statistics detailed in the previous section. The tests evaluated whether any of the factors could be judged to affect Statistics and Dissertation module marks significantly. That is, whether the findings for the 2006 sample could be generalised to future cohorts of Sports Science students at the university. Parametric tests were applied to evaluate potential differences between gender, degree routes, and level of Mathematics qualification, because the assessment marks for Statistics examinations and the Dissertation module could be assumed to be normally distributed. Procedures used to carry out checks for normal distribution and some representative results from those investigations can be seen in appendix *ii*.

Initial analyses assessed the influence of each individual factor. Two, one-way, within-subjects, analysis of variance tests (ANOVA) evaluated whether marks for Statistics One, and Statistics Two were significantly different from other compulsory modules at the same level. Paired samples *t*-tests were used to locate group differences if the ANOVAs indicated that this was necessary. These *t*-tests were preferred to the more common *post-hoc* tests because they accommodate the covariance inherent in repeated measures designs. Independent samples *t*-tests assessed whether gender affected marks in Statistics One, Statistics Two and the Dissertation module. One-way, between groups ANOVAs were used to evaluate the effects of Mathematics qualifications and degree programme on marks in the three modules. Prior to analysis, the range of Mathematics qualifications was coded into three groups, GCSE grade C, GCSE grade B and GCSE grade A or higher. The last group included students who had AS- or A-level Mathematics or other post sixteen qualifications. Grade combination was necessary as there were few students with

Mathematics qualifications above GCSE grade B, but this procedure rendered the comparison between Mathematics qualifications somewhat imprecise. Games-Howell *post hoc* tests were used to locate differences where appropriate, as sample sizes were unequal and homogeneity of variance could not be assumed (Field, 2009a). The relationship between UCAS tariff points and the marks for the three modules was evaluated through Pearson's Product Moment Correlation Coefficients.

Three-way between groups analysis of covariance (ANCOVAs) were used to explore the influence of each factor, and all possible interactions of factors (gender by maximum Mathematics qualification by degree programme), on Statistics One, Statistics Two and Dissertation marks. UCAS tariff points were included as a covariate as there was evidence from entry requirements that the UCAS point scores differed between degree programmes. Prior to computing each ANCOVA the assumption of equal population variance (homogeneity of variance) was investigated using Levene's tests for independent groups. The additional assumption of homogeneity of regression slopes was evaluated (Field, 2009a). The example in appendix *iii* indicates the decisions that were necessary during the verification of homogeneity of regression slopes. Greenhouse-Geisser epsilon corrections were applied if preliminary analysis revealed a lack of homogeneity of covariance.

ANCOVA identified whether there were significant differences between any of the groups included in the analysis, but it did not identify *which* groups were different. Simple contrasts were employed to locate differences because they enabled the effect of the covariate to be retained in the *post hoc* procedure. The reference qualification of GCSE grade C was selected for the contrasts, because it was the minimum Mathematics requirement for registration on a Sports Science degree programme. Sport and Exercise Science formed the 'base-line' degree programme for comparisons because Coaching Science, Exercise and Health Science and Sports Therapy all included some Sport and Exercise Science modules as compulsory elements within the programmes.

Cohen's f and Cohen's d were used to measure effect sizes of factors examined through ANOVA and t-test respectively (Cohen, 1988). These measures were selected because both assess effect size referent to standardised means (Tabachnick and Fidell, 2007; Cohen, 1988).

3.3.3 Statistical modelling

Modelling procedures needed to take into account potential interdependence because degree programme groupings included in this investigation could not be considered random. This meant they could cause clustering of individuals within groups (Goldstein, 2003). The aggregation of scores across students within a degree programme was inappropriate as this would have:

- masked the effect for each student and therefore could not be applied to individuals, only to degree programmes;
- led to potential errors by ignoring the spread of student data within the groups – group means do not reveal patterns in the way that examining individuals nested into groups does. This was particularly pertinent to the Exercise and Health Science programme as the relatively small number of students exhibited the largest spread of marks;
- given rise to findings that may not have related to individuals. Relationship between groups at the degree programme level does not necessarily point to relationships at the individual student level.

(Snijders and Bosker, 1999)

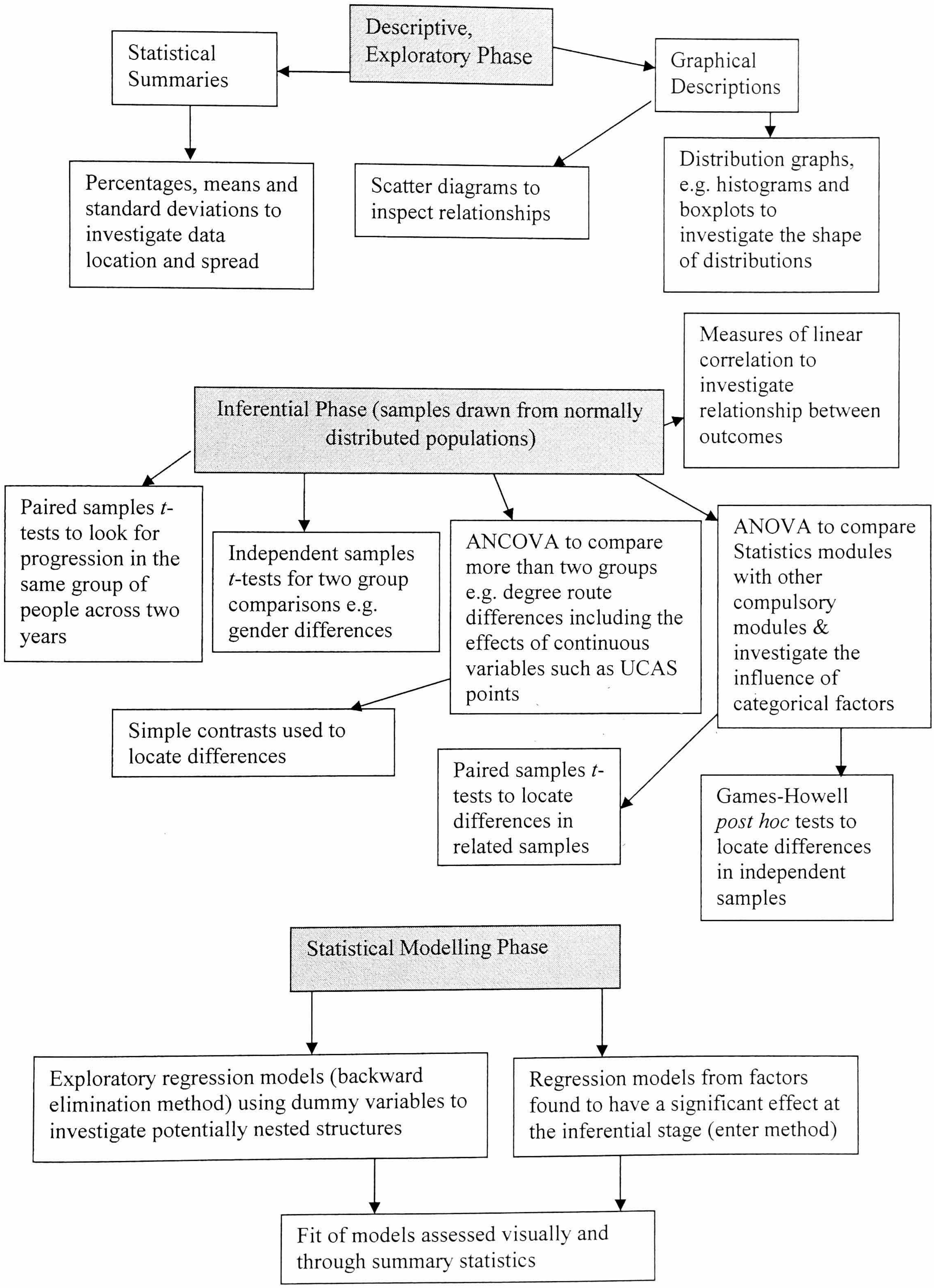
Aggregation of scores has the added disadvantage of decreasing the reliability of the resulting data (Simonite, 2000; Kreft and de Leeuw, 1998).

Data were unsuitable for multilevel modelling because there were only four degree programmes. Maas and Hox (2004) conducted a series of simulations to investigate robustness in multilevel models which led them to recommend more than fifty macro-level groups (in this project macro-levels would be degree programmes). Rasbash *et al.* (2004) advocated that in situations where the macro-level variable (degree programme) has less than five groups fitting a single, micro-level, model (each individual student's results in the context of this project) is more efficient at finding variation at the macro-level. In such situations, dummy variables need to be included to indicate group effect. Following the advice of Rasbash *et al.* (2004), single level, ordinary least squares (OLS) regressions were used to model Statistics marks at levels four and five and Dissertation marks at level six. Dummy variables were included in the models to account for degree programme, gender, and Mathematics qualification differences (Agresti and Finlay, 1997).

Backward elimination was the preferred regression method for these exploratory models because it is less susceptible to the effects of suppressor variables (Field 2009a). Dummy variables and all possible interactions resulted in the inclusion of forty-four separate variables. Analysis of this number of variables requires a large sample size. For such an analysis, statistical texts advise sample sizes of between 148 and 1760 depending on the formula used to determine the values (Stevens, 2009; Tabachnick and Fidell, 2007; Pallant, 2005). Some models included in Chapter Five were developed from samples which fell just below the lower limit of these estimates and therefore needed cautious interpretation.

Disadvantages of the backward elimination procedures include the potential to retain inappropriate interactions of variables when main effects have been excluded from the model (Agresti and Finlay, 1997). The exploratory models produced by procedures such as backward elimination or other automated stepwise methods are often accepted as the 'best' models for prediction. It is important to be aware that the models that are statistically the 'best' do not imply causality. Such methods should be used for exploratory work, but not if there are good theoretical justifications for inclusion of specific variables in a model (Tabachnick and Fidell, 2007; Agresti and Finlay, 1997). Backward elimination was an appropriate method to produce the first models of potential predictors of Statistics and Dissertation marks because this research project was exploratory. Second models were produced which included only the variables that ANOVA or ANCOVA identified to have an effect. The resultant models were compared. This approach followed the advice of Stevens (2009) and Field (2009a).

Figure 3.2 The stages of quantitative data analysis



The fit of the regression models was visually assessed through a comparison of observed and predicted values on a scatter diagram. Further evaluation of the fit of the model considered the amount of data variation explained by the regression. The effect of influential cases on the outcome of regression was assessed through Cook's distances (Stevens, 2009; Field, 2009a; Tabachnick and Fidell, 2007). A summary of the stages of quantitative analysis of entry profile and assessment outcome data is provided in figure 3.2. The descriptive phase documented in Chapter Four guided decisions about the inferential testing and regression modelling that is presented in Chapter Five.

3.4 The exploration of students' experiences of learning Statistics

Previous research in Sports Science settings had not investigated students' experiences of learning Statistics. Murtonen (2005a) collected qualitative and quantitative data about statistical literacy in different dominant subject domains as part of her doctoral thesis, but employed quantitative methods to analyse categorisations arising from qualitative data. These studies could not examine the complex interactions within the experiences they quantified. A critical dimension to this research project was the qualitative analysis of interviews that enabled students to provide opinions and feelings using their own words. The insight that resulted enabled an evaluation of students' statistical literacy and whether there was development towards statistical thinking or reasoning.

3.4.1 Participant selection

All students in the 2005 cohort, registered on the Statistics Two module in 2006, were contacted via e-mail. Participation details were attached to the e-mail and students were invited to volunteer to be interviewed. The e-mail contact was followed-up by a personal request (by a colleague of the researcher), at the beginning of Statistics classes in the second week of the module. Twelve volunteers formed a self-selected sample of participants. Each interviewee was provided with a printed copy of the information sheet (appendix *iv*) and signed to indicate informed consent prior to the first interview (appendix *v*).

3.4.2 Interview methods

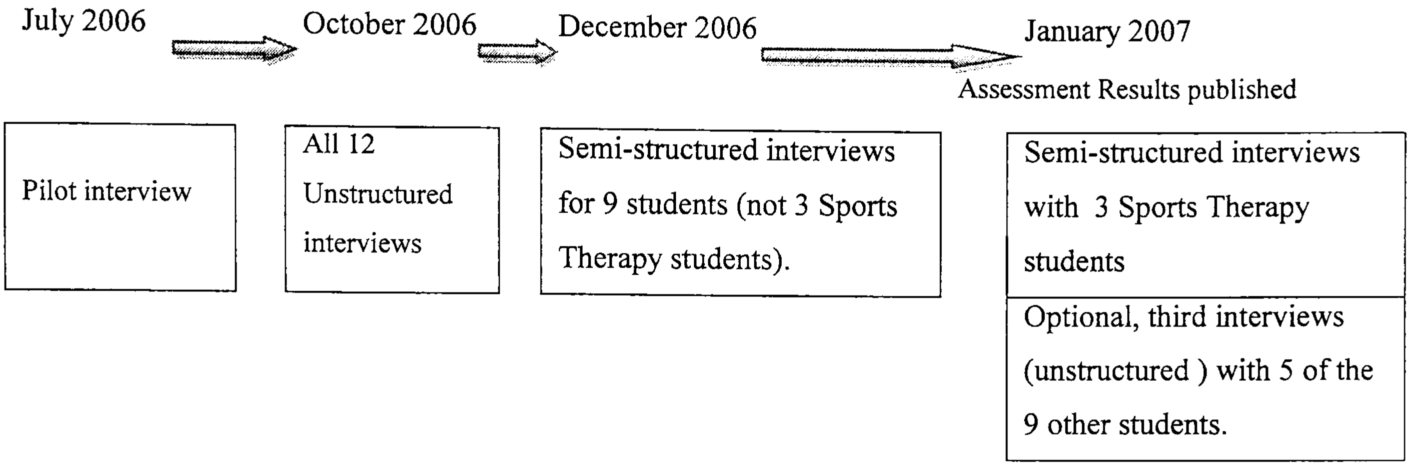
Each participant had two (n=7) or three (n=5) interviews. The first interviews occurred close to the beginning of the Statistics Two module. A reflexive, unstructured interview method enabled students to describe personal events which they thought impinged on their experiences of learning numeric subjects. Interviews had a narrative quality, because most participants provided events from their life histories through short vignettes (Hopf, 2000). Elliott (2005) defined narratives as chronological, representing sequential occurrences, meaningful and 'social' such that they relate to a specific audience, while Polkinghorne (1988) asserted that "*narrative* is the primary way through which humans organize experiences into temporally meaningful episodes" (p.200). These characteristics were evident in the interview responses. Participants' described their experiences and feelings about learning Mathematics and Statistics. They were advised to begin wherever they felt was appropriate; for some this was as they began school, while others explained their experiences of a GCSE course. The interview progressed to explore feelings about the Statistics One module that had been completed by all except one interviewee.

An unstructured approach enabled individuals to select their own memories with minimal influence from the researcher, who was the interviewer. The interviewer used prompts and encouragement rather than remaining silent during students' descriptive accounts so that silence could not be construed as a negative form of power (Wengraf, 2001). These prompts were not a structuring device as the fluid, conversational nature of the interview was central to the retrieval of students' opinions in their own words. There was no attempt to check the 'truth' of data provided, and no constraining questions. The data gathered were important to augment the published questionnaire-based research in a way that facilitated a deeper exploration of *why* certain situations arose. It was recognised that the researcher was sufficiently embedded in the situation under investigation to be able to influence interviews in a way that enabled preconceptions to be confirmed (Eisner, 1992). To minimise this possibility, interjections by the researcher endeavoured to provide encouragement without agreement or rebuttal (Drever, 2003). Arksey and Knight (1999) cautioned that unstructured interviews provide a wealth of rich data that can be difficult to analyse as it is easy to lose relevant focus. A pilot interview was undertaken with a male student who had already completed level five, to ascertain whether the researcher could conduct an unstructured interview adequately, and facilitate a focussed response from a participant.

Preparation for the pilot interview consisted of a series of phrases that encapsulated areas the researcher wished to explore, for example, experiences of Mathematics and feelings about studying Statistics at level four. The same planning preceded each subsequent unstructured interview. In each case these prompts were abandoned if the participant steered the interview in a different, but valid and relevant direction. The pilot interview indicated that this unstructured approach to interviewing minimised the influence of the researcher because the participant was free to select memories that he felt most important. In retrospect, it was unfortunate that the student who participated in the pilot interview needed little encouragement in his narrative account. The experience did not provide the researcher with adequate preparation for making spontaneous, value-free, encouraging interjections where respondents were more reluctant to talk.

Experiences of studying the Statistics Two module were elicited from second, semi-structured interviews (schedule is available in appendix *vi*). A semi-structured approach was employed in order to guide students to consider the same aspects of Statistics Two. These were issues that had been identified as problematic either through previous students' module evaluations, or from concerns of tutors teaching the module. This second interview was delayed from December 2006 to January 2007 for Sports Therapy students (n=3) because of a heavy practical assessment schedule at the end of the year (figure 3.3). Although most students related experiences prior to assessment, the Sports Therapy participants provided retrospective accounts in full knowledge of their examination results. This difference affected the data gathered, because work of this nature elicits specific information from a unique group at a particular time (Crang and Cook, 2007). In order to partially address the effect of time the nine students who had already undertaken their second interview were invited to participate in a third, unstructured, interview after results were published. Five students felt they had a further contribution to make at that stage.

Figure 3.3 Timings for interviews



One-to-one interviews were conducted in the majority of cases. However, a group of four students volunteered in person rather than via e-mail and asked if they could be interviewed in pairs. This enabled data collection from a group of Coaching Science students who found Statistics more difficult than most other interviewees, so two sets of paired interviews were conducted. One student from each pair subsequently failed the Statistics Two examination. The joint interviews required less researcher input as the students discussed experiences between themselves and filled each other's silences. Arksey and Knight (1999) indicated this as a method of gaining reliable data. In each case there was a more dominant partner, but the effect of this reduced as the interviews progressed and a sustained lack of concentration by one participant was not evident (Arksey and Knight, 1999).

3.4.3 Analysis of interview data

Interviews were transcribed verbatim and pauses were coded, because they were deemed an important component for interpretation. Participants' construction of their responses was more important than the structure provided by the questions (Legard, Keegan and Ward, 2003; Drever, 2003). Transcription was undertaken by the researcher. One interview containing sensitive material was partially transcribed omitting sections of responses that were not deemed directly relevant to the research project.

Brief field notes were taken during the interview process and augmented immediately afterwards. These notes assisted interpretation as they acted as an *aide* *memoire* for analysis of the emotions, body-language and behaviour of the participant and thus rendered more valid the attribution of meaning during analysis. Although the researcher minimised the potential for her to affect the content of participants' responses, interview data were influenced by the participants' knowledge of the researcher's professional role. The interviewees alluded to particular situations, events or location that they knew were within the researcher's experiences. It was therefore important that the interpretation undertaken was that of the researcher. A further exploration of insider research is included in section 3.5.1.

Twelve students were interviewed, so data needed to be presented in a form which would provide an overview of the information gathered, but fragmentation of interviews that results from the separation of data into themes can obscure individual experiences. Riessman (2008) contended that interpretation is linked to organisation, and other features recorded in the text, that are lost when fragmentation occurs. She claimed that a thematic analysis could aid interpretation if "combined with close analysis of individual cases" (p12), as each perspective provides a different and unique insight. Qualitative research is recognised as having 'fuzzy' boundaries, and this renders a bricolage approach to analysis acceptable, provided the methods employed are clearly documented and plausible within the research context (Riessman, 2008; Spencer, Ritchie and O'Connor, 2003).

Interviews from three participants, one female and two male, were selected for preliminary analysis. The interviews were read and reread to identify themed categories that resulted from questions in the semi-structured interviews. Themes that recurred in the students' unstructured accounts of their past experiences were added to those generated by the semi-structured interviews and used to produce a matrix-style 'framework' (Ritchie, Spencer and O'Connor, 2003). The process was both deductive and inductive (Wengraf, 2001; Schmidt, 2000).

Phrases from each response were placed into raw data columns, grouped for commonality of content or idea. The students' original words were preserved (Drever 2003). This process was conducted over each of the interviews from the three participants. Each interviewee's data were analysed on separate occasions so that the interpretation of one participant's data was unlikely to impinge on the next one. The resulting framework was then used to index all twelve participants' interviews so that data could be compared and contrasted, while still enabling interviewees' experiences to be explored individually. The individual student's perspective was preserved by the rows of the framework. Commonality and differences in opinions could be examined, through each theme-based column. The individual perspective was enhanced by the use of a different colour of paper for each person that could be followed over each theme-based column. During analysis it was found that some categories had considerable overlap. The separate categories were retained within the framework and, if necessary, one piece of data was placed in two categories. Analysis of the interview data continued until no new understanding emerged through the consideration of different perspectives. The themes were thus 'saturated' (Crang and Cook, 2007). The themes were arranged to present arguments, both individually and thematically, that could be used to challenge theoretical and experiential perspectives in the research. Classification of participants' responses was validated through discussion with a critical friend, who was not part of the Statistics teaching team.

Once completed the framework could be inspected both horizontally and vertically as a colour-coded matrix so that overlapping categories were traceable. Blank sections emphasised where some participants did not address any issues or elements. Dominant concerns were evident in dense sections of framework. These patterns enabled quotations to be clustered into common threads between different students' interviews which generated overarching themes in the manner described by Hanton and Jones (1999). This final stage is illustrated by the diagrams in Chapter Six (figures 6.2-6.4) which summarise the student pen-profiles and thematic discussion. A case-centred commitment, missing from grounded theory approaches, was maintained through the pen-portrait and thematic analysis included in Chapter Six (Riessman 2008).

3.4.4 Reliability, validity and trustworthiness

Reliability of the data obtained could not be claimed because each individual had a unique perspective. Additionally, student participants were volunteers and therefore not a representative reflection of the opinion of the cohort. However, similarities existed between participants, and from this correspondence, trustworthy conclusions could be drawn following Richardson and St Pierre's (2005) image of 'crystallization'. Data from individual students were interpreted by the researcher to identify similar issues, in the way that "crystals are prisms that reflect externalities and refract within themselves, creating different colours, patterns, and arrays casting off in different directions. What we see depends on our angle of repose – not triangulation but rather crystallization" (Richardson and St Pierre, 2005, p.963).

Interpretation can be considered valid if the methods employed are clearly appropriate for the research questions. It is therefore necessary to demonstrate how methods are applicable to research questions and to document sources (Riessman, 2008; Matt, 2000). Transparency about data collection and analysis increases the sense of validity and can be strengthened if findings from different sources of evidence support each other (Riessman 2008). This could be between interviews although in the context of this research that is questionable because the same researcher elicited data in all interviews. This project drew on Riessman's (2008) claim that a link between what students said and quantitative findings increased validity. However, validity in a qualitative context should not be confused with the same term used in quantitative settings. Trustworthiness is a more apposite term as it does not suggest that each interviewee explains the *same* feeling or experience when using similar wording. Rather, it allows for each individual to provide a meaningful insight that can be accepted as a personal reality. Riessman (2008) advocated participant verification of transcription and interpretation to increase the trustworthiness of the conclusions drawn. Interview participants in this research project were given the opportunity to review and amend transcripts although nobody accepted it. This lack of confirmation by the interviewees increased the potential for researcher bias as her interpretive perspectives remained unchallenged.

3.4.5 Summary of qualitative methods

Qualitative data were obtained through unstructured and semi-structured interviews most of which were conducted between September and December 2006. Sports Therapy participants undertook second interviews in January 2007. This was the semester following the collation of quantitative data. Analysis of interview data was through the development of a framework which preserved individual identity while allowing the identification of recurring and contrasting themes in the data. Students' original phrases were preserved within the framework and are included in Chapter Six. This approach made the analysis and interpretation process more transparent as the diagrams demonstrated how the researcher collected phrases into particular themes. Additionally, pen-portraits of individual students, using original quotations, provided further support for the researcher's interpretations.

3.5 Ethical problems raised by the research

3.5.1 The problem of self as researcher

The evaluation of one's professional practice is a key component of a professional doctorate which positions the individual within the research context because knowledge of previous events is shared by all parties. The research is with the participants rather than on them (Lyons, 1992). The researcher is part of the instrumentation and is acknowledged to have an effect on it (Legard, Keegan and Ward, 2003). The research for this project was "constructed out of an intersubjective research process always saturated with relations of power/knowledge" (Crang and Cook, 2007, p.8) and so had a political perspective. The researcher was following at least two personal agenda – a need to provide a more informed response to the university's internal quality standards monitoring panels, and to external examiners, who sought an explanation for low marks in Statistics assessments, and a professional aim to improve those marks through more effective learning and teaching opportunities that extend beyond statistical literacy to encourage the evaluative criticality required for statistical thinking and reasoning. These intentions shaped the researcher's interactions with the participants. Interviews engaged the participants and the researcher in the construction of Mode 2 knowledge about statistical education within Sports Science, a transdisciplinary process of developing professional knowledge (Nowotny, Scott and Gibbons, 2003; Gibbons *et al.*, 1994).

Arksey and Knight (1999) postulated that interviewer knowledge of participant identity may cause respondents to be more cautious about their answers, although having an established persona can enable participants to identify with the researcher in the area of interest and possibly to speak more freely. In the context of this project the common ground was thought to be advantageous, which made the researcher a more appropriate interviewer than someone further removed from Statistics teaching (Crang and Cook, 2007).

Interviews were unstructured or semi-structured to minimise researcher effects. Critically the volunteer participants had prior knowledge of the research aims and had volunteered because they were interested, or had opinions to air. This procedure rendered the interview data particularly subjective. The researcher's prior knowledge of the participants enabled her to challenge individual students to consider information gleaned from earlier interviews. The ability to verify the gathered material in this way not only increased the subjectivity, but enhanced the trustworthiness of the data, because interviewees were prompted to respond to the researcher's reflections on interpretations from earlier interviews.

Students and interviewer had clearly defined roles that impinged on the interactions through which interview data were elicited. This interaction would not have been free from the "system of power which blocks, prohibits, and invalidates [this] discourse... the idea of their [the academic tutors'] responsibility for 'consciousness' and discourse forms part of the system" (Foucault, 1977, p.207). As such the research cannot be free of bias nor would this be desirable within the specific context of this project. However, individuals in particular circumstances can often illuminate more general phenomena. The subjective interaction that constructed the findings from the interviews is acknowledged, but exploration of why specific Sports Science students have difficulty with Statistics provided insight into factors which may relate to other students in similar circumstances in this, or other universities; a generalisation from elements of the particular (Pring, 2000; Lave and Wenger, 1991). Crang and Cook (2007) asserted that the "task for *all* researchers is to recognise and come to terms with their/our partial and situated 'subjectivity' rather than to aspire to impossibly distanced 'objectivity'. Once this is done 'subjectivity' is much less a problem and much more a resource for deeper understanding" (p13). The investigation of professional practice is steeped in subjectivity that demands reflexive evaluation and adjustment to prevent superficial, mechanistic teaching (Clarke and Erickson, 2003).

3.5.2 Risk of compromising professional boundaries with student participants

The professional role of the researcher included management of the field of study in which this project was positioned. Consequently, careful consideration of ethical issues surrounding the student/tutor relationship influenced the design of the research. In order to minimise the potential for compromised professional boundaries the request for volunteers was made through a third party and interviews were conducted on neutral, semi-public territory (a university coffee bar). The setting established an environment which discouraged confession or complaint and the interviewer could guide students away from such disclosures. Interview arrangements were monitored to avoid academically demanding times of the year. Additionally, the researcher did not mark the assessments of any student participant in order to remove the possibility of biased marking. Students had right of access to their own data, and retained the power of veto to minimise misrepresentation.

3.5.3 Anonymity and confidentiality

Anonymity and confidentiality of quantitative data were guaranteed through data collection methods. The university from which data were collected was not identified by name. Complete cohorts of data, from 2003-2006 were collated from the university's central database. At initial registration each student had given written consent for data to be used for statistical analysis by the institution. The proposed quantitative data analysis fitted within the rubric of that permission. Students were assigned numeric identifiers that differed from their university 'student number'. This identification code was kept in hard copy in a locked drawer, and in electronic format on the researcher's private computer. The data and identifiers were not stored in the same location.

Anonymity and confidentiality were harder to guarantee in the interview situation as the students interviewed were sufficiently diverse for identification to be possible unless careful consideration was given to how certain issues would be discussed. To consider stories and opinions without considering participants' backgrounds was problematic as part of the focus of the study was on biographical detail prior to university registration. For example, one student gave an insightful account of his upbringing overseas and how that had impacted on his study of Mathematics and Statistics. This was of obvious interest as governmental policies in 2006 encouraged widening participation and ethnic diversity in higher education (Great Britain. Department for Education and Skills 2003 and 2006; Great Britain. Higher Education Act, 2004). The university had few students from ethnic minorities; therefore exploration of the particular experiences of this student was valuable. However, considerable care was needed to explore and interpret interview data while maintaining anonymity. As a result the decision was made to exclude from this project any explicit analysis of specific ethnic issues raised, although these were used to inform the wider debate on diversity and inclusivity that was on-going in the university. The student indicated satisfaction with the procedures. Interview data, tapes, transcripts and analyses for all participants were locked in a drawer on the university premises and were identified by code numbers and pseudonyms only.

3.6 Conclusion

This research project, completed in partial fulfilment of a professional doctorate, focussed on the particular, contextualised practices of the researcher. The methods and decisions documented in this chapter generated data that enabled the researcher to evaluate critically personal and theoretical perspectives and formulate recommendations to improve the learning experiences of Sports Science students (Waghid, 2002). The choice of methods was influenced by a need to understand *why* assessment marks for Statistics were low and *how* students experienced statistical learning. A mixed methodology was adopted that enabled an objective assessment of the position of Statistics in the diet of compulsory modules and whether marks were affected by factors beyond the influence of Statistics lecturers. A subjective interpretation of students' situated learning experiences added a crucial dimension to the evaluation of the pedagogic strategies at the university.

Quantitative data analysis was designed to provide information about students' achievement in Statistics, compared to Biomechanics and Physiology which were core disciplines at the forefront of Sports Science. In addition, the potential effects of gender, degree programme, highest Mathematics qualification and UCAS points enabled the researcher to gauge whether situations beyond the influence of pedagogy mediated against high levels of achievement in Statistics examinations. The results from quantitative analysis informed the direction of the subsequent interviews. As participants raised issues related to degree programmes or Mathematics, the researcher could seek insight to explain quantitative findings. During interviews it emerged that students perceived Statistics modules to be particularly relevant to the Dissertation module. This echoed the findings of Lane, Devonport and Horrell, (2004). Further quantitative analysis, including regression models, was conducted to evaluate the strength of this perceived link. The exploratory models are interpreted in Chapter Five.

Student interviewees were provided space to voice their opinions and experiences in their own words through unstructured interviews. Subsequent, semi-structured interviews explored the Statistics Two module and imposed parameters on the responses that focussed on specific research questions. These boundaries were achieved through reflexive interjections by the researcher, who was aware that her professional role within the university impinged on every stage of data collection and interpretation. Researcher interaction with the data was carefully structured and bounded by the research questions to enable quantitative and qualitative findings to inform one another and provide verification for the subjectivity inherent in the project.

The methods adopted to gather and analyse data for this research project were undertaken to secure improvements to pedagogic practices in Statistics at the university. The researcher was aware that quantitative results and qualitative interpretations could facilitate recommendations for evidence-based practice and further research but would not produce definitive conclusions or solutions. The recommendations that emerged from the analyses documented and interpreted in Chapters Four, Five and Six, are an important component of Chapter Seven.

Chapter Four

Investigation of Students' Assessment Outcomes in Statistics

Part 1: Exploratory Data Analysis

4.1 Introduction

The quantitative part of this research project focussed on the objective measurement of statistical literacy through marks gained in Statistics examinations. This chapter explores the data gathered from the 336 students reading for Sports Science related degrees at a particular university in June 2006. Gender, UCAS tariff points, highest level of Mathematics qualification and students' chosen degree programme were collated from existing university records and matched to assessment marks in Statistics and Dissertation modules. These variables provided quantitative measures of factors thought to affect students' ability with Statistics (Murtonen 2005a; Orton, 2004; Onwuegbuzie and Wilson, 2003; Schram, 1996). In addition, marks from compulsory Physiology and Biomechanics modules were included to determine the level of achievement in Statistics modules compared to that in modules from the dominant Sports Science disciplines.

The chapter begins with a description of the student sample. It documents the exploratory analysis conducted to investigate the core research questions presented in section 1.2. Statistical summaries and data tables are included to represent the findings. All descriptive statistics are split by gender. Prior to a detailed analysis of marks for Statistics One and Statistics Two these part-modules are compared to other compulsory elements of the Sports Science programmes. Exploration of the influence of the key factors identified in this project (gender, degree programme, Mathematics qualification and UCAS points) follows the positioning of Statistics among the diet of compulsory modules. Conclusions from this chapter informed further statistical analysis, documented in Chapter Five, and identified the Statistics Two module as a suitable focus for the qualitative investigation interpreted in Chapter Six.

4.2 The student sample

Data for analysis consisted of three cohorts of students, the 2003, 2004 and 2005 entry groups. Level four had been completed by all students, two cohorts (2003 and 2004) had marks for level five modules, and only those students who entered the university in 2003 had progressed to the Dissertation at level six.

Table 4.1 illustrates how the proportions of male and female students differed between degree programmes. Sports Therapy attracted a higher proportion of female students while Coaching Science and Sport and Exercise Science programmes recruited more males. The small Exercise and Health Science degree route recruited fairly equally from both sexes. There was a larger than usual number of Sports Therapy students in the 2003 cohort because of a shortfall in student numbers elsewhere in the university. This impacted on the investigation as the sample contained more female students than would previously have been expected. Data from all students were retained for analysis because Sports Therapy consistently generated a high number of applicants. Overall, the sample was thought to be reflective of what might occur in future years.

Table 4.1 Numbers of students by gender and degree programme for three years' entry (*percentage of total)*

		Degree Programme				
Cohort	Gender	Sport and Exercise Science	Coaching Science	Exercise and Health Science	Sports Therapy	**Total**
2005	Male	29 *8.6%*	20 *5.9%*	8 *2.4%*	10 *3.0%*	**67** ***19.9%***
	Female	12 *3.6%*	4 *1.2%*	4 *1.2%*	18 *5.4%*	**38** ***11.3%***
	Total	**41** ***12.2%***	**24** ***7.1%***	**12** ***3.6%***	**28** ***8.4%***	**105** ***31.3%***
2004	Male	41 *12.2%*	19 *5.7%*	1 *0.3%*	8 *2.4%*	**69** ***20.5%***
	Female	13 *3.9%*	4 *1.2%*	5 *1.5%*	23 *6.9%*	**45** ***13.4%***
	Total	**54** ***16.1%***	**23** ***6.9%***	**6** ***1.8%***	**31** ***9.3%***	**114** ***33.9%***
2003	Male	26 *7.7%*	14 *4.2%*	5 *1.5%*	12 *3.6%*	**57** ***16.9%***
	Female	16 *4.8%*	1 *0.3%*	8 *2.4%*	35 *10.4%*	**60** ***17.9%***
	Total	**42** ***12.5%***	**15** ***4.5%***	**13** ***3.9%***	**47** ***14.0%***	**117** ***34.8%***
Totals	**Male**	**96** ***28.2%***	**53** ***15.8%***	**14** ***4.1%***	**30** ***8.9%***	**193** ***57.4%***
	Female	**41** ***12.2%***	**9** ***2.7%***	**17** ***5.1%***	**76** ***22.6%***	**143** ***42.6%***
	Overall	**137** ***40.8%***	**62** ***18.5%***	**31** ***9.2%***	**106** ***31.5%***	**336** ***100%***

Small discrepancies in percentage totals are due to rounding to one decimal place.

The clear differences between the degree programmes in terms of the number of males and females recruited suggested potential gender differences in entry profile data that justified the inclusion of a comparison between the sexes.

Of twenty-seven (8%) mature-entry students, four were twenty-two years old, little older than those classed as 'standard' students. The remaining seventeen males and six females were over twenty-two. This proportion of mature students was representative of that expected across three cohorts of Sports Science students in the university, and reflected the pattern of mature entry to similar undergraduate programmes in UK HEIs (HESA, 2008). The views and experiences of mature students were explored through interviews (Chapter Six) but participant numbers were insufficient for quantitative investigation.

Eighty percent of Sports Science students at the university had a maximum Mathematics qualification of grade B or grade C at GCSE. This situation could affect achievement in Statistics as the confidence with which students transfer mathematical knowledge to a different context may be affected by limited experience with that subject (Orton, 2004; Onwuegbuzie and Wilson 2003). Entry qualifications in Mathematics were unavailable for just over 7% of the total sample. Table 4.2 indicates the proportion of male and female students with each level of Mathematics qualification on each of the four degree programmes.

A close inspection of Table 4.2 revealed that females were better qualified mathematically than males. Most female students achieved GCSE grade B or higher (46.9% + 12.6% = 59.5%) while the majority of male students had grades B or C (37.3% + 42.0% = 79.3%). Seventy of the 106 (66%) Sports Therapy students gained a grade B or higher, a proportion which was representative of both sexes (males 63% and females 67%). This was a considerably higher ratio than in any other degree programme (Coaching Science, 39%; Sport and Exercise Science, 49%; Exercise and Health Science, 55%). Few Coaching Science students achieved a GCSE grade A or higher (5/62) and most of them (27/62) had a grade C. The proportion of male and female students achieving each grade differed between the degree programmes. This situation made it impossible to separate a degree programme effect from Mathematics background or gender. The factors selected for analysis in this project were therefore perceived as interrelated.

Table 4.2 Maximum Mathematics qualification on entry to the university (*percentages of males/females/all students*)

Maximum Mathematics Qualification	**Sex**	**Sport and Exercise Science**	**Sports Coaching Science**	**Exercise and Health Science**	**Sports Therapy**	**Total**
GCSE A or higher	M	13 *6.7%*	5 *2.6%*	1 *0.5%*	4 *2.1%*	23 *11.9%*
	F	2 *1.4%*	0	0	16 *11.2%*	18 *12.6%*
	Tot	15 *4.5%*	5 *1.5%*	1 *0.3%*	20 *6.0%*	41 *12.2%*
GCSE B	M	33 *17.1%*	18 *9.3%*	6 *3.1%*	15 *7.8%*	72 *37.3%*
	F	19 *13.3%*	3 *2.1%*	10 *7.0%*	35 *24.5%*	67 *46.9%*
	Tot	52 *15.5%*	21 *6.3%*	16 *4.8%*	50 *14.9%*	139 *41.4%*
GCSE C	M	44 *22.8%*	23 *11.9%*	7 *3.6%*	7 *3.6%*	81 *42.0%*
	F	17 *11.9%*	4 *2.8%*	7 *4.9%*	22 *15.4%*	50 *35.0%*
	Tot	61 *18.2%*	27 *8.0%*	14 *4.2%*	29 *8.6%*	131 *39.0%*
Not Known	M	6 *3.1%*	7 *3.6%*	0	4 *2.1%*	17 *8.8%*
	F	3 *2.1%*	2 *1.4%*	0	3 *2.1%*	8 *5.6%*
	Tot	9 *2.7%*	9 *2.7%*	0	7 *2.1%*	25 *7.4%*
Total	M	96 *49.7%*	53 *27.5%*	14 *7.3%*	30 *15.5%*	193 *100%*
	F	41 *20.7%*	9 *6.3%*	17 *11.9%*	76 *53.1%*	143 *100%*
	Tot	137 *40.8%*	62 *18.5%*	31 *9.3%*	106 *31.5%*	336 *100%*

Small discrepancies in percentage totals are due to rounding to one decimal place.

A measure of students' overall academic ability, arguably could be indicated by UCAS tariff points, see section 3.3.1. These scores were generated from two different forms of qualification. Most students (79%) entered the university after AS- and A-level studies; a further 20% had BTec diplomas in Sports Science or Sports Studies. The remaining 1% were overseas or mature students who were individually assessed for suitability to the course of their choice. AS-level, A-level and BTec grades were converted to UCAS tariff points using the conversions outlined in appendix *vii*.

Boxplots were produced to examine the range of UCAS points (minimum to maximum) for males and females on each degree programme. The boxplot partitions the data into quarters. The median is contained in a box that represents the spread of the middle 50% of the data around the median. This is known as *the interquartile range* (IQR). A whisker extends out of the top and bottom of the box to represent the top 25% and the bottom 25% of the data. If there are outliers in the data these are represented by points plotted beyond the end of the whiskers. Data values that are between 1.5 and 3 IQRs away from the top or bottom of the box are deemed outliers, and are identified with 'O', and those more than 3 IQRs from the end of the box are extreme outliers, represented by '*'. The boxplots, and other graphs in this project are scaled to begin from values just below the minimum data value. This scaling meant that the similarities and differences in the data were as visible as possible. Three students were indicated as outliers (figure 4.1). These students had considerably higher or lower UCAS tariff points than the rest of the students on their respective programmes.

Figure 4.1 UCAS tariff points on entry to the university for Sports Science degree programmes

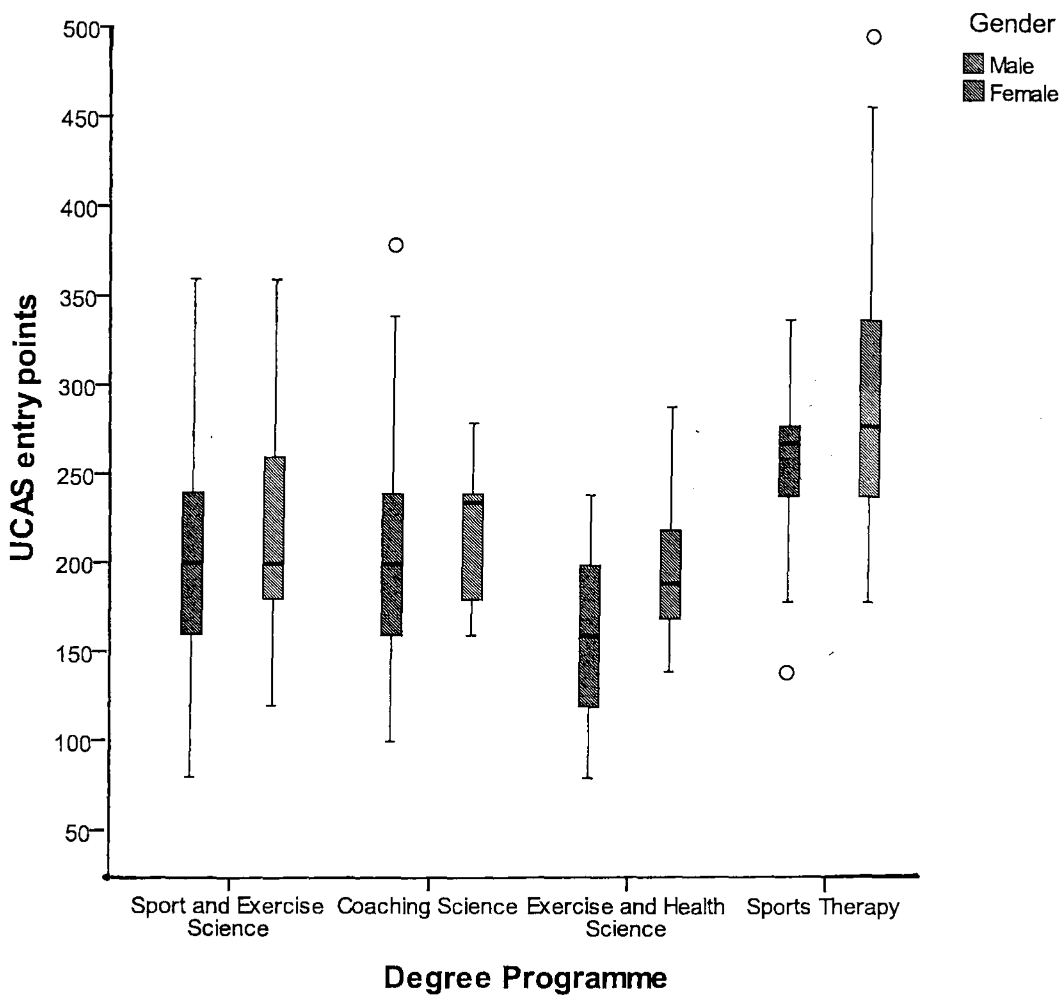


Figure 4.1 shows that both Coaching Science and Sport and Exercise Science students had similar UCAS tariff points when they entered the university. The median of both male and female boxplots for Sports Therapy students' UCAS points are higher than the upper quartile (3/4 through an ordered list of data) for most of the other plots which indicates that these students had substantially higher entry profiles.

During the period of data collection Sports Therapy was an emergent discipline, offered at few universities; therefore admission requirements were higher than for the other Sports Science degree programmes. The Exercise and Health Science programme was entered into the national 'clearing' process after A-level results were published, which may explain the lower entry profiles, but this could not be verified from data records.

Female students tended to have slightly higher UCAS points across all degree programmes, except Coaching Science. The small number of female Coaching Science students compared to males (9/62) made it impossible for a reliable pattern to be ascertained. Findings from the students' profile data led to the conclusion that to treat each factor in isolation would oversimplify the complex interactions between gender, degree programme, Mathematics qualifications and UCAS points. The combined effect of how these factors influence assessment marks emerges over sections 4.3-4.8.

4.3 A comparison of Statistics marks with those of other compulsory modules

To qualify for a B.Sc.(Hons.) degree from the university, students undertook eight modules per year. Each module contributed fifteen 'credits' to the 120 credits required at each level (four, five and six). At level six all students completed a thirty credit Dissertation module, equivalent to two taught modules. When the data were collated, 336 students had completed level four modules, 231 had passed level five and 117 students had just finished level six.

Students' marks for Statistics were compared to marks in other compulsory modules for all four degree programmes, or for the three largest ones - Sport and Exercise Science, Coaching Science and Sports Therapy. Without the exclusion of Exercise and Health Science students (n=31) the comparison would have been limited to Statistics and Physiology. As Sports Science students typically experience three dominant subject disciplines, Physiology, Psychology and Biomechanics, a Biomechanics module, compulsory for three programmes, was included at both level four and level five. Psychology was excluded from the comparison because no modules were compulsory across three or more degree programmes. Comparison of compulsory modules ensured that the same students would be in each group. Without this control, differences in module marks could be affected by many factors. For example, class size, ability level, or the greater motivation that students feel, for self-selected modules over compulsory ones.

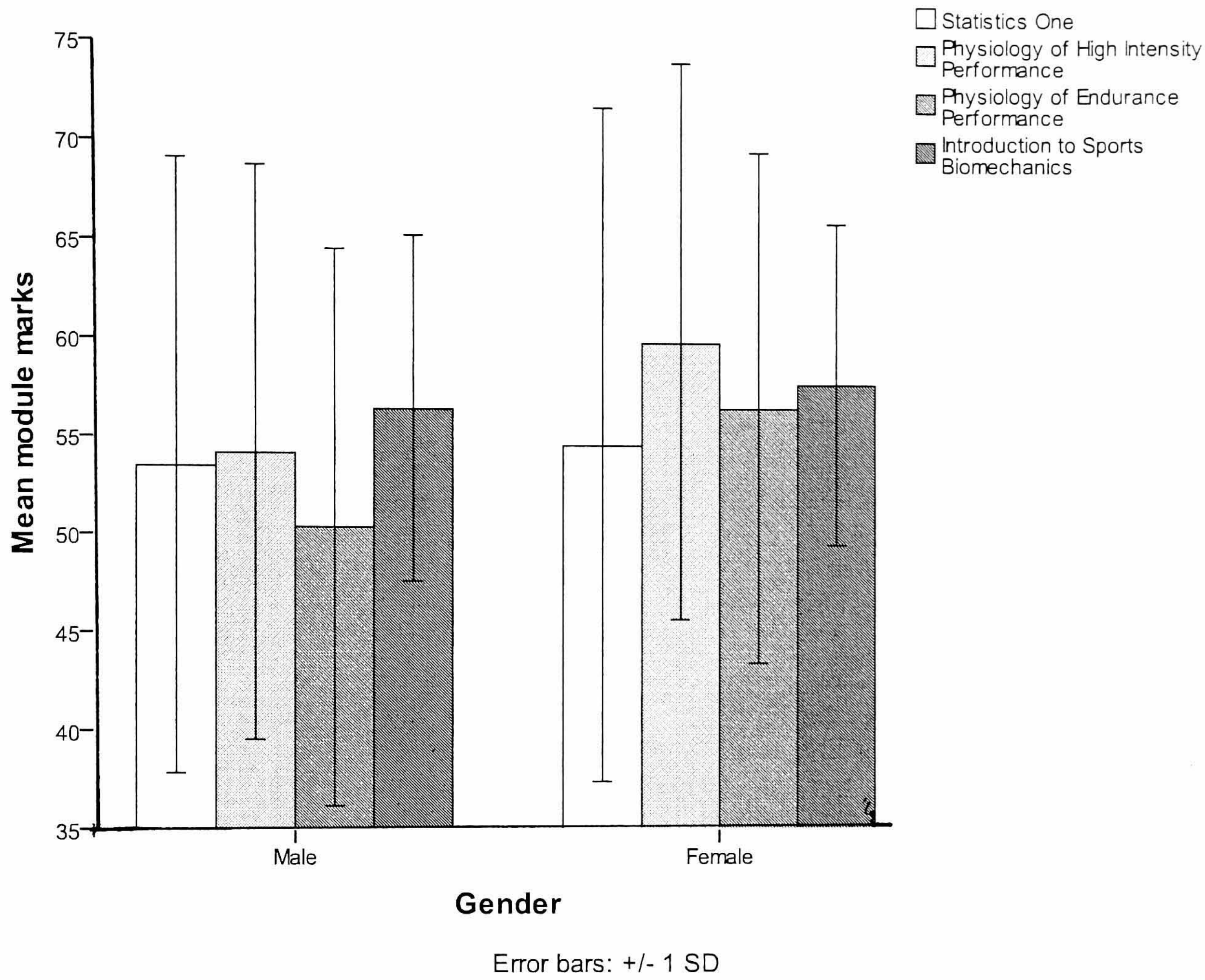
Students were offered one reassessment opportunity in any failed module (a 'fail' resulted from a mark of less than 40% in their first assessment attempt). At the reassessment stage students could attain a maximum mark of 40% if their work reached or exceeded that 'pass' boundary. In order to improve validity, module marks gained in first assessments were analysed. Thus achievement was measured at the same time point in the module for all students, and the full range of marks was available. The university had a system of second marking and moderating to check marking consistency between tutors, and followed rigorous external examining procedures; therefore, assessment marks were accepted as valid indicators of achievement.

4.3.1 A comparison of Statistics One marks with those of compulsory modules at level four

Two Physiology modules (Physiology of High Intensity Performance and Physiology of Endurance Performance) were compulsory at level four. Introduction to Sports Biomechanics was a requirement for the three larger programmes. All the module assessments included an unseen examination, although 25% of marks in both Physiology modules, and 60% in Introduction to Sports Biomechanics, were allocated to laboratory reports.

Figure 4.2 shows how marks differed between male and female students for the four modules. The bar chart indicates the means for the modules with the error bars indicating the standard deviation of the marks. The graph illustrates that in all modules female students out-performed their male peers in assessments at level four, although the size of the difference varied.

Figure 4.2 Mean marks (with standard deviation error bars) for level four compulsory modules showing male and female differences



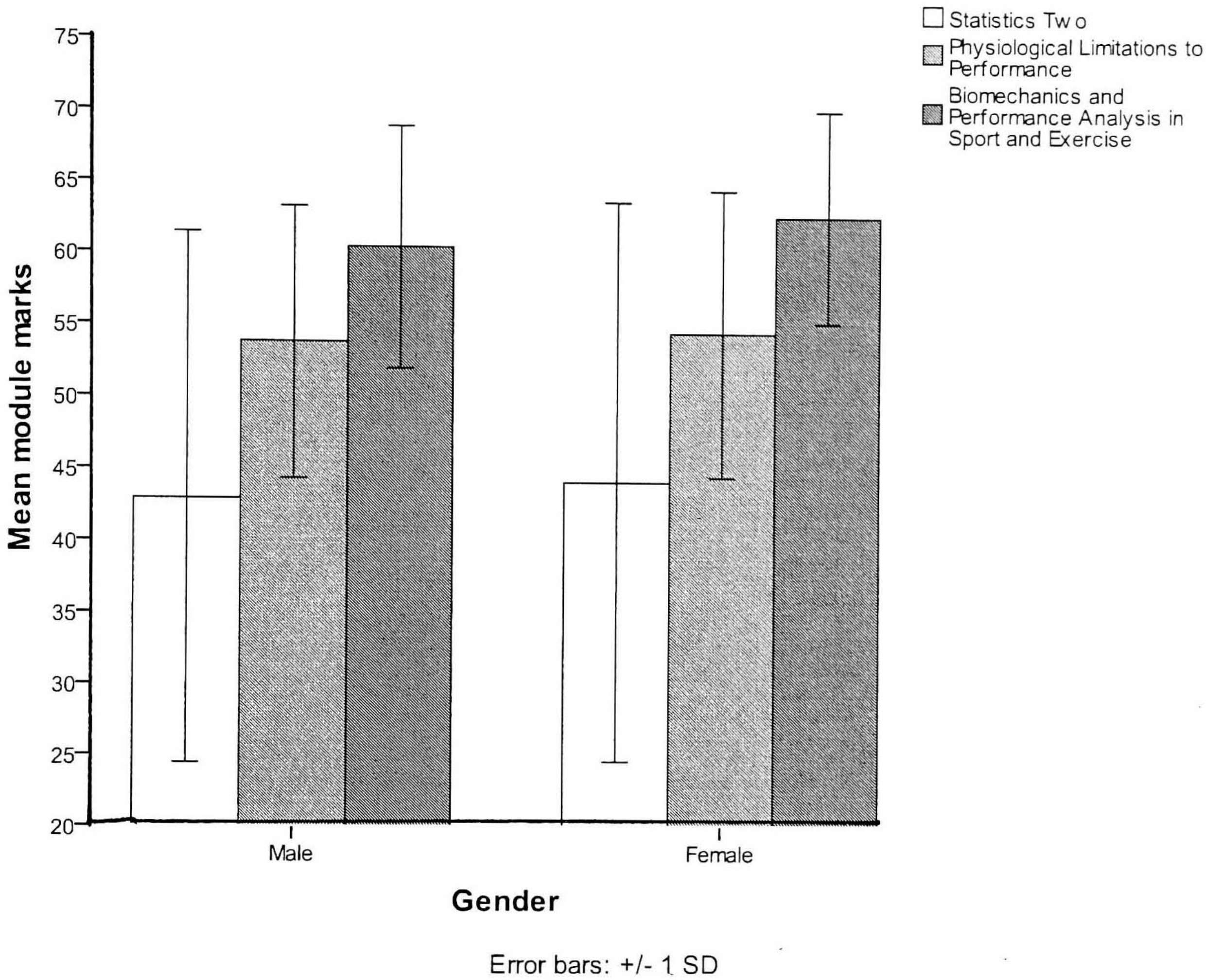
A comparison of the difference in marks showed that Introduction to Sports Biomechanics had the highest mean mark for males (almost 57%) and the smallest variability between students for both sexes (SD = 8.6%). It was the only module to demonstrate a non-normal distribution of marks. The inclusion of a student with a penalty grade of zero slightly suppressed the mean of the main body of data and marginally inflated the standard deviation, although these effects did not alter the conclusions drawn from the module comparisons (appendix *ii)*. The different pattern of variability may be a reflection of the low examination weighting in the assessments for the Biomechanics module. The impact of different types of assessment on student learning is explored in Chapter Six. Female students' marks in both Physiology modules were approximately 5% better than those of males but this difference was not as evident in either Statistics One or Introduction to Sports Biomechanics, where the mean differences were very small (females were 0.3% and 1% higher respectively). The variability around the mean marks was similar for both sexes across all modules, although the greater spread identified in Statistics One marks was more evident in female students - 2% higher than any other module, and double that of Introduction to Sports Biomechanics. These patterns highlighted the need for an exploration of the suitability of examinations as a tool to assess statistical learning. The decision to include interview questions to evaluate whether examinations promoted the development of statistical literacy, reasoning and thinking was influenced by these quantitative findings.

A critical outcome from the comparison of module marks was the evidence that students handled data more effectively in the Physiology and Biomechanics modules than they did in Statistics One. The contextual, situated element of statistical reasoning was likely to be more explicit in Sports Science modules than in Statistics ones (delMas, 2004; Gal, 2002). Interviews provided insight into the relationship between developing Sports Science knowledge, the application of statistical concepts, and the perceived link with Mathematics (sections 6.5 and 6.6.2).

4.3.2 A comparison of Statistics Two marks with those of other compulsory modules at level five

There was one compulsory module, Physiological Limitations to Performance, across all four degree programmes at level five and a Biomechanics module, Biomechanics and Performance Analysis in Sport and Exercise, which was a requisite module for students reading Sport and Exercise Science, Coaching Science and Sports Therapy. In addition all students studied the mandatory Statistics Two part-module that formed two thirds of the Research Methods for Sport and Exercise Sciences Two module and was independently assessed through an examination. Figure 4.3 shows that for each module the means and standard deviations for both male and female students were similar. The overall mean mark for Statistics Two was 42.5%, 11% lower than that for Physiological Limitations to Performance and 19% lower than that for Biomechanics and Performance Analysis in Sport and Exercise. Additionally the standard deviation was considerably higher for Statistics Two, which was indicative of greater variability in marks.

Figure 4.5 Mean marks (with standard deviation error bars) for level five compulsory modules showing male and female differences



Statistics marks for both sexes demonstrated similar variability, and ranged from under 10% to nearly 90%. This was a much wider spread than in either Biomechanics and Performance Analysis in Sport and Exercise or Physiological Limitations to Performance. The highest mean mark was for the Biomechanics module, which was assessed entirely through coursework. Marks in Biomechanics and Performance Analysis in Sport and Exercise deviated slightly from a normal distribution, but this was insufficient to impact on further analyses (Tabachnick and Fidell, 1996). Physiological Limitations to Performance included two unseen examinations which accounted for 60% of the assessment while the remainder of the marks were available from coursework. Statistics Two was assessed through one unseen examination, so the lower mean mark and higher standard deviation could have reflected examination anxiety rather than difficulty with Statistics (DeCesare, 2007).

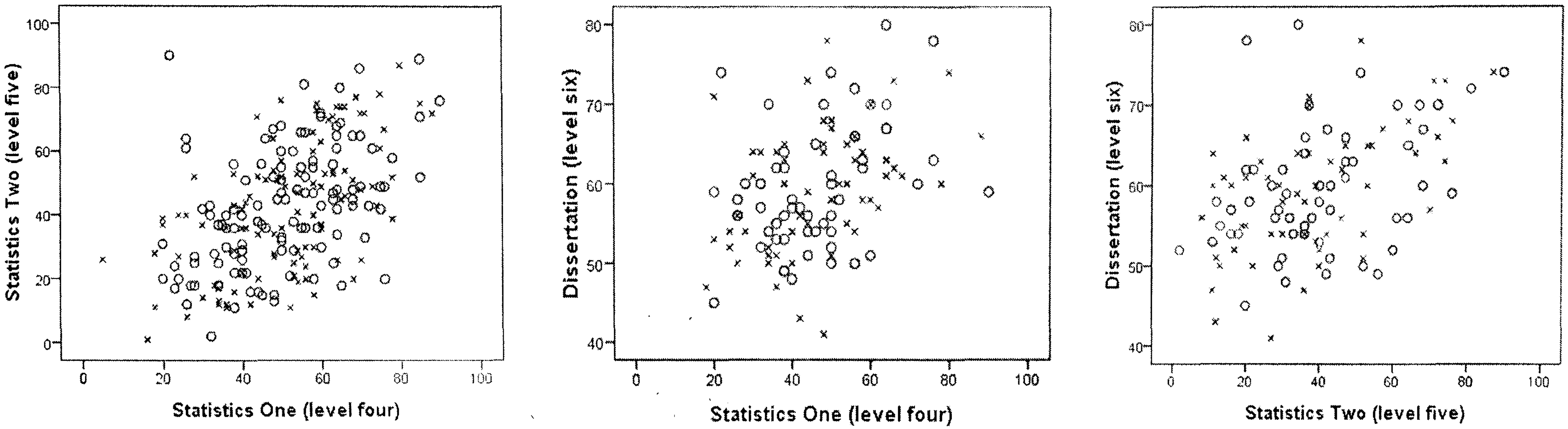
Nearly one-half of both male and female students failed the Statistics Two examination (marks below 40%), while there were few fail marks in Physiological Limitations to Performance and none in the Biomechanics module. This difference was a crucial factor in the decision to make Statistics Two the subject of close scrutiny through the qualitative section of this project.

4.3.3 A comparison of Statistics One and Statistics Two marks with those for the Dissertation at level six

For most students the double credit Dissertation module at level six included a statistical element. The mean mark for the Dissertation (for the 114 of the 117 students in the 2003 cohort who had completed it) was 59.5% (SD = 7.8%). The pattern for male students (59.6% SD = 7.9%) was almost identical to that of females (59.4% SD = 7.8%). The variability in marks was considerably smaller than that for Statistics One or Statistics Two and the mean was higher.

Scatter diagrams (figure 4.4) indicated very weak positive relationships between marks in the Statistics One and Statistics Two modules and marks for the Dissertation. The relationship between Statistics One and Statistics Two was not as strong as expected, which suggested that students did not necessarily build from previous achievement. There was also little evidence that Statistics marks influenced students' ability to conduct independent research projects. However, there are many factors that could account for the weak relationship, for example tutor support with Statistics, or the coursework nature of the Dissertation. These confounding factors are difficult to explore because of the variety of work possible in Sports Science dissertations. Nevertheless, it is important to acknowledge the student perception of Statistics in relation to their independent project work apparent both in literature (Lane, Devonport and Horrell, 2004) and in interviews which formed part of this project (see Chapter Six).

Figure 4.4 The relationship between Statistics One, Statistics Two and Dissertation marks



O represent marks for male students, X for females.

4.4 Comparison of Statistics marks by gender

Schram's (1996) meta-analysis established consistent evidence that examinations were a mode of assessment that favoured male students. The last row of table 4.3 shows that this pattern did not emerge from the data collated for this research project. The female students' mean mark was marginally better than that for the males at level four (by 0.3%), but dropped slightly below the male students at level five (by 0.2%). The low achievement in Statistics Two that was initially identified in section 4.3.2 is further illuminated in table 4.3. Mean marks for both sexes were close to the 40% pass boundary with very large standard deviations (18.9% for males and 20.2% for females) indicative of considerable variability.

Table 4.3 Means (standard deviations) of marks for Statistics One and Statistics Two examinations, split by gender and degree programme

	Statistics One (Level Four)			**Statistics Two (Level Five)**		
	Male	**Female**	**All**	**Male**	**Female**	**All**
Sport & Exercise Science	53.8 (15.8)	54.0 (17.4)	53.9 (16.3)	42.5 (20.4)	40.9 (20.7)	42.0 (20.4)
Coaching Science	50.8 (15.8)	41.6 (17.2)	49.4 (16.2)	36.9 (16.1)	38.7 (18.3)	37.0 (16.0)
Ex. & Health Science	53.9 (18.4)	51.2 (16.7)	52.4 (17.2)	45.8 (19.9)	33.2 (22.3)	37.2 (21.9)
Sports Therapy	56.5 (14.0)	55.5 (17.3)	55.8 (16.4)	50.4 (15.4)	45.3 (19.4)	46.6 (18.5)
All Programmes	53.4 (15.8)	53.7 (17.4)	53.5 (16.5)	42.6 (18.9)	42.4 (20.2)	42.5 (19.5)

All values are percentages

Differences under 1% in an examination are not recorded, therefore table 4.3 supported the conclusion that gender did not influence students' ability to achieve in Statistics examinations. However, at both levels female students had greater variability in their marks, and previous exploration indicated that they also had higher UCAS points and Mathematics qualifications than male students. The higher entry qualifications together with evidence that girls out-perform boys at all levels of education, led the researcher to anticipate that female students' marks would have exceeded those of their male peers (Higher Education Policy Institute [HEPI], 2009). These findings consolidated the possibility that gender was a confounding factor in the emerging picture of Statistics achievement. For example, conflicting gender effects in two different degree programmes could demonstrate a neutral effect when combined. Further investigation of the data to include a separation by degree programmes was warranted because Sports Therapy recruited students with higher UCAS points and was the only programme to have a substantially greater number of females (72%). Sport and Exercise Science and Coaching Science were respectively 70% and 85% male (table 4.1).

4.5 Comparison of Statistics marks by the interaction of degree programme with gender

The empirical experiences of tutors at the university suggested those students following Sport and Exercise Science and Exercise and Health Science degree programmes to be better equipped to learn Statistics than students reading for Sports Therapy or Coaching Science degrees. Section 4.3 revealed that female students slightly out-performed male students at level four, but table 4.3 clarified that this was only the case in students on the Sport and Exercise Science degree programme. In Coaching Science the very small number of female students rendered the mean very sensitive to one girl who received a mark of 10% for Statistics One. Excluding this student raised the female mean to 45.5% which was closer to the means of the other degree programmes, although still the lowest. At level five female Coaching Science students achieved slightly higher mean marks than males, although both were below the accepted pass mark of 40%.

At both level four and level five the male Sports Therapy students gained the highest mean marks. Female Sports Therapists were second highest in Statistics One and third for Statistics Two. Clearly tutors' perceptions that Sports Therapy and Coaching Science students were not as good at Statistics as those on other Sports Science programmes was not evidenced by Statistics marks for the former group, although it appeared true for both males and females reading Coaching Science. Of vital importance was the evidence in table 4.3 that male and female students' patterns of differences depended on the degree programme.

4.6 Comparison of Statistics marks by the interactions of Mathematics qualification with gender

Statistics marks were analysed for potential effects of maximum Mathematics qualification because previous studies suggested links between students' Mathematics achievement and statistical ability (Davies, 2006; Hencken, 2005; Cullingford and Crowther, 2005; Onwuegbuzie, 2004, 2000a, 2000b; Onwuegbuzie and Wilson, 2003). There was a clear advantage gained from Mathematics qualifications above GCSE grade C that was demonstrated in both Statistics One and Statistics Two. Although section 4.3 showed female students' mean Statistics One marks to be marginally better than those of males, table 4.4 revealed that this was the case only for girls with a Grade B in GCSE Mathematics. The low marks in Statistics Two that have already been noted, predominantly affected students with a GCSE grade C for Mathematics, although female students with grade C had a marginally higher mean mark than males. A critical clarification of the low marks at level five is that the mean mark was below the 40% pass boundary for students with grade C.

Table 4.4 Means (standard deviations) of marks for Statistics One and Statistics Two examinations split by gender and highest Mathematics qualification

	Statistics One (Level Four)			Statistics Two (Level Five)		
	Male	**Female**	**All**	**Male**	**Female**	**All**
GCSE Grade A or higher	64.3 (14.6)	61.9 (17.3)	63.2 (15.7)	54.7 (21.5)	53.9 (19.3)	54.3 (20.2)
GCSE Grade B	53.9 (15.2)	57.0 (15.6)	55.4 (15.4)	45.6 (17.4)	43.9 (21.1)	44.4 (19.4)
GCSE Grade C	51.2 (15.1)	48.5 (16.1)	50.2 (15.5)	37.0 (16.7)	38.2 (17.0)	37.5 (16.7)

All values are percentages

Statistical logic is similar to, but not the same as mathematical logic (delMas, 2004). One interview participant, Hazel, provided insight into the way a mathematically able student could succeed in Statistics examinations at the university, despite little ability to reason statistically (sections 6.3.10 and 6.5). These findings could suggest the applied Statistics modules were biased towards the computational aspects of Statistics. An alternative interpretation, that students with Mathematics qualifications above GCSE grade C are more willing to engage with Statistics and are less fearful of figures, would support the theories of Murtonen *et al.* (2008), Murtonen and Titterton (2004), Onwuegbuzie and Wilson, (2003) and Mann (2001). Findings from this section shaped the structure of the second interview conducted with twelve student volunteers, which elicited surprising information about the interplay between self-efficacy, confidence, motivation and Mathematics qualifications (section 6.4).

4.7 Comparison of Statistics marks by the interactions of gender, degree programme and Mathematics qualification

A comparison of Statistics marks between students who entered the university with different levels of Mathematics qualification for the four degree programmes enabled identification of the largest changes between level four and level five. Table 4.5 includes the marks for all the modules included in this chapter split into the smallest possible subgroups through the inclusion of all the factors of interest.

The grey columns in table 4.5 demonstrate that in places where marks from more than one student were available there was a clear advantage to higher Mathematics qualifications. The exception to this was for male Exercise and Health students, where those with a grade C in GCSE Mathematics were slightly better than those who had a B grade (55.3% compared to 55.0%). However, the difference between these marks is too small to be contextually important.

In each degree programme males with Mathematics grade A or higher, or GCSE grade C, had a better mean mark for Statistics One than females with the same Mathematics grades. The situation was reversed for students with a grade B. This pattern was not apparent at level five where means generally indicated that grades higher than a C were more beneficial, although grade A or higher was not consistently better than a grade B (table 4.5).

The differences between mean marks were most evident in Coaching Science students. Male students with GCSE grade A, or a higher qualification in Mathematics, gained the highest marks in both Statistics modules, approximately 20% higher than those of students who had a GCSE grade C. Female students with

GCSE grade A or higher and reading Sport and Exercise Science achieved the highest marks for Statistics One, a position held by their Sports Therapy peers in Statistics Two.

Over sections 4.3-4.7 data exploration clearly indicated the importance of the interactions between gender, degree programme, and Mathematics qualification. From table 4.5 it can be concluded that Mathematics qualification had the smallest effect on Sports Therapy students as there is greater consistency of Statistics marks between the GCSE grade groups at both levels. Sports Therapy students were often more diligent than those reading for the other Sports Science degrees; evidence which supported Garfield and Ben-Zvi's (2007) contention that conscientiousness is a better indicator of success in Statistics than mathematical ability. Coaching Science and Exercise and Health Science students show little consistency in mean marks between Mathematics qualifications or between the sexes. This may have been due to small and very unbalanced group sizes. The very small numbers of students in some sub-groups was particularly important for the interpretation of the quantitative analyses discussed in Chapter Five.

Table 4.5 Mean (standard deviation) marks for each module split by gender, degree programme and highest Mathematics qualification

Sex	Degree Programme	Highest Maths Qualification	Number of Students Level 4	Statistics One	Number of Students Level 5	Statistics Two	Number of Students Level 6	Dissertation
Male	Sport & Exercise Science	GCSE grade A or more	13	65.1 (15.4)	9	55.6 (26.0)	3	61.7 (7.4)
Male	Sport & Exercise Science	GCSE grade B	33	54.4 (16.9)	23	45.8 (18.7)	10	58.6 (8.7)
Male	Sport & Exercise Science	GCSE grade C	44	51.0 (13.3)	31	37.9 (18.3)	13	58.8 (9.9)
Female	Sport & Exercise Science	GCSE grade A or more	2	63.5 (13.4)	1	29	1	60
Female	Sport & Exercise Science	GCSE grade B	19	60.3 (13.0)	13	43.4 (21.6)	8	61.9 (8.7)
Female	Sport & Exercise Science	GCSE grade C	17	49.6 (18.3)	12	45.3 (18.9)	4	65.5 (5.4)
Male	Coaching Science	GCSE grade A or more	5	68.0 (14.4)	3	57.0 (11.5)	1	67
Male	Coaching Science	GCSE grade B	18	50.8 (14.3)	12	36.4 (13.7)	4	59.5 (3.5)
Male	Coaching Science	GCSE grade C	23	48.7 (15.5)	14	32.9 (15.8)	7	60.0 (6.7)
Female	Coaching Science	GCSE grade A or more	0		0		0	
Female	Coaching Science	GCSE grade B	3	53.7 (17.9)	3	38.7 (18.3)	0	
Female	Coaching Science	GCSE grade C	4	42.8 (7.8)	1		1	
Male	Exercise and Health Science	GCSE grade A or more	1	38	1	56	1	49
Male	Exercise and Health Science	GCSE grade B	6	55.0 (12.3)	2	63.5 (4.9)	2	61.0 (12.7)
Male	Exercise and Health Science	GCSE grade C	7	55.3 (23.8)	3	30.7 (16.4)	2	57.5 (0.7)
Female	Exercise and Health Science	GCSE grade A or more	0		0		0	
Female	Exercise and Health Science	GCSE grade B	10	55.1 (18.5)	8	36.8 (22.9)	3	55.7 (5.5)
Female	Exercise and Health Science	GCSE grade C	7	45.6 (12.9)	5	27.4 (22.6)	4	52.3 (8.7)
Male	Sports Therapy	GCSE grade A or more	4	63.8 (9.7)	2	47.0 (25.5)	1	50
Male	Sports Therapy	GCSE grade B	15	55.7 (14.1)	9	51.2 (15.7)	6	60.2 (8.7)
Male	Sports Therapy	GCSE grade C	7	56.4 (15.1)	7	44.4 (9.8)	3	63.3 (6.5)
Female	Sports Therapy	GCSE grade A or more	16	61.8 (18.1)	12	55.9 (18.6)	8	62.6 (4.6)
Female	Sports Therapy	GCSE grade B	35	56.2 (16.2)	26	46.0 (21.2)	15	58.3 (8.6)
Female	Sports Therapy	GCSE grade C	22	49.5 (16.8)	17	36.9 (12.5)	11	59.0 (6.6)

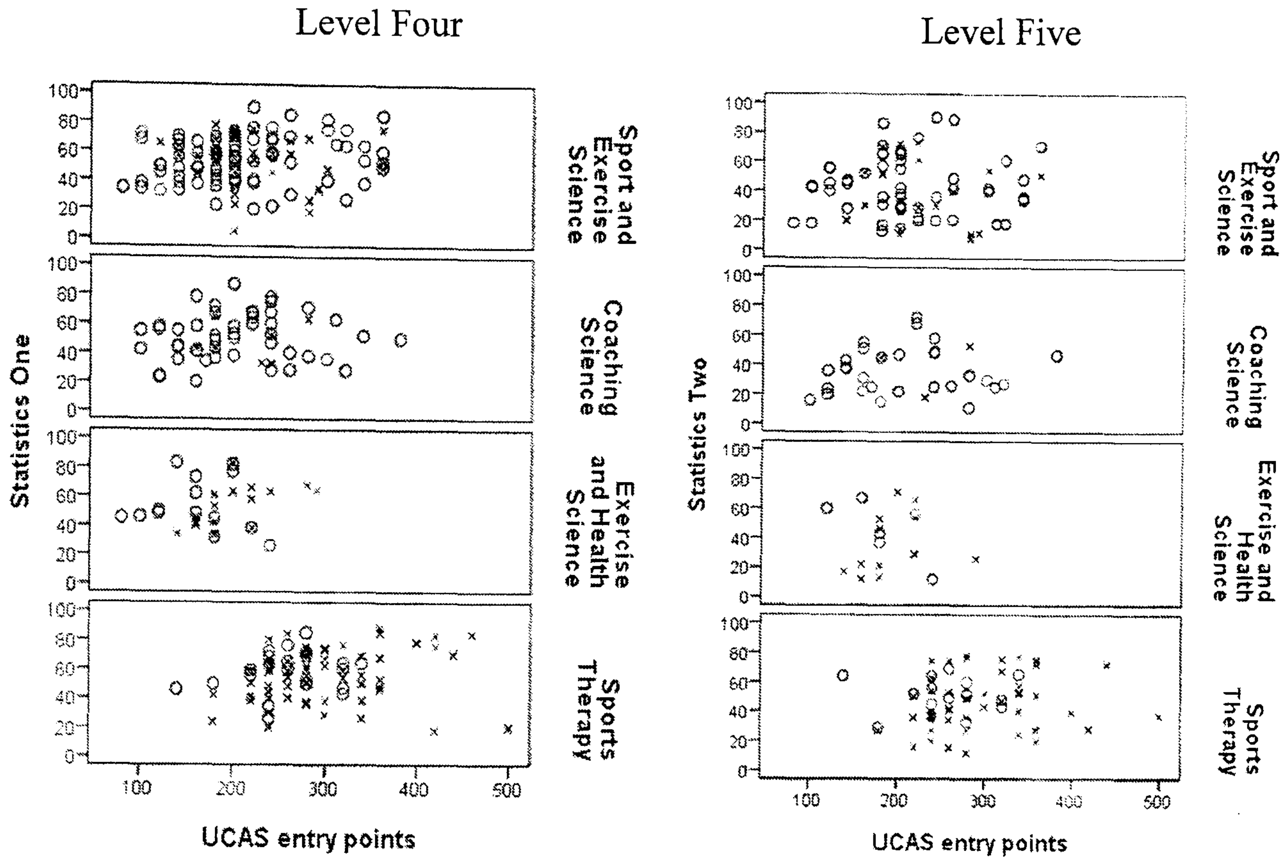
4.8 Investigation of the relationship between UCAS tariff points and Statistics marks

In 2006, Sports Therapy students had higher UCAS points than those on the other three degree programmes that contributed to the sample. The exploration of the relationship between UCAS tariff points on entry to the university and Statistics marks included gender and degree programme effects because female students had slightly higher UCAS points than males across all courses (section 4.2).

Scatter diagrams in the left hand column of figure 4.5 indicated that there was little evidence of UCAS points affecting Statistics One marks. The tendency for female students to have higher UCAS points in some degree routes was demonstrated by more cross-markers than circle-markers towards the right hand side of the graphs in figure 4.5. This pattern was particularly prominent for Sports Therapy students, as expected from the patterns in figure 4.1. A few of the girls with very high UCAS points gained very low Statistics One marks. This occurrence may have contributed to the tutors' perceptions that Sports Therapy students underachieve in Statistics.

The column on the right side of figure 4.5 confirmed that both male and female students had a similar pattern of marks in Statistics Two and that these were unrelated to UCAS points. The number of cross-markers at the bottom of the Exercise and Health Science and Sports Therapy graphs for level five indicates that female students did not do as well as males despite the higher UCAS points (section 4.5).

Figure 4.5 Statistics marks in relation to UCAS points for male and female students on each degree programme



O denotes male students and X female students.

4.9 Reliability and validity of the quantitative data analysis

The lack of consistency in the way UCAS tariff points were aggregated for each student, both in subjects and in the ratio of A-levels to AS-levels, rendered problematic the use of UCAS tariff points as a valid measure of academic ability. Validity was compromised further by the use of marks boundaries to provide the final grades that generated the UCAS points, and the modular structure of A-levels that enabled students to undertake repeated reassessment in component modules. Subjects such as P.E. and Biology were included in the A-level qualifications of most students. However, some had profiles that demonstrated ability to study at A-level, but in subjects that had no commonality with the field of Sports Science. For example one interview participant, Jack, entered the university to study for a Coaching Science degree, with French, Politics and Business Studies at A-level. The researcher analysed UCAS tariff points as an indicator of students' academic ability because they were the basis for registration on the Sports Science degree programmes.

The broad categorisation of Mathematics qualification documented in section 3.3.2 reduced the reliability of findings relating to that factor. However, as most students entered the university with a GCSE grade C or B for Mathematics, the differences between those grades were most pertinent to this project. The grades were collated from entry records, verified at students' registration, which made the data more reliable than the self-reported Mathematics grades used by Murtonen and Titterton (2004).

4.10 Conclusions

Analysis of the sample of Sports Science students registered at the university in 2006 revealed distinctive sub-groups distinguishable by particular characteristics. This occurrence made it impossible to separate the effects of degree programme from gender, UCAS points and Mathematics qualification. The different patterns of effects between the variables informed the investigation of possible interactions of factors undertaken as part of the analysis in Chapter Five.

A finding that was consistent across most of the sample was the advantage of Mathematics qualifications above GCSE grade C. Since the beginning of the twenty-first century many authors have contested the need for a mathematical focus to applied Statistics. For example, Murphy (2008) and Hencken (2005) claimed a conceptual focus to be more beneficial than a computational one. Garfield and Ben-Zvi (2007) found conscientious application and a desire to learn to be more beneficial to statistical literacy than mathematical competence. The effect of Mathematics qualification on examination outcome in the particular university setting could be indicative of a mathematical focus to teaching or in the examination papers that inhibited the development of statistical literacy. In Chapter Six, the interpretation of qualitative data illuminates this complex interplay of disciplines.

The effect of Mathematics qualification differed between male and female students and between degree programmes. This differentiation was further complicated by the demand for higher UCAS points for entry to the Sports Therapy programme, although there was little evidence at this stage that these points related to achievement in Statistics examinations. The potential interaction effect of UCAS points was not evaluated in this chapter, but formed a component of the analysis in Chapter Five.

Findings demonstrated students' difficulty with Statistics examinations when compared to other compulsory level four modules, although one Physiology module (Physiology of Endurance Performance) produced a lower mean mark. By level five, Statistics marks were much lower, and more variable, than those of other modules. Crucially, this was the case for all sub-groups of students regardless of their entry profile or choice of degree programme. Statistics Two was the only module assessed entirely through examination, which emphasised the vital importance of investigating the pedagogic strategies and assessment mode at this level. It was necessary to develop a clearer rationale for the utilisation of examinations to assess statistical literacy, reasoning and thinking.

There was no evidence of a strong relationship between Dissertation marks and Statistics marks. It was arguable that Statistics examinations did not test the skills needed to undertake prolonged independent analytical study. The self-directed, interpretative nature of the Dissertation required critical evaluation of published research as well as research design, data collection and analysis; the practical application of the components of statistical literacy reasoning and thinking. Lane, Devonport and Horrell, (2004) found that students who had completed dissertations valued the contribution of Statistics to their degree programme. Interview participants in this research project were not yet working on dissertations so they could not provide further insight. However, several of them valued the learning opportunities provided by small-scale project work within the Statistics Two module (sections 6.3.3, 6.3.5).

The data exploration undertaken in this section provided an overview of the place of Statistics within the compulsory elements of Sports Science degrees, and revealed achievement in Statistics modules to be comparatively low. Students made a less satisfactory transition from level four to level five in Statistics than they appeared to in Physiology and Biomechanics. Assessment through a single examination may have emphasised this difference, but students' perceptions of the link between Statistics modules and other parts of their courses (interpreted in Chapter Six) indicated that apportioning blame to the examination alone would be too simplistic.

For the analysis in Chapter Five the students examined in this chapter are taken to be a representative sample of Sports Science students at the university. The findings from these analyses are used to inform inferential hypothesis tests that extend the findings documented here. Statistical modelling is employed to illuminate the complex contributions of the factors introduced in this chapter to students' achievement in Statistics and the Dissertation modules.

Chapter Five

Investigation of Students' Assessment Outcomes in Statistics

Part 2: Inferential Statistical Analysis

5.1 Introduction

This chapter extends the exploratory analysis documented in Chapter Four to determine whether the findings for the 2003-2005 entry cohorts can be generalised to future Sports Science students at the university. The chapter begins with a scrutiny of the place of Statistics in the diet of compulsory modules at levels four and five. Analysis of variance (ANOVA) and *t*-tests evaluate whether the differences in marks between modules, found in Chapter Four, suggest a situation that could recur.

The core research questions for this project (section 1.2) are addressed through specific hypotheses, which were presented in section 3.2 and are reproduced in table 5.1 for ease of reference. The hypotheses are tested through three-way analysis of covariance (ANCOVA), so that the interaction effects identified in Chapter Four can be included, together with the main effects of each factor.

There was evidence that students considered understanding theory, including statistical theory, to be the most important contributor to dissertation success (Lane *et al.*, 2003). The Dissertation was the most heavily weighted single piece of assessment in the calculation of a final degree classification at the university. The chapter includes backward elimination ordinary least squares (OLS) regression models to explore the potential contribution of all the main effects and interactions to marks for Statistics One, Statistics Two and the Dissertation modules. The results of between-groups ANCOVAs are used to inform the inclusion of variables in further simultaneous entry or hierarchical OLS regression models. These models are compared to clarify the contributory effects of gender, highest Mathematics qualification, UCAS tariff points, and degree route to the module marks.

Table 5.1 The hypotheses investigated in this chapter through inferential tests.

- Gender affects achievement in Statistics assessments at levels four and five, and in the dissertation;
- Level of Mathematics qualification attained prior to registration at university affects achievement in Statistics assessments at levels four and five, and in the dissertation;
- UCAS tariff point score at entry to university affects achievement in Statistics assessments at levels four and five, and in the dissertation;
- Degree programme affects achievement in Statistics assessments at levels four and five, and in the dissertation;
- There are some interaction effects between the factors in the previous hypotheses.

The data distribution of each variable was assessed separately prior to partitioning the variables into groups, as advocated by Munro and Page (1993). At the same time data were checked to ascertain whether they fulfilled the assumptions of the statistical tests used to investigate the research hypotheses. Appendices *ii* and *iii* provide examples of the procedures undertaken to check the assumptions of normality and homogeneity of regression slopes.

5.2 The place of Statistics within the diet of compulsory modules

An inspection of table 4.2 indicated that some of the interaction groups from the 2006 sample of students contained few participants, which could impact on the reliability of inferential test results. The very small Exercise and Health programme (n=31), and the low number of female students reading Coaching Science (n=9) were the major causes of this problem. The number of students with GCSE grade A, or more, for Mathematics was also low (n= 40). It was decided not to combine these students with those who had grade B in order to increase the group sizes as the data exploration in section 4.7 showed that the effect of a grade A and B differed between male and female students. Potential interactions identified in Chapter Four informed the decisions about hypothesis tests.

One-way ANOVA found the differences in mean marks for compulsory modules to be significant at both level four ($F_{(2.250,648.131)} = 12.265$, $p<0.001$) and level five ($F_{(1.357,264.663)} = 161.940$, $p<0.001$). Paired *t*-tests were used instead of *post-hoc* tests to locate differences because the within-groups comparison necessitated an evaluation of covariance. Table 5.2 shows the results of these *t*-tests which indicated that Statistics marks were significantly lower than all other compulsory modules except Physiology of Endurance Performance at level four, and much lower than both the other level five modules (figures 4.2 and 4.3 indicate the directions of differences for the sample of students).

Effect sizes for the ANOVAs were medium ($f = 0.326$ at level four) or large ($f = 0.454$ at level five)[1], which indicated that the type of module has a much greater influence on students' marks at level five. Effect sizes for the *t*-tests, included in table 5.2, indicated that the significant differences at level four reflected small module influences[2]. It is important to remember that statistically significant results do not necessarily indicate meaningful differences in the particular context.

Table 5.2 Results of *t*-tests for significant differences between Statistics and other compulsory modules

Comparison	**Mean Difference**	**Test statistic (*t*)**	**Degrees of freedom**	**One-tailed probability**	**Effect size (*d*)**
Level Four					
Statistics One – Physiology of High Intensity Performance	-2.3	2.332	324	0.010*	-0.10
Statistics One – Physiology of Endurance Performance	0.7	1.119	321	0.132	0.061
Statistics One – Introduction to Sports Biomechanics	-3.2	3.929	292	<0.001*	-0.234
Level Five					
Statistics Two – Physiological Limitations to Performance	-11	10.186	200	<0.001*	-0.70
Statistics Two – Biomechanics and Performance Analysis in Sport and Exercise	-18.8	14.493	195	<0.001*	-1.236

*Denotes a significantly lower Statistics mark ($\alpha = 0.05$)

[1] Cohen (1988) indicated effect size values of f close to 0.10 to be small, 0.25 as medium and 0.40 as large.

[2] Effect sizes for d are considered small at 0.2, medium at 0.5, and large at 0.8 (Cohen, 1988).

The critical issue of very low Statistics Two marks, identified in section 4.3.2, was supported by statistically significant differences from Physiological Limitations to Performance and Biomechanics and Performance Analysis in Sport and Exercise with medium to large effect sizes. These results confirmed Statistics Two as likely to be meaningfully lower than the other modules for as long as pedagogic strategies and assessment procedures remained unchanged.

5.3 The influence of the main effects of gender, Mathematics qualification and degree programme on Statistics and Dissertation marks

Independent *t*-tests confirmed any gender differences to be chance occurrences which had little effect (table 5.3). These results contradicted the findings of previous studies undertaken in the USA, which suggested female students to be disadvantaged in examinations and in numeric subjects (Schram, 1996), although the results resonated with research in the UK which found female students to out-perform their male counterparts at all levels of education (HEPI, 2009). Data exploration in Chapter Four demonstrated that the sample groups of male and female students behaved differently when other factors, such as degree programme or highest Mathematics qualification, were included in the comparison (section 4.7). Gender cannot be considered a primary influence on Statistics and Dissertation marks but it could be a component of an interaction effect. This possibility is included in the analyses in sections 5.4 to 5.6.

Table 5.3 Results of *t*-tests for gender difference in Statistics and Dissertation module marks

Comparison	Mean Difference (%)	Test statistic (*t*)	Degrees of freedom	Two-tailed probability	Effect Size (*d*)
Level four male-female	-0.249	0.135	325	0.892	-0.016
Level five male-female	0.212	0.080	218	0.936	0.011
Dissertation male-female	0.245	0.167	112	0.868	0.031

Three one-way ANOVAs assessed the impact of Mathematics qualifications prior to university entry on marks in Statistics and the Dissertation. Results indicated that Mathematics qualifications significantly affected success in Statistics One ($F_{(2,303)}=$

11.633, $p < 0.001$), and Statistics Two ($F_{(2,203)}$= 9.384, $p < 0.001$) but not in the Dissertation ($F_{(2,103)}$= 0.245, p = 0.783). A medium effect size was reported for both Statistics One (Cohen's f = 0.277) and Statistics Two (Cohen's f = 0.304). Games-Howell *post hoc* tests indicated that Statistics marks differed between each of the Mathematics groupings; GCSE grade C, GCSE grade B, GCSE grade A or a higher qualification. Mathematics qualifications above GCSE grade C were confirmed as significantly beneficial which may indicate a mathematical focus to teaching or that mathematical skill is necessary to do well in Statistics (Murtonen and Titterton, 2004).

Three further one-way ANOVAs evaluated whether degree programme affected marks in each Statistics module and the Dissertation. Results indicated that there were differences, at the 10% significance level, in Statistics Two marks between degree programmes ($F_{(3,216)}$= 2.584, p = 0.054). No significant differences were found between degree programmes in Statistics One ($F_{(3,323)}$ = 1.975, p = 0.118) or in the Dissertation ($F_{(3,110)}$= 1.473, p = 0.226). Games-Howell *post hoc* tests found the only significant difference (p = 0.037) to be between Sports Therapy with the highest mean mark and Coaching Science with the lowest (table 4.6), but the effect size was very small (Cohen's f= 0.025).

Correlations of UCAS tariff points with Statistics and Dissertation marks indicated little or no relationship, see table 5.4. The weakness of the correlation is illustrated by the 'loose' scatter of points in figure 4.5 towards the end of Chapter Four. Overarching correlations are usually weaker than those of subgroups in the sample, so later sections of this chapter considered the relationships between UCAS points and Statistics marks for male and female students in each degree programme to identify whether UCAS points could be considered as a covariate in further analysis. The probabilities of the correlations suggest the weak relationship to be reliably applicable to future groups of students. These findings are due to the large sample size included in this project.

Table 5.4 Correlations between UCAS tariff points and marks in Statistics and Dissertation modules

	Pearson's Product Moment Correlation Coefficient	Probability
UCAS points with Statistics One	0.171	0.003
UCAS points with Statistics Two	0.126	0.079
UCAS points with Dissertation	0.308	0.002

All correlations are significant at the 10% level, but weak, suggestive of little relationship between the variables.

The previous two sections have indicated that highest Mathematics qualification was the only factor to influence marks for the two Statistics module, but that none of the variables selected for investigation affected Dissertation marks. The following sections evaluate the possible interactions of the four factors selected for analysis in this research project.

5.4 Statistics marks at level four

Examination of the student sample revealed that the effect of Mathematics qualification on Statistics One could not be separated from gender and degree route (section 4.7). The possible interaction of UCAS point effects with the other variables was not apparent from the graphical inspection in Chapter Four (section 4.8) or from the overarching correlations at the end of section 5.3. Three factors separated students into categories (for example male and female), but UCAS points were measured on a discrete scale which could not be included in ANOVA. Significant correlation coefficients were found between UCAS points and Statistics marks for some smaller subgroups from each categorical factor, which provided a justification for the inclusion of UCAS points as a covariate for the evaluation of possible interactions between the factors (table 5.5).

Table 5.5 Correlation coefficients between Statistics One marks and UCAS points that were significant at the 10% level (group sizes of 5 or less were not included)

Factor group	Pearson's correlation coefficient	Probability	Number of students
Male Sport and Exercise students, GCSE B	0.355	0.046	32
Male Exercise and Health students, GCSE B	0.837	0.037	6
Female Sports Therapy students, GCSE A+	0.581	0.018	16
Female Exercise and Health students, GCSE C	0.794	0.033	7

GCSE A+ denotes GCSE grade A or higher.

The correlations included in table 5.5 were the only relationships with UCAS points to be significant at 10% level. A three-way between groups ANCOVA (gender*degree route*Mathematics qualification) including UCAS points as a covariate was conducted to explore all possible interactions.

ANCOVA revealed UCAS tariff points to be a significant covariate ($F_{(1,261)}= 7.383$, $p = 0.007$) and Mathematics qualification ($F_{(2,261)}= 3.327$, $p = 0.037$) a significant main effect, as previously identified. The effect of UCAS points score as a covariate was small (Cohen's $f = 0.157$) which reflected the influence it had on some subgroups of the sample only. The effect of Mathematics qualification was also small (Cohen's $f = 0.149$). Simple contrasts indicated that students with GCSE grade A or higher qualification gained significantly higher Statistics marks than those with a grade C ($p = 0.057$). The grade B contrast with grade C was not significant ($p = 0.107$). This result can be explained by the discovery that female students with a grade B at GCSE were the only group of females to do better in Statistics than their male counterparts (section 4.6). No significant interaction effects were identified by the ANCOVA. The SPSS output for this analysis can be found in appendix *iii*.

Gender, degree programme, UCAS tariff points, Mathematics qualifications and all possible interactions of these factors were checked for multicollinearity. Following common research practice in the social sciences, a backward elimination ordinary least squares (OLS) model was produced that included all variables that satisfied the assumptions of regression (Field, 2009a). This model enabled the assessment of the possible importance of each variable and interaction. Dummy codes were used as explained in chapter three (section 3.3.3). The beginning of appendix *viii* indicates how dummy codes were assigned to the variables that contained more than two categories so that regressions could be undertaken in SPSS. The inclusion criterion for variables was at the 5% significance level. Equation 5.1 informs the findings from the ANCOVA by revealing the effects of UCAS tariff points and Mathematics qualification to the prediction of Statistics One. Some evidence of degree programme influence was also evident in the equation, although it had a small effect.

Statistics One = $49.60 - 35.54_{female*E\&H} + 0.08_{GCSEA*UCAS} + 0.026_{GCSEB*UCAS} - 12.34_{female*GCSEA*ST} + 0.181_{female*E\&H*UCAS} - 0.132_{GCSEA*E\&H*UCAS}$

(Equation 5.1[3])

The elements of this and subsequent equations that included UCAS points, had small coefficients for UCAS points because they were measured on a scale of 80 – 500 while all the other variables were dummy categories coded as zero or one. An explanation of how this was achieved can be found in appendix *viii*. As a result of this coding, the third element of the equation which reads $+ 0.08_{GCSEA*UCAS}$ can be interpreted that a Mathematics qualification of GCSE grade A and 180 UCAS points would add 14.4% to a student's Statistics mark (0.08*1*180 = 14.4). It was important to look at the whole equation to assess the effect of the factors on students' Statistics One marks. Illustrative examples of marks for hypothetical students from each degree programme predicted from equation 5.1 were calculated (table 5.6). The first student presented in table 5.6 received the constant value because male Sport and Exercise Science students were used as the comparative category for dummy codes as they were the largest group (table 4.1).

Table 5.6 Illustrative examples of how equation 5.1 could be used to predict Statistics marks

Equation	**Male S&E# with GCSE C and 240 UCAS points**	**Male CS# with GCSE A and 280 UCAS points**	**Female E&H# with GCSE B and 200 UCAS points**	**Female ST# with GCSE A and 300 UCAS points**
Constant = 49.60	+49.60	+49.60	+49.60	+49.60
$-35.54_{female*E\&H}$			-35.54	
$+0.08_{GCSEA*UCAS}$		+22.40		+24.00
$+0.026_{GCSEB*UCAS}$			+5.20	
$-12.34_{female*GCSEA*ST}$				-12.34
$+0.181_{female*E\&H*UCAS}$			+36.20	
$-0.132_{GCSEA*E\&H*UCAS}$				
Predicted percentage (to nearest 1%)	**49.6**	**72.00**	**55.46**	**61.26**

[3] In all models in this chapter the following codes are used to refer to specific effects:
'female' the effect of being a female student compared to male;
#'E&H', 'CS', 'ST' the effect of reading Exercise and Health Science, Coaching Science or Sports Therapy compared to Sport and Exercise Science;
'GCSEA' 'GCSEB' the effect of having higher Mathematics qualifications than a GCSE grade C;
'UCAS' the number of UCAS tariff points on entry to university

The regression model explained 13.8% of the variation in Statistics One marks, which is an unsatisfactory amount if the model is intended as a reliable predictor of marks. Additionally, the model contained interactions of variables which had not been included as main effects. This condition was deemed 'inappropriate' by Agresti and Finlay (1997), as the main effect should also remain in the equation. The problem arises from using modelling procedures, such as the backward elimination method, that employ statistical criteria to determine the variables that are retained in a regression model. For a fuller discussion of this problem see section 3.3.3.

Chapter Four revealed that each of the four factors interrelated to have different effects on Statistics marks. The model in equation 5.1 indicated *how* the most influential combinations of factors impinged on students' statistical achievement. The results *must* be interpreted as exploratory, and it is vital that these influences are not interpreted as a causal relationship between predictor variables and Statistics marks. There are likely to be factors outside the scope of this research project that cause specific entry profiles to relate to Statistics marks. However, it is valuable to know which groups of students may find Statistics more difficult.

A second backward elimination model that included only UCAS tariff points and highest Mathematics qualification was computed, because they were the only variables found to be significant in the ANCOVA (equation 5.2). This second model addressed the problem with interaction effects identified by Agresti and Finlay (1997). It explained 9.8% of data variation, about three quarters of that explained by equation 5.1. Equations 5.1 and 5.2 provided clarification of the benefit of GCSE Mathematics qualifications above grade C. The complex interplay between factors exemplified in table 5.6, meant that a grade A or more at GCSE was not as advantageous to female Sports Therapy or Exercise and Health students' achievement in Statistics examinations as it was to students reading Sport and Exercise Science or Coaching Science. The small samples of Exercise and Health Science (n=17) and Coaching Science (n=9) females made these conclusions tentative.

$$\text{Statistics One} = 43.14 + 0.03_{UCAS} + 12.71_{GCSEA} + 5.59_{GCSEB} \quad \text{(Equation 5.2)}$$

How closely the generated models match the data used to produce them is known as the 'fit' of the model. The fit was assessed using the procedures documented in the example in appendix *viii*. The model was a poor fit to the data because it underestimated the very high marks and overestimated the very low ones, restricting most students' predictions to between 49-61%. The researcher was aware that the predictive ability of the equation would be limited because of the small effect sizes and low correlations reported in the early parts of this section. The value of the regression models was the identification of the variables that were retained in each equation as these guided subsequent interviews.

The same methods of analysis were used to investigate Statistics Two marks. A direct comparison between the levels revealed whether the effect of variables working in combination was similar as students progressed through the degree programmes.

5.5 Statistics marks at level five

The crucial finding from Chapter Four was that approximately one-half of the students with a GCSE grade C or reading Coaching Science were not reaching a 'pass' mark of above forty percent in the Statistics Two module examination (tables 4.3 and 4.4). Correlation revealed a weak relationship between Statistics Two marks and UCAS tariff points, at the 10% significance level, which led to the inclusion of UCAS points as a covariate in the analysis (tables 5.4 and 5.7). Statistics One marks were an additional covariate as there was evidence of a significant, moderate correlation between marks for both Statistics modules (r_P = 0.496, $p<0.001$). Table 5.7 revealed the results for female students to be significant at the more stringent 5% level. These findings mean that the strength of relationship conveyed by the correlation coefficient could be applied to future groups of female students with greater confidence than to males. It is important to interpret this with some caution as the group sizes are small, which has a detrimental effect on the reliability of the statistics obtained.

Table 5.7 Correlation coefficients between Statistics Two marks and UCAS points that were significant at the 10% level (group sizes of 5 or less were not included)

Factor group	Pearson's correlation coefficient	Probability	Number of students
Male Sport and Exercise students, GCSE A+	0.602	0.086	9
Male Sport and Exercise students, GCSE B	0.390	0.073	22
Male Sports Therapy students, GCSE C	0.713	0.072	7
Female Sports Therapy students, GCSE A+	0.647	0.023	12
Female Sports Therapy students, GCSE B	-0.445	0.023	26
Female Sports Therapy students, GCSE C	0.509	0.037	17

GCSE A+ denotes GCSE grade A or higher qualification.

A three-way ANCOVA (gender*degree route*Mathematics qualification) was conducted. The effect of Statistics One marks was highly significant ($F_{(1,165)}$= 41.688, p<0.001). Additionally, Mathematics ($F_{(2,165)}$= 2.850, p=0.061) and, surprisingly, gender ($F_{(1,165)}$= 2.773, p=0.098) were significant main effects at the 10% level. The results demonstrated a diminished effect of UCAS points, which were used to quantify general academic ability ($F_{(1,165)}$ = 0.296, p=0.587). Effect sizes indicated that Mathematics qualifications and gender had a small influence on Statistics Two marks (Cohen's f = 0.150 and 0.104 respectively). The covariate of Statistics One marks had a medium to large effect on Statistics Two marks (Cohen's f= 0.439). Simple contrasts uncovered a benefit of Grade B Mathematics over grade C, which was not sustained to grade A, or higher. This result was probably influenced by the small numbers of students who entered the university with a GCSE grade A or higher in Mathematics, and therefore was likely to be unreliable. Nevertheless, the effect of mathematical skills and the content of Statistics modules should remain under constant review as a result of these findings.

Despite the clear effect of Statistics One marks on those of Statistics Two, the relationship between the modules (r_p = 0.496, p<0.001) was not close to the very high correlations, 0.8-0.9 or above, deemed to suggest interdependence (Field, 2009a; Tabachnick and Fidell, 2007; Pallant, 2005). Therefore, a backward elimination model included both these and all the other factors that did not demonstrate multicollinearity (equation 5.3).

$$\text{Statistics Two} = 12.43 + 0.51_{\text{Statistics One}} + 12.38_{\text{GCSEA}} + 5.62_{\text{GCSEB}}$$

(Equation 5.3)

The Statistics One marks had the greatest influence on performance in the Statistics Two examination, but equation 5.3 also suggested Mathematics qualifications above GCSE grade C to be advantageous. Crucially the model did show grade A to have more influence than Grade B. The contradictory outcomes from the ANCOVA and the backwards elimination regression served to reinforce the problematic nature of the Mathematics/Statistics interface. Equation 5.3 accounted for 29.6% of the variation in recorded Statistics Two marks. It can be seen that unless Statistics One marks were very low (less than 24%) they could account for more than half of the predicted marks for Statistics Two. A further 6% (to the nearest whole percentage) was added for each level of Mathematics qualification above GCSE grade C.

A second regression model was produced that forced Statistics One examination mark into a hierarchical regression as the first variable. The other factors included in equation 5.3 were entered for backward elimination at a second stage. As a result of this procedure, Statistics One was the only predictive factor retained in the model (equation 5.4).

$$\text{Statistics Two} = 13.918 + 0.567_{\text{Statistics One}}$$

(Equation 5.4)

It was unsurprising that the Statistics One mark was the most important factor in determining performance in the Statistics Two examination as the second module aimed to develop skills learned in Statistics One. Equation 5.4 explained 24.6% of data variation. Mathematics qualifications above GCSE grade C that were included in equation 5.3 contributed an additional 5% to the explained variation in the data.

As with the models for Statistics One, the fit of the models for Statistics Two to the data was poor. For example equation 5.3 predicted middle value percentages for those with very low marks and low marks for those who in reality gained high marks. The model was statistically acceptable, but of little practical use for prediction. This could be attributed to the role of Statistics One in the model, but to do so would be to ignore the complexity of statistical education. The challenge is in the facilitation of effective statistical literacy for all Sports Science students, despite the Mathematics qualification with which they enter the university. Mean marks for Statistics Two that did not reach 'pass' level suggested that pedagogic practices and/or assessment modes did not cultivate such skills.

5.6 An investigation of Dissertation marks

Ninety-two students' data included UCAS points and a mark for the Dissertation. The relationship between these two variables was stronger than that between UCAS points and Statistics marks (table 5.4). Two sub-groups had a moderate or strong significant relationship (table 5.8). As with previous analyses, the small sample size in both cases compromises the reliability of generalising the results to future cohorts of students. Female Sports Therapy students with GCSE grade A in Mathematics showed a relationship between UCAS points and assessment outcome across all three investigations in this chapter (tables 5.5, 5.7 and 5.8). Correlations between Dissertation marks and Statistics One marks (r_p = 0.389) and Statistics Two marks (r_p = 0.465) across all students were weak to moderate, and significant ($p<0.001$) in each case, so these variables were included as covariates in the analysis.

Table 5.8 Correlation coefficients between Dissertation marks and UCAS points that were significant at the 10% level (group sizes of 5 or less were not included)

Factor group	Pearson's correlation coefficient	Probability	Number of students
Male Sport and Exercise students, GCSE C	0.552	0.078	11
Female Sports Therapy students, GCSE A+	0.817	0.013	8

GCSE A+ denotes GCSE grade A or higher.

A three-way ANCOVA (gender*degree route*mathematics qualification) with UCAS tariff points, Statistics One marks and Statistics Two marks as covariates found UCAS points and Statistics Two marks to be the significant parts of the analysis (table 5.9). The results suggested that entry profiles are less important to Dissertation marks than achievement at university; a possible indication of *value-added.*

Table 5.9 Factors demonstrating a significant effect on Dissertation marks

Covariate	Test statistic (F)	Degrees of freedom	Probability	Effect size (*f*)
UCAS tariff points	11.744	1, 69	0.001	0.330
Statistics Two marks	9.881	1, 69	0.002	0.300

For stepwise regression procedures, Tabachnick and Fidell (2007) advised a sample size of 104 participants, plus an additional participant for each predictor variable. The sample size (n=92) fell short of the 106 individual sets of data recommended for two independent predictor variables. In order to retain some reliability in the model, regression was conducted with the two variables identified in the ANCOVA. The forced entry method, of regressing both variables simultaneously, was employed, as this will tolerate a lower sample size (Stevens, 2009; Tabachnick and Fidell, 2007).

$$\text{Dissertation} = 46.66 + 0.03_{\text{UCAS}} + 0.16_{\text{Statistics Two}}$$

(Equation 5.5)

Equation 5.5 accounted for 23.6% of the variation in the data. Equation 5.4 accounted for a similar amount of the variation in Statistics Two marks. Both Statistics Two and the Dissertation could be explained more satisfactorily by the documented regression equations than Statistics One. Equation 5.5 showed that high UCAS point scores were of little benefit to dissertation marks (approximately 3% for every hundred UCAS points). The variable was of limited practical value for differentiation between students, even though it was a *statistically significant* predictor. An additional 1.6% for every 10% gained in Statistics Two revealed an ability to pass Statistics examinations to be beneficial to Dissertation marks, but it did not clarify the effect on statistical literacy. Information elicited from interviews in Chapter Six suggested that it was possible to succeed in a Statistics examination without statistical literacy or thinking skills (for example, Mark's account of his experiences in section 6.3.2).

It was clear, from the amount of variation in the data that remained unexplained by the regression model, that there were other factors that determined success in the Dissertation. The facility for students to choose the field of study for their dissertation and the obvious importance of the double-weighting of this module in the calculation of degree classification were likely to sustain students' interest and motivation. The effect of motivation on the Dissertation was outside the scope of this project, but its contribution to the effective development of statistical literacy, thinking and reasoning was explored qualitatively in Chapter Six. Equation 5.5 showed that it was possible for a student who achieved approximately 60% for Statistics Two to benefit by 10% and cross a degree classification boundary for the double-weighted Dissertation module. This finding supported Lane, Devonport and Horrell's (2004) and Lane *et al.*'s (2003) conclusions that Sports Science students perceived Statistics to be important for Dissertation success.

The analysis indicated that the statistical fit was adequate, although not good. The model would be of little practical predictive value because it did not explain sufficient variation in the data and underestimated the upper range of marks. It is important to remember that increased marks in a Statistics examination will not necessarily result in higher Dissertation marks. The skills needed for high examination marks can be very different from those necessary to produce an excellent dissertation. The latter requires a synthesis of information resulting from careful evaluation of literature and empirical data, the former could be achieved through relatively superficial recall of factual knowledge as evidenced by some of the accounts in Chapter Six. Clearly the university's modes of assessment for statistical literacy needed to be reviewed, together with pedagogic strategies, to see if factual recall is emphasised to the detriment of statistical thinking (Birkhead, 2009).

5.7 Conclusions

This chapter extended the findings of Chapter Four to include an assessment of the identified interactions between gender, degree programme, highest Mathematics qualification and UCAS tariff points. The critical findings of this chapter centred on the Statistics Two module. It had significantly lower marks than both other compulsory modules at level five with a pattern of marks indicative of problems with module content, pedagogic practice, assessment, or a combination of these. Level four marks did not provide evidence of similar issues because marks for the Statistics One module were similar to those of other compulsory modules, albeit at the lower end of the range.

Mathematics qualifications above GCSE grade C were advantageous to success in Statistics One and Statistics Two examinations, but other tentative conclusions that there were small degree route or gender differences were only apparent in Statistics Two. The decision to make this module the vehicle for the qualitative exploration of students' learning experiences was reached following the quantitative analysis documented in this, and the preceding, chapter.

Most interaction groups were too small to provide reliable coefficients for regression equations so models were produced from the variables found to affect the marks, in earlier ANOVA or ANCOVA. This decision simplified the equations produced and increased the stability of predictions. Models showed Mathematics qualifications, above GCSE grade C, to be the most beneficial factor at level four (equation 5.2) and this was still evident at level five (equation 5.3), although the most influential factor to predict Statistics Two was Statistics One (equations 5.3 and 5.4). This finding was perhaps to be expected, but the variation in the former that was described by the latter was surprisingly low (24.6%) and provided further indication that progression from level four to level five Statistics was problematic for Sports Science students. The sustained influence of Mathematics qualification on Statistics marks suggested a need to evaluate the mathematical demands of the Statistics examinations. Module teaching with statistical literacy as its main aim does not prepare students for examinations which place computational demand above interpretive skill. Conversely, transmission modes of teaching stifle statistical thinking. Whether students perceive their statistical activities as a branch of Mathematics or as a means to understand real-world Sports Science data is vital to the enhancement of statistical literacy in this university setting. This was a critical dimension of the interviews interpreted in the next chapter.

The analysis in this chapter and Chapter Four addressed the core research questions that aimed to evaluate the effect of gender, degree route previous educational qualifications both in Mathematics and, more generally, through UCAS points. The mixed methodology employed by this research project aimed to explore specific quantitative factors and some qualitative issues impinging on students' ability to improve their statistical literacy and develop towards statistical thinking and reasoning. Regression models are tools for prediction and suggest relationships, not causes. Qualitative interpretation of interview data, in Chapter Six, enabled causal relationship between the quantitative factors and Statistics marks to be explored, which added to the information gleaned from the analyses presented in this chapter. Chapter Seven draws both quantitative and qualitative findings together in an overarching discussion to develop recommendations for pedagogic change and further research.

Chapter Six

An Interpretation of Students' Perceptions of their Experiences of Learning Statistics

6.1 Introduction

A review of literature in preparation for this project revealed a paucity of research that explored students' opinions of statistical learning experiences. One published paper was located which used focus groups to investigate the retrospective opinions of level six (BSc (Hons)) and level seven (MSc) Sports Science students (Lane, Devonport and Horrell, 2004). Part of the originality of this project was the occasion for students to express their learning experiences during a period when they were studying Statistics. This opportunity was long overdue and enabled reflection on professional practice to extend beyond the parameters of the tutors' perceptions; a situation conducive to pedagogic improvement.

This chapter presents evidence elicited through interviews with student respondents. Data were collected between October 2006 and January 2007, while the participants were studying the Statistics Two module. Pen portraits of interviewees provide individual contexts, and a thematic analysis presents an exploration of areas of commonality and contrast between participants. Riessman (2008) claimed this to provide a more rigorous interpretational framework as it enables individual and comparative perspectives. Throughout the chapter findings are critically interpreted to illuminate the initial research questions:

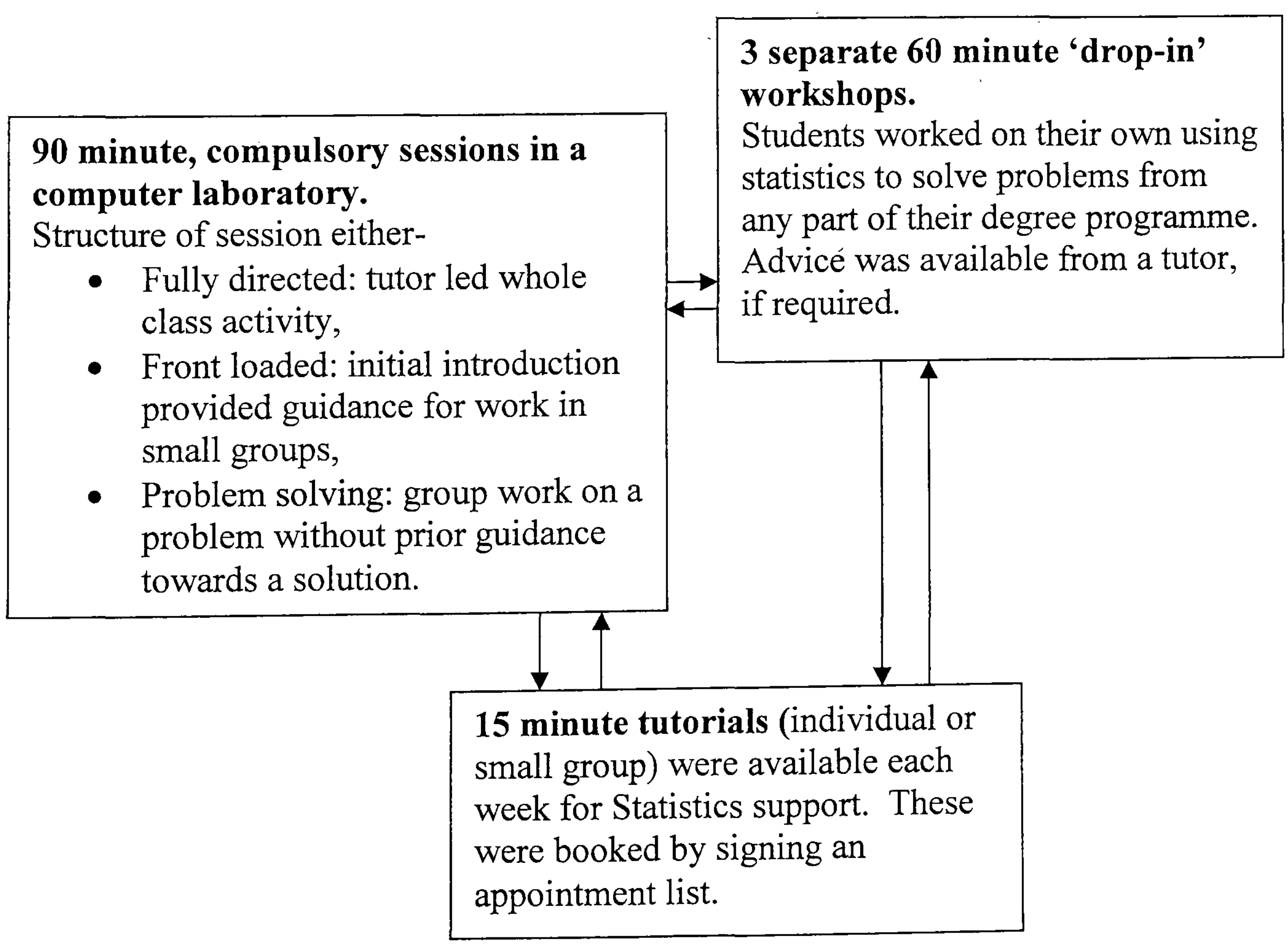
- How previous experiences with Mathematics affect Sports Science students' perceptions of Statistics;
- The nature of the evolving relationship between statistical literacy and the developing professional knowledge of Sports Science students, as they progress from level four to level five;
- Students' experiences of learning Statistics within a specific level five compulsory module.

Twelve level five student volunteers were interviewed, on two (n=7) or three (n=5) separate occasions. Firstly, unstructured interviews, and then semi-structured interviews, six to eight weeks later, explored subjective experiences of learning statistics. A time line of the interview can be found in figure 3.3 (section 3.4.2).

6.2 The Structure of the Statistics Two module

The Statistics Two module comprised of weekly, compulsory, ninety minute classes in a computer laboratory, supported by voluntary workshops and tutorials. Each laboratory session was led by two tutors who used a variety of different pedagogic approaches (summarised in figure 6.1). Each week three, sixty minute "drop-in" workshops enabled students to analyse their own data. A tutor was available to offer advice if required. In addition, fifteen minute individual tutorials could be arranged by appointment. During the data collection period, workshops and tutorials were accessed by approximately one-quarter of the students registered on the module. Figure 6.1 provides a diagrammatic representation of the teaching and support provision.

Figure 6.1 The weekly structure of Statistics Two



6.3 Participants' Pen Profiles

Nine male students and three female students volunteered to be interviewed. They represented all Sports Science degree programmes offered at the university, although only one student volunteered from the largest programme (table 6.1).

Table 6.1 The spread of interview participants as a proportion of the cohort group separated by degree programme and gender

Degree Programme	Male	Female	Proportion of Cohort
Sport and Exercise Science		1	1/41 (2.4%)
Sports Coaching Science	6		6/24 (25%)
Exercise and Health Science	1	1	2/12 (16.7%)
Sports Therapy	2	1	3/28 (10.7%)
Total proportion			12/105 (11.4%)

Chapters Four and Five of this research project considered the effects of gender, degree route, UCAS points and Mathematics qualification on examination marks for Statistics One and Statistics Two. Interviewees demonstrated considerable diversity with respect to these characteristics as shown in table 6.2. The table includes the marks students achieved in both modules, although those for Statistics Two were gained after most interviews had been conducted. Each participant was given a pseudonym to protect his or her identity.

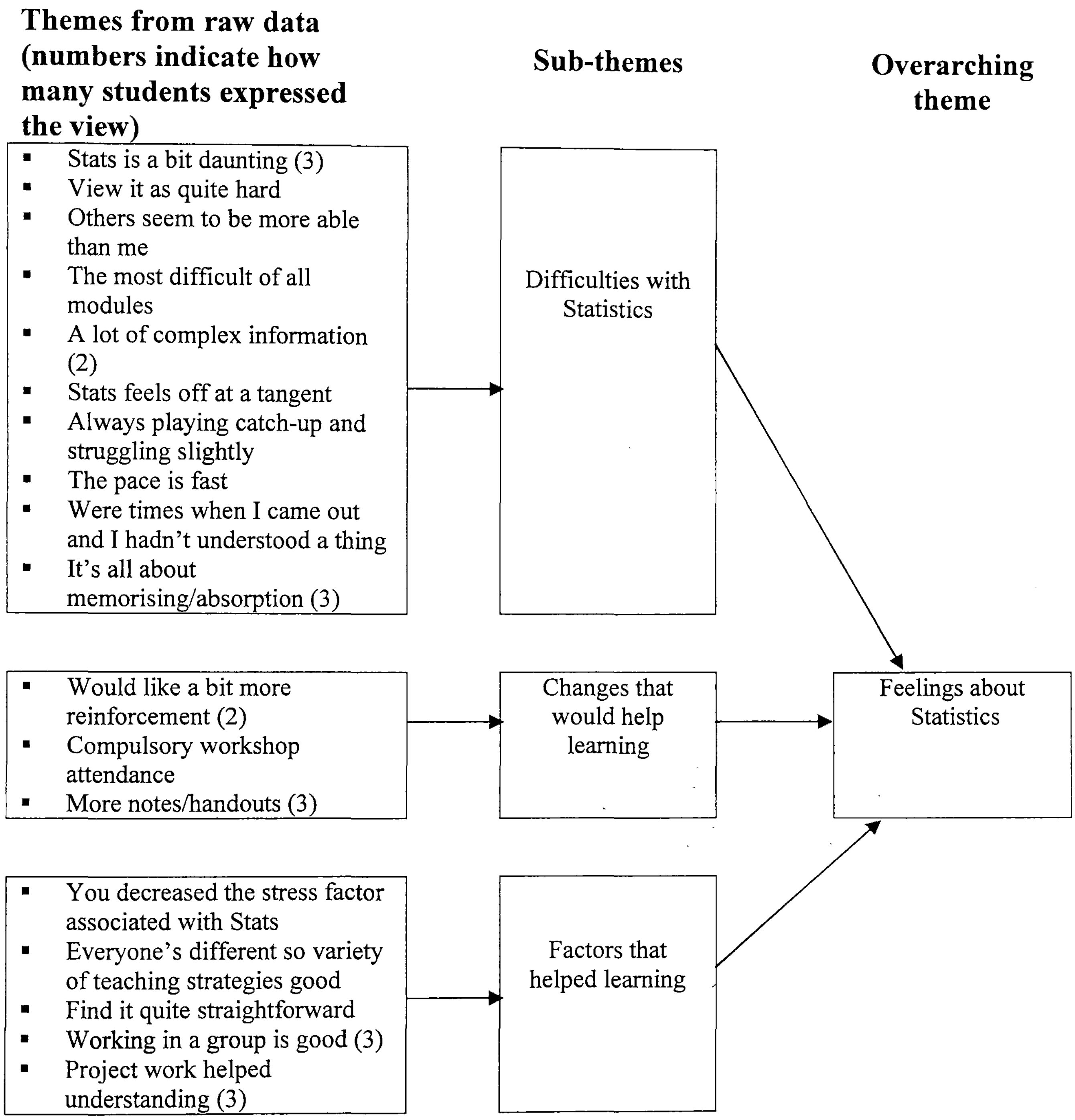
Table 6.2 Interview participants' profiles on the variables investigated in Chapter Four and Chapter Five

Name	Degree Programme*	Maths Qualification	UCAS Points	Statistics One		Statistics Two
Alan	C.S.	GCSE B	340	52%		20%
Anna	E&H	GCSE B	240	63%		33%
Billy	S.T	Mature entry	Mature	57%		41%
Colin	C.S.	GCSE C	Unknown	L2 entry		44%
Donald	C.S	GCSE C	220	68%		65%
Frank	S.T.	Mature entry	Mature	68%		23%
Freddy	E&H	GCSE B	200	77%		80%
Hazel	S.T.	A Level B	420	83%		98%
Jack	C.S.	GCSE C	200	50%		28%
Mark	C.S.	GCSE B	220	67%		45%
Tim	C.S.	GCSE C	260	28%		3%
Yvonne	S&E	GCSE C	360	53%		65%

* C.S. = Coaching Science, E&H = Exercise and Health Science, S&E = Sport and Exercise Science, S.T. = Sports Therapy.

An overview of students' feelings about Statistics can be seen in figure 6.2. The thematic analysis gives both context to the participants' pen profiles, and extends comparative points raised in the profiles, as advocated by Riessman (2008).

Figure 6.2 Inductive thematic analysis of interview participants' feelings about Statistics



6.3.1 Alan

Alan entered university directly from college with a grade B at GCSE Mathematics and 340 UCAS points from A-levels in English, Sociology and Sports Science. He perceived some of his friends to learn Statistics through memorisation; recognised as a 'surface' approach to learning (Biggs and Tang, 2007; Ramsden, 2003). He explained that he needed to explore *'why'* in order to learn, and his responses exhibited characteristics associated with deep learning. Alan experienced Statistics as largely factual content 'delivered' to students through a transmission model of teaching (Jarvis 2002), stating, "if the majority of the lesson is mainly loads of information...there is only so much you can sort of take in, you sort of lose it" (Alan and Mark 2.80)[1]. This perceived pedagogic strategy reduced his opportunity for reflective thought (Furedi, 2005; Dewey, 1966). Alan's preferred approaches to study did not transfer to learning Statistics, "It's a funny exam to prepare for cause in other exams you have to read through your notes and issues and stuff...but for this you have to work through loads of examples. You can't read notes" (Alan and Mark 3.157). Altman and Bland (1991) found similar issues with medical students. Alan's retrospective description of preparation for the examination suggested he understood it to test competencies and memorisation skills rather than concepts; a common problem documented by Jolliffe (1997). Alan expressed frustration that he could not develop skills of statistical reasoning because of the way the subject was taught and assessed. He appreciated statistical concepts but did not feel supported to develop an understanding of them.

6.3.2 Mark

Mark had a year in employment between school and university. He gained a GCSE grade B for Mathematics, with the help of a private tutor, and 220 UCAS tariff points from an A-level in Sport and a double vocational A-level in Leisure and Recreation. He was a voluble interviewee who emphasised his need to *get on* with his teachers in order to learn. He implied that this included an element of respect both for and from the tutor, "I got on well with her, we had quite a laugh...I sort of like respected her, because I liked her...she had time to go through it again until I understood" (Alan and Mark 1.30). Field (2009b), Wilson (1999), and Snee (1993) stressed the importance of tutor effect as a vital ingredient for student engagement and minimisation of barriers to learning. However, the particular attributes of a 'good' Statistics tutor are not easily defined.

Mark was interviewed with Alan and between them they described clearly how 'engagement' impacted on their learning:

[1] Information in brackets indicates the participant, the interview and the line number at which the quotation began. For example here the quotation is from the second interview with Alan and Mark and began at line 80.

A: "I engage more in Sports Psychology and Coaching"
M: "Well that's cause you enjoy it more isn't it?"

(Alan and Mark 1.363)

Alan's descriptions of his experiences in Statistics indicated that he wanted to learn, even though he felt his engagement to be greater in other parts of his degree programme. Mark viewed university as a 'means-to-an-end'; he had a strong sense of coach-identity and felt a Coaching Science degree would help him realise a career goal. Mark demonstrated one of Mann's (2001) 'theoretical perspectives' of alienation. He disengaged because he did not feel learning Statistics to be important to his self-identity as a sports coach.

Mark described how he had succeeded in the Statistics One examination through memorisation "using charts in front of you going click here...click here...click here" (Alan and Mark 3.92). Mark passed the Statistics Two examination yet could not apply statistical thinking to other parts of his degree programme; a key characteristic of surface learning (Ramsden, 2003). Alan failed the Statistics Two examination, yet a deeper engagement with statistical concepts enabled him to develop skills of interpretation that could be transferred to other parts of the Coaching Science degree programme. An important conclusion at this point is that the Statistics examinations did not assess transferrable statistical literacy, reasoning or thinking, but rewarded algorithmic computation. Mark and Alan's experiences suggested memory to have been more advantageous than the ability to form a conceptual argument.

6.3.3 Donald

Donald was a dyslexic student who lived at home, some distance from the university. He occasionally needed to assume responsibility for a disabled family member. Donald entered university with a GCSE grade C in Mathematics and 220 UCAS tariff points from A-levels. His initial interview was short. He explained his experiences in Mathematics with strict chronology. He used hand movements to aid communication and spoke in short phrases, almost in 'note form'. Donald, like Mark, emphasised the role of enjoyment in learning and described how a poor relationship with one Mathematics teacher had adversely affected that enjoyment. Unlike most interviewees he did not quantify past mathematical achievement.

Donald demonstrated motivation to improve his confidence with Statistics and admitted competitiveness, “I don’t know whether self-satisfaction is… but it’s quite nice being quite competitive to have done something and everybody else is still doing it and I’m off doing something else now… That’s good” (Donald 2.178).

Donald liked to listen, make notes, and then try to apply newly acquired statistical knowledge to a problem straight afterwards, before he had time to forget. He found short questions easy to answer, but longer ones more difficult to solve; indicative of a ‘surface’ approach to learning that Chatzisarantis and Williams (2006) saw as evidence of poor intrinsic motivation. Yet Donald demonstrated considerable motivation to develop and transfer learning to new situations, “I learnt from my own [quantitative research] project…it really helped me for in the future for stuff I’m doing…you can’t really give a lecture on that because every case is different but by practising we got used to looking for certain clues in the data” (Donald 2.114), a characteristic of ‘deep’ learning (Ramsden 2003). It was contra-indications such as these that led Haggis (2003) and Case (2008) to question the value of traditional deep and surface conceptualisations of learning. An important insight for this project is that the type of assessment influenced Donald’s learning. Characteristics associated with surface learning were apparent when he was talking about the Statistics Two examination; the deeper learning needed for statistical reasoning and thinking was evident when he spoke of project work.

6.3.4 Anna

Anna had been educated at home until the age of ten and spent a further six months at home just before her GCSE examinations, due to glandular fever. She spent three years in post sixteen schooling because she changed from an A-level route to a BTec following poor AS-level results. Although Mathematics had been one of the subjects she studied at AS-level, she did not take any examinations, therefore her highest Mathematics qualification was a B grade at GCSE. Anna had 240 UCAS tariff points from her Merit profile in BTec Sports Science and was studying for a degree in Exercise and Health Science.

Anna liked to work, "in a group... that really helped because we got to talk things over, I'm used to that kind of thing too, at home, and having more interaction rather than big classes. And... I think it's really good the way you've got two teachers in that class because it means that everybody can talk to you a bit more" (Anna 1.84). Anna's confidence increased with tutor reassurance that she was learning purposefully. She benefited from constructive feedback, "I think you need to be able to talk to the teacher...on a kind of like equal level kind of thing too...to be able to get feedback ... to be able to feel comfortable" (Anna 1.43), and clearly demonstrated her need to learn in an active, social context.

The significant role of the tutor was emphasised by nine other interview participants. An ability to engender mutual respect and being approachable were seen as desirable attributes of a Statistics tutor. Both of these characteristics partially address the interpersonal anxieties of 'fear of tutor' and 'fear of asking for help' that Onwuegbuzie and Wilson (2003) identified as component parts of statistics anxiety.

6.3.5 Billy

Billy was a quietly spoken, mature, overseas student who gained access to higher education through a Diploma in Sports Therapy from an English further education college. Prior to his UK diploma Billy had studied in his native country, where he had developed antipathy towards number work and computers. During interview Billy raised his voice, used shorter sentences and more assertive language, such as *"forced"* and *"survived"*, when talking about Mathematics, Statistics and computers. Mathematics was a compulsory part of 'A level' study in his native country and "I failed in my A-levels because of Maths and Statistics and anything related to Maths and like er Physics. I failed terribly in all those subjects" (Billy 1.46). He also became estranged from his father following pressure, "my mother wasn't so overbearing that my results had to be good...but [because] there was always a kind of psychological pressure on my dad's part to be, to come out top of the class" (Billy 1.75) and, "after I quit, well, my father was really disappointed and, strange as it may sound he disowned me" (Billy 1.105). After dropping out of the degree programme selected by his father, Billy had started but not completed several other academic and vocational courses in his own country before coming to the UK to study Sports Therapy.

Billy relied heavily on his group of friends to construct knowledge, "In a group session I could put in mind an idea and I'm probably seeing it from my own angle and someone in my group is seeing it from another angle whatever deficiencies are there in my point of view they'll put in some more elements which will start making up something which looks more right" (Billy 2.49). Billy found it frustrating that he could contribute or lead a group to solve a class problem, but found it difficult to successfully address similar problems on his own. He observed that, "Some people in my class are much more comfortable with being tutored and taught what they are expected to know and then work along those lines instead of trying to understand what the whole thing is about. Cause I mean some of them, the way I've seen, they want to go through it just by somehow memorising a sequence, instead of trying to understand they've just memorised." (Billy 2.63).

Billy was concerned about the value of memorising and did not consider it to be learning. However, previous experiences had made him anxious about working with numbers which led him to memorise, unsuccessfully, for examinations. He adopted a method that gave the perception of working faster, but this was at the expense of improving his understanding (Case and Gunstone, 2003). Billy's revision did not enable him to demonstrate the statistical reasoning that he had developed through constructivist group work.

Alan and Mark's description of learning Statistics indicated that they experienced a transmission style of teaching (Jarvis, 2002). Anna, Donald and Billy emphasised the positive effects of constructivist pedagogies experienced in individual and group project work. Alan did not consider working in a group as enjoyable despite his desire to engage with the subject. He could have experienced negativity through lack of support from his friends, Mark, Jack and Tim. A vital issue is that Statistics examination marks did not necessarily reflect the level of engagement with statistical concepts that some interviewees described. Statistics assessment is critically examined in section 6.6.4.

6.3.6 Frank

Frank was a mature student in later middle age whose body language suggested some anxiety about being interviewed; he adopted body positions that included a barrier, for example folded arms or one hand in front of his mouth. He had gained a place on the Sports Therapy degree programme through a mature entry portfolio and had found Statistics One to be "common sense".

Most of Frank's initial interview was factual and he needed encouragement to speak about feelings and experiences. He perceived himself as different from other students and had tried to plan for university by taking some introductory level courses to prepare him to resume learning as he had, "A big, big, a really massive gap… I couldn't have tackled uni straight away" (Frank 2.394). Frank did not like to ask for help as, "in Sports Therapy when I'm, I'm exposed, when we have to do something in class, you know, practical…then in that sort of situation um…they [other students] tend to make me...you know because I'm more mature and that…so that's where they see me you know so I just don't want to expose myself again" (Frank 2.169).

Alan, Mark, Donald and Anna all stressed the importance of tutor interaction. Frank considered the help offered in Statistics either inaccessible or counterproductive "there was no point in help of that kind (pause) I think that you guys are pretty (pause) You couldn't help me" (Frank 2.178). Frank felt communication barriers to be his "fault" for being "different" and blamed himself for most of what he explained. Interpersonal anxiety (Onwuegbuzie and Wilson, 2003) may have contributed to Frank's sense of frustration. He was alone among the interview participants in feeling unsupported by his tutors and his statistical literacy did not develop beyond the "common sense" that he brought to Statistics One. He exhibited Mann's (2001) "Leave me alone" alienation which may have developed from a self-inflicted isolation because he emphasised his differences and clearly felt them very keenly. Billy and Frank were both mature students who spent much of their time in university together, yet Billy did not express the same sense of isolation from his fellow students or from tutors.

6.3.7 Colin

Colin transferred to the university at level five, to follow the Coaching Science degree programme. He completed a year of study on a similar programme at a different university where he "didn't like the way it was being taught" because he felt that "they were doing like their masters or whatever and... they didn't really care about what we thought" (Colin 1.158 and 1.176). When he volunteered to be interviewed Colin had been at the university for three weeks. He had a grade C in GCSE Mathematics and A-levels in Sports Science, History and Information Technology.

Colin's first interview focussed heavily on measurable achievements, including higher than average 'SATS' results at eleven years old. He did not like associating himself with difficulties in Statistics and spoke of problems using the third person. With a mixture of confidence and uncertainty he articulated a preference for learning within a structure, "it's quite a difficult, difficult thing to like" but "you gave us a structure of what we need to do. I then knew what you wanted from me and I could go ahead and do it...a starting point that then I could, I would jot down notes from it and think right this needs thinking about" (Colin 2.156).

Colin liked to feel supported but was gaining confidence to learn autonomously (Ramsden, 2003; Jarvis, 2002). He perceived this to be an improvement on his level four experiences where, "we were given all the results and then we put it into our lab. report" and "they would tell you go and read research methods books um and then um just explain it to yourselves" (Colin 1.78 and 1.117). Colin's insecurity with this fragmented approach may stem from Pfannkuch and Wild's (2004) assertion that statistical thinking needs to be taught as a separate and distinct skill. Individual autonomous study needs to be preceded by activities that build confidence and inspire a desire to know. The relationship between self-efficacy, confidence and motivation is pivotal in students' engagement with Statistics. Interviewees' perspectives on motivation and confidence are evaluated in section 6.6.2.

6.3.8 Freddy

Freddy entered the university to study Exercise and Health Science after a year in employment. He had a GCSE grade B in Mathematics and 200 UCAS tariff points from A-levels. He appeared embarrassed by his A-level achievement and stressed that, "it was just being too lazy…concentrating on other things. I started working and I didn't think it was that important at the time" (Freddy 1.23).

Freddy's responses were somewhat 'brisk'. He offered limited information focused precisely on what he understood to be the purpose of the question. He perceived Statistics to be, "quite laid out, quite simple….it just continued on in a linear fashion" (Freddy 1.92) and indicated that he considered a good memory an asset to learning. He appeared to use memorisation as a precursor to deep learning (Webb, 1997). Lane, Hall and Lane (2004) reported that students found reading about Statistics counterproductive, but Freddy found statistical theory to be "quite light reading, not too… jargonese" (Freddy 1.96). He could see the relevance of Statistics to Sports Science more readily than most of his peers and attributed this to reading journal papers regularly. Like Anna, Freddy's, "personal experiences [of Statistics One] were quite good. I think cause you know when you're all in a team…so there's communication in between you all so you are all learning" (Freddy 1.111). Freddy clearly preferred to construct his knowledge with his peers, although during a second interview, he indicated that he learned, "different facets from each one [type of teaching strategy]. I think a combination's good" (Freddy 2.53).

Freddy differed from the rest of the interview participants because he engaged with directed reading for Statistics. He also read diligently for other parts of the degree programme and was able to make connections that were not apparent to other students. These activities exposed Freddy to situations through which statistical literacy and reasoning would improve (Garfield and Ben-Zvi, 2007; Garfield and Ben-Zvi, 2004; Gal, 2002).

6.3.9 Yvonne

Yvonne came to the UK to study for A-levels having previously attended schools in France. She took GCSE Mathematics alongside A-level study and gained a grade C.

Yvonne had 360 UCAS tariff points and was the only student from the Sport and Exercise Science degree programme to volunteer to be interviewed.

Yvonne was a private person who expected high standards from her tutors and from herself. She used the third person throughout interview, particularly to distance herself from problems, "everyone might have been getting more worried about the exam and that they probably didn't understand that much…"(Yvonne 2.243). She was driven by the desire for a specific degree classification and was motivated to do whatever necessary to reach the standard of work that would secure that classification; a source of external motivation that Newstead and Hoskins (2003) deemed to be as effective for academic achievement as intrinsic motivation. Her diligence was apparent in her application to the module.

Yvonne's approach to learning was organised, almost regimented, a "need for routine". She preferred every taught session to follow the same pattern so that she knew what to expect from the learning situation. This preference contrasted with that of most other interviewees, who indicated that it was the variety of teaching methods that sustained their interest in Statistics; a subject they expected to be dull. Yvonne talked about "doing" and "remembering", as Frank did, and was of the opinion that tutors should be "enforcing" learning. During the first contact with a new discipline Yvonne demonstrated a need for a high level of direction in order to be able to transfer learning to new situations (Carnell and Lodge, 2002). She, like Freddy, appeared to use memory to provide the foundation for later, deeper learning (Webb, 1997). Yvonne's account supported Haggis's (2003) claim that students need some initial spoon-feeding to guide the development of skills akin to statistical literacy through "situated, working understanding" (p.101). This support is particularly important when students are working outside their main subject discipline, in cognate fields where they feel insecure. Yvonne and all the other interviewees except Hazel (see below) expressed doubt about their ability with Statistics. Yvonne voiced an anxiety that she might not achieve the grade she aspired to, for others it was fear that they might not reach the pass mark. The significance of this lies in students' focus on assessment. Students prioritise learning that they perceive to benefit their module grades; learning for assessment, not necessarily for personal development. Assessments need to be constructed so that the learning students perceive to be important resonates with the desired learning outcomes of the module. Evidence from Alan and Mark (section 6.3.2), suggested that students did not pursue conceptual understanding or the development of statistical literacy, in preparation for the Statistics examination.

6.3.10 Hazel

Hazel had the strongest background of her cohort in Mathematics and was in the top six students for UCAS tariff points. She had an A grade at GCSE and a B grade for A-level Mathematics and 420 UCAS tariff points. Although Hazel had a quiet demeanour, very still and with her hands in her lap, her face registered considerable enthusiasm for Statistics. She showed clear enjoyment of calculation, but less enthusiasm for the reading that informed the application of statistical theory to the Sports Science context.

Hazel had confidence in her statistical ability, "there were examples that we had during the week that I couldn't do so it was obviously hard enough that the hardest person, that the strongest stats person could find it hard" (Hazel 2.111). She saw this as a beneficial challenge. Hazel indulged a preference for calculation and Mathematics but provided little evidence that she had developed statistical reasoning. She did not appreciate the relevance of Statistics to Sports Therapy. Instead, she demonstrated mathematical reasoning; computational skill which lacked contextualisation (delMas, 2004). In contrast, Freddy and Anna showed considerable appreciation of the application of Statistics in health and exercise contexts. They provided examples of how a conceptual understanding of Statistics enhanced other aspects of their degree programme, and their ability to communicate health issues to the wider population. The significance of this is the insight that Hazel's description provided into the teaching of Statistics Two. Her confidence with mathematical skills enabled her to enjoy the sessions, "it's the only thing, erm the only session that I really looked forward to going to cause there's others like my Sports Therapy ones that I get quite nervous about cause I know they're hard and whatever" (Hazel 2.155). Students who had less mathematical confidence did not experience such success or enjoyment. The balance between analytical procedures and conceptual problems has long been an issue for Statistics tutors (Holmes, 2000). It is crucial to review regularly the structure and interrelationship of modules to improve the relationship between computational procedures, statistical literacy, and professional Sports Science knowledge.

6.3.11 Jack

Jack was a Coaching Science student and a member of a close social group who all volunteered for interview (Alan, Mark, Tim and Jack). Jack entered university with a grade C in GCSE Mathematics and 200 UCAS tariff points from French, Politics and Business Studies A-levels. Consequently, both Sports Science and Statistics were new disciplines for him.

Like Alan, Jack used language associated with school to describe his experiences of Statistics. He gave little evidence of taking control of his own learning, "we rely on you quite a lot as well. When we get stuck we waste a lot of time" (Jack 2.49). He wanted workshops to be compulsory and spoke of Statistics classes largely in terms of tutor activity, although he emphasised that he wanted these sessions to be about, "why I'm doing that…that's why I find lessons easier with you than with A*** ... I'd rather know why do I do that?" (Jack 2.363).

Jack preferred to learn statistical concepts in a culture of dependence whereas Tim, interviewed with Jack, maintained that students had to be responsible for their own learning. Jack was unable to take that responsibility in a statistical context, because he could not see the logic that Freddy identified in the progression of Statistics teaching. Teaching appeared disorganised which made it harder for Jack to link learning with prior experiences. His strong sense of self-as-coach created a further barrier to statistical literacy as he distanced himself from anything that threatened that identity (Mann, 2001). He demonstrated a mixture of perception and the beginnings of statistical reasoning juxtaposed with a lack of interest in anything that interfered with his focus on coaching, which was his *raison d'être*.

6.3.12 Tim

Tim entered university with a grade C for GCSE Mathematics and 260 UCAS tariff points. He was the only student interviewed to have failed the Statistics One examination, with 28%, and had undertaken reassessment to progress to level five. Tim required direct questions to elicit information. By the second interview there was evidence that Tim was more relaxed, for example he helped to carry tea and coffee from the café counter to a table.

Tim was easily distracted. His interview responses demonstrated an inability to focus on key parts of the module. He had a short concentration span and provided evidence of enthusiasm for interesting contextual anecdotes without an appreciation of theoretical content; a characteristic associated with Mann's (2001) alienation through estrangement. Tim said he would have appreciated conducting more of the statistical tests by hand yet expressed reservations about his ability, "we had to do a Statistics module in our GCSE [Mathematics] and I struggled with that as well" (Tim 1.110). During interview, he contradicted himself on several issues, which emphasised his inability to grasp statistical logic.

Tim felt a responsibility for his own learning and on several occasions indicated that each student should be expected to learn autonomously. He did not share other interviewees' opinions that the tutor was an important part of learning but believed that there was little higher education tutors could do if students chose not to take responsibility, "You take out what you put in it's a personal choice as to, to what grade you get really" (Tim 2.531). He employed several analogies to explain tutors' inability to make students complete required work; "You can show us the door but you can't lock it" (Tim 2.537). "You can only give someone the fabric you can't work the machine" (Tim 2.558). Tim appeared to hide his insecurity with Statistics behind either silence or complex, allusive communication. His emphatic position about students' responsibility for their learning legitimised his refusal to attend voluntary workshops or tutorials, and to hide the extent of his difficulties. Despite his reluctance, Tim, together with Jack, Alan and Mark, acknowledged the value of stand-alone Statistics modules for the opportunity to learn statistical content. They thought that to integrate Statistics into Physiology, Biomechanics and Psychology modules would render it invisible, and consequently impossible to understand; an assertion of Pfannkuch and Wild (2004).

Tim was one of three of the twelve interviewees who did not consider the tutor to be an important facet of the learning experience. Otherwise, students identified mutual respect, personal interest and patience to explain things in different ways to aid understanding, as characteristics that inspired a desire to please. The wish to succeed was tempered by the participants' association of Statistics with Mathematics. In accordance with findings from a study of Finnish students, interview participants perceived previous mathematical achievement as pertinent to potential statistical literacy (Murtonen and Titterton, 2004). Evidence of possible advantages in assessment was provided by analysis in Chapter Four (table 4.4) and Chapter Five (section 5.3) which found that the mean Statistics marks increased with Mathematics qualifications higher than the requisite grade C. These differences were statistically significant, suggestive of a situation that could be expected to recur in future groups of students if the same pedagogic strategies and assessment modes were employed. Statistical analysis of entry qualifications in Chapter Four indicated that most Sports Science students entered the university with grade B or C in GCSE Mathematics, yet interviews clearly demonstrated the diversity of mathematical experiences that contributed to students' GCSE grades. The next section explores students' perceptions of the effect of prior mathematical understanding on their statistical literacy. The thematic sections that follow also analyse students' experiences in greater depth.

6.4 Participants' previous experiences with Mathematics

Two students, Anna and Donald, missed a large part of their secondary schooling through injury or illness. Both experienced feelings of mathematical inadequacy on their return to school, "during that six months they learned lots of new things like quadratic equations and whatever and that meant by the time I came back we weren't learning them any more we were using them or working on with them and my teachers never really had time to, cause I missed the whole year, they never really had time to work over those things again....so suddenly I found Maths a lot harder so I didn't enjoy it as much" (Donald 1.16). Jack also felt he had incomplete mathematical knowledge, as a result of a succession of different 'supply' teachers over a short period of time. Frequent group changes and poor class behaviour also affected his engagement with Mathematics, "if you are stuck down the lower sets then sometimes you get all sorts of idiots who disrupt Maths lessons as well and you never really learn a lot … so in three years I'd been in almost every group" (Jack and Tim, 1.26). Jack, Donald and Anna all completed GCSE Mathematics in year eleven and might be seen as similar, yet the accounts provided by these students indicated considerable diversity of experience.

Yvonne gained GCSE Mathematics as part of her sixth form studies, but found her experiences insufficient preparation for Statistics, "In France, Maths is very more based upon algebra, trigonometry and geometry and stuff like that, it's not how the English GCSE Maths is it's completely different to how the French teach their Maths…to get into uni because obviously you have to have GCSE English and Maths, so I did that in my year 13 and that's when I had to start learning about mean, median and mode and things I'd never even heard of" (Yvonne 1.16 & 1.24). Billy was also educated overseas and had a fear of Mathematics, "My earliest memory of it is, I still remember whenever there used to be a Maths test er, probably when I was in class 3, I used to make up excuses not to go to school" (Billy 1.8). He was intimidated by Statistics, and employed violent language to describe experiences, "it was forced down my throat" and "a fear". Although Yvonne's experience had caused initial difficulties with Statistics, Billy's background promoted a more extreme alienation from the subject through anxiety and pressure.

Over half the students interviewed indicated that there was something in their past experiences with Mathematics that had caused them concern or shaken their confidence. Onwuegbuzie and Wilson (2003) identified this lack of confidence to be a source of statistics anxiety. Interviews revealed that self-efficacy for Mathematics was not necessarily reflective of achievement. Colin perceived himself to be "quite good", achieved a grade C at GCSE, and felt prepared to address statistical work. Mark had a personal tutor outside school and Alan had attended extra classes in school in order to pass GCSE Mathematics with a grade B. Alan explained that, "if I hadn't gone to those after school lessons I'd have been way behind probably on the rest of the people in my set" (Alan and Mark 1.82). Alan and Mark appreciated the effort required to achieve a B grade and as a result felt their mathematical ability to be limited. Those interviewees who had grade A or B expressed their experiences in terms of enjoyment and interest rather than confidence. Those with grade C spoke mainly in terms of outcome suggesting a sense of achievement at having 'passed' which boosted their confidence. These individual differences may partially explain why the effects of Mathematics qualification identified in sections 4.6, 4.7, 5.4 and 5.5 were not consistently positive for higher grades. The critical point is that a focus on assessment outcome is equated with learning transient, factual knowledge, perceived to relate to Mathematics (Lane, Dale and Horrell, 2006). For most interviewees, the memorisation of algorithms to meet an assessment goal inhibited the development of effective statistical literacy.

6.5 The evolving relationship between Statistics and the developing professional knowledge of Sports Science students

Hazel perceived Statistics to be a branch of Mathematics, and she clearly conveyed her enthusiasm for it. She admitted undertaking little reading for any part of the degree programme, and her perception of the relevance of Statistics was limited to academic need, "I can't see that I am going to be using it that much when I'm actually in the field of work, but you need it for your dissertation don't you? To actually get the degree." (Hazel 1.75). All three participants following the Sports Therapy degree programme had difficulty relating Statistics to their professional role as future therapists. They had a clear expectation that their professional careers would entail practical patient assessment and treatment but did not consider the benefit of statistical literacy to continuing professional development. At the time of data collection Sports Therapy lecturers at the university did not undertake research projects, but *were* engaged in clinical practice. This situation reinforced the perception that the Sports Therapy community was care focussed rather than engaged in academic research. These students' main exposure to Statistics was in Physiology and Biomechanics modules, which were also perceived as non-dominant subjects, peripheral to the core professional knowledge of the sports therapist.

Some Coaching Science students viewed their degree programme as vocational preparation for a coaching career. They equated coaching with practical skills training and did not consider reading research reports to be a part of a future professional role. Like the participants from Sports Therapy they demonstrated Case's (2008) characteristics of alienation from learning Statistics due to their academic community and shared Hazel's opinion that Statistics was only useful to satisfy the demands of the degree programme (Becher and Trowler, 2001). Coaching Science students, for example Colin and Donald, who did not have a strong sense of coach-identity were better able to understand the value of statistical literacy within their professional development, "I didn't want to do Stats... but then realised that if I was going to work in the sport and exercise science environment then I'd need some basic knowledge of Stats" (Donald 1.29).

Anna's discovery that "you find that you're using it in other subjects and you see it then and it's kind of...ah now I understand where you're coming from" (Anna 2.89) did not occur for any interview participants until level five. Yvonne described how "putting it in context of something we had to do, and that was important for us, and it just, everything kind of gets a bit more clearer... it just gets a bit 'Oh wow I'm actually using this'" (Yvonne 1.355). The crucial element of Yvonne's statement is "and that was important for us". Students analysed sport-related data in Statistics classes, but these lacked the personal relevance that Yvonne identified as necessary to enhance statistical literacy; the emotional investment identified by Snee (1993). Interviews provided evidence of changing attitudes to Statistics as students progressed from level four to level five. Interviewees' limited Sports Science knowledge at level four hampered their appreciation of the need for statistical literacy. Some students explained how the relationship between the dominant and non-dominant disciplines became clearer as they learned more Sports Science and more Statistics at level five. Other participants remained sceptical about the value of Statistics to their studies and to their future professional roles.

'Real' Sports Science problems require statistical literacy to lend meaning to the situation and can enable students to relate learning to their developing professional knowledge. Students with a strong practical, vocational perspective appeared unable to develop an appreciation of the benefits of statistical literacy beyond the university setting, which affirmed the findings of Lane, Devonport and Horrell (2004). Only Anna and Freddy, both Exercise and Health Science students, and Donald, reading Coaching Science, perceived Statistics to be a skill transferrable to a future role in employment. This limited awareness of the need to develop statistical literacy and reasoning adds complexity to the balance of components included in modular programmes. Statistics is dependent on other disciplines to give it meaning, so it is vital that students understand the value of the subject in their particular context if they are to develop statistical skills.

6.6 Students' experiences of learning in the Statistics Two module

6.6.1 Pedagogic strategies

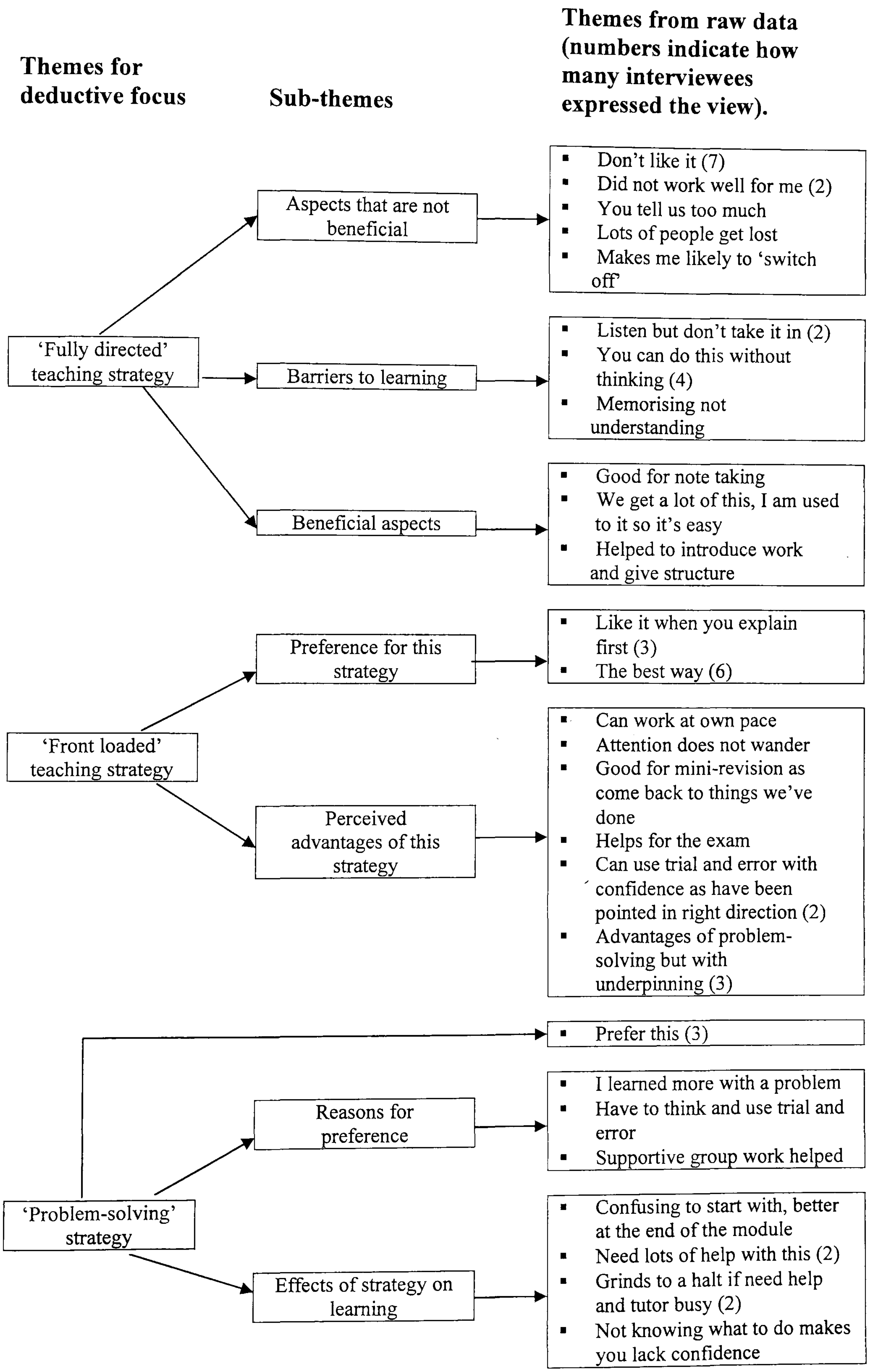
Interviewees experienced three different, potentially overlapping pedagogic strategies during Statistics Two. These were explained to them as:

- Fully directed: whole class activity led by a tutor;
- Front loaded: initial guidance and classroom discussion followed by group or individual work on a problem;
- Problem solving: work on a sports science problem with no prior guidance towards a solution.

Tutors aimed to maintain constructivist perspectives on learning and teaching through each of these strategies. They aimed to provide practical experiences within which students could share prior knowledge and build solutions to problems (Mvududu, 2005; Holmes, 2003; Carnell and Lodge, 2002).

Second, semi-structured, interviews, elicited participants' experiences of learning Statistics over the preceding ten to twelve weeks (the schedule can be found in appendix *vi*). A deductive thematic analysis of students' perceptions can be seen in figure 6.3. Questions from the interview were used to identify sections of interview response related to each teaching strategy. Raw themes were listed using the original words and grouped into sub-themes as explained in Chapter Three section 3.4.3. The column on the left shows the teaching strategy that prompted the response.

Figure 6.3 Deductive thematic analysis of students' perceptions of the teaching strategies used in Statistics

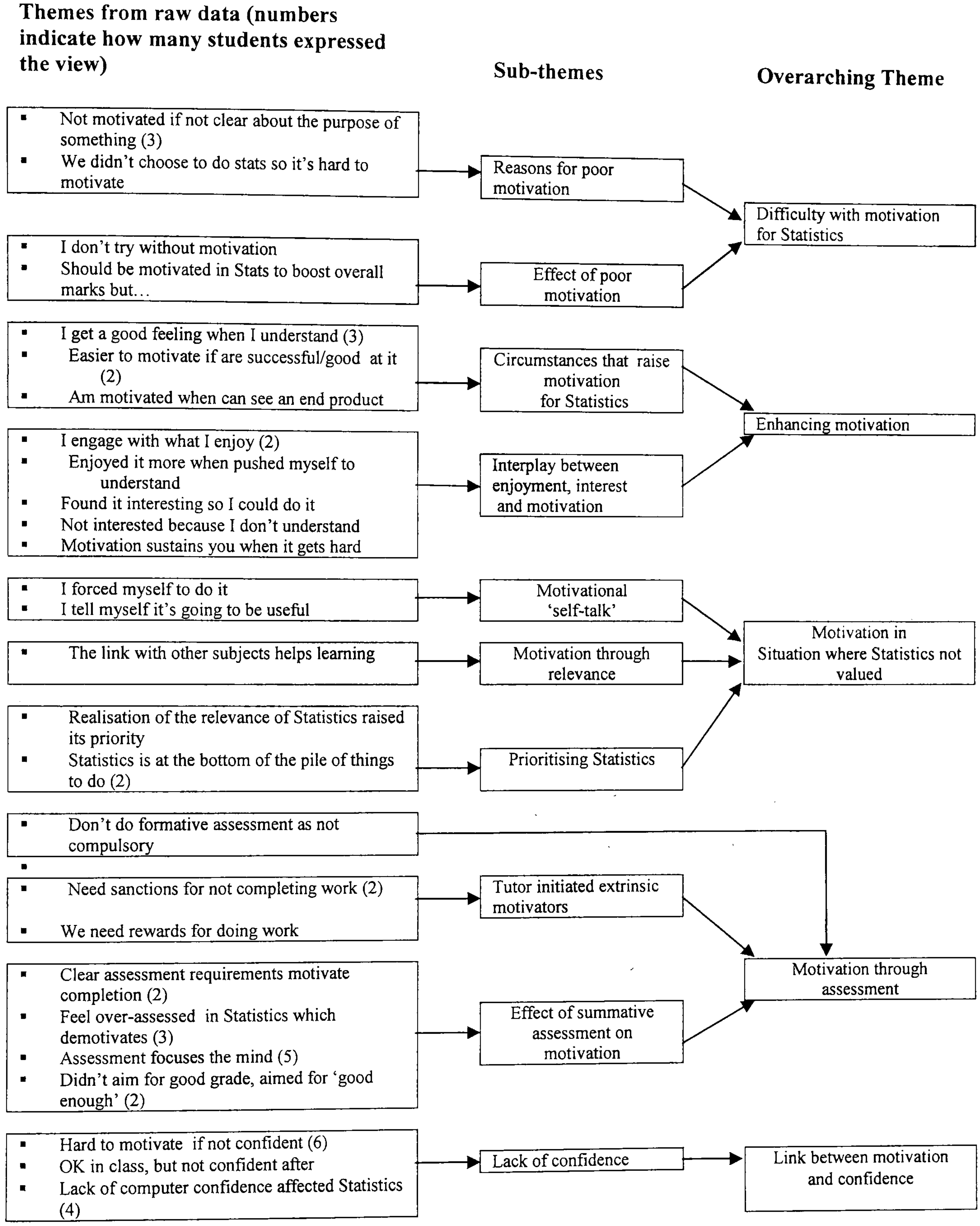


Students were almost unanimous in their dislike of the 'fully directed' strategy. Yvonne's opinion that, "We get to the results but we don't really know how we got there and we don't really know what it means cause we didn't really pay attention to what was going on in between" (Yvonne 2.72) encapsulated the feelings expressed by most participants. Several interviewees indicated a preference for the 'front loaded' teaching strategy as the guidance provided gave them confidence to work in groups. Reluctance to engage in 'problem-solving' was attributed to anxiety lest they were 'wrong'. Colin had "a good feeling when I know I know" (Colin 2.509), although Alan pointed out that "if you're not confident in Stats then it's hard to motivate to do it" (Alan 2.201).

6.6.2 Motivation

Students' perceptions of their motivation to learn Statistics are summarised in figure 6.4. The figure illuminates the importance of enjoyment and interest on both motivation and confidence. There was little evidence of intrinsic motivation among the respondents. Students explained how they were more motivated to undertake work they enjoyed, but most qualified this as excluding Statistics. An insightful combination of effects can be seen in figure 6.4; students "feel good" and "enjoy" Statistics when they understand, but have to "push" themselves to do so. However, without initial motivation they are less likely to "force myself to do it". Many of the comments suggest a need for the tutors to be proactive in the provision of extrinsic motivators that build a sense of self-efficacy in relation to statistics (Lane, Hall and Lane, 2004). If tutors are successful in the stimulation of interest or enjoyment; if they can achieve an assessment balance that is perceived as relevant; if they can use feedback to increase confidence as advocated by Newstead and Hoskins (2003) and Boud (1995), then intrinsic motivation for Statistics could increase.

Figure 6.4 Inductive thematic analysis of students' motivation for Statistics



Hazel was the only participant to look forward to Statistics; all the others expressed a need for incentives to make them complete work. Participants suggested measures that tutors could take to extrinsically motivate students rather than assuming responsibility themselves. Suggestions included, offering rewards (even chocolate), and making tasks compulsory, "They just had to do it and… it's forcing people to do something but at the end if they aren't gonna learn for themselves they're not gonna push themselves on their own thing" (Yvonne 2.308).

Mark considered the personal guilt about not completing work to be a form of motivation "she'd never say anything, you'd just feel guilty if you didn't do it" (Mark 1.36). Anna identified similar motivation as "If I'm close to someone I want to do well by them kind of in a way not to disappoint them I guess" (Anna 1.67). Mark clarified his 'guilt'. He explained that as ability to understand new concepts decreased, interest waned, and guilt ceased to be an effective motivator. This is indicative of a complex interrelationship between competence, confidence and motivation. Previous studies that employed quantitative methods had identified these three attributes as vital ingredients for learning Statistics (Chatzisarantis and Williams, 2006; Lane, Devonport and Horrell, 2004; Lane, Hall and Lane, 2004). Interviewees illuminated *how* they perceived motivation to affect their learning.

Donald could see the relevance of Statistics to his degree programme and was motivated to complete computational tasks, but not the required reading. He did not "like learning about stuff that I can't see how you can use or how it fits in with the degree" (Donald 1.41). Jack did not prioritise statistical work and attributed this to a lack of relevance of Statistics to the Coaching Science degree programme. He explained, "I'd like to say that I've worked really hard in trying to do it. But I'd just rather struggle and get an alright grade than really put my heart and soul into it and try to get an amazing grade" (Jack 2.540).

Motivating students to complete private study for Statistics was a persistent problem. Mark and Alan suggested that each week a group of individuals should be advised that they would be required to present their findings from an investigation or task to the rest of the group. They felt this would act as beneficial reinforcement at the beginning of the next class and that, "then you'd definitely do it for one week wouldn't you. If it was our group then you'd do it and we'd come and check with you [tutor] like is this right because we'd got to present it to the class. You don't want to be presenting something that's completely wrong so you'd definitely do it that week and then if we did it with the others in the class then they'd have the answers written down and then, they'd probably be more easy to ask us questions if we were sure than to ask like you lot" (Alan and Mark 2.451). Alan and Mark were enthusiastic about the responsibility and autonomy inherent in their suggestion. Colin identified a further benefit in Alan and Mark's idea as, "explaining things to people is also a way of learning themselves" (Colin 2.260). The support provided through workshops and tutorials may encourage students to rely too heavily on tutors and dismiss private study and peer support as unnecessary. The ready assistance provided could be counterproductive as it denies the student autonomy that Ryan and Deci (2000b) claimed to increase intrinsic motivation.

Few Sports Science students are sufficiently intrinsically motivated to conduct statistical analyses for the pleasure of solving a problem. However, the feeling of achievement that follows the accomplishment of a challenging task can be an effective extrinsic motivator that increases self-efficacy and increases intrinsic motivation for further statistical work. The balance of difficulty is crucial. Too simple a problem can be perceived to be patronising, but complex problems can undermine confidence and reduce self-efficacy and motivation if students consider them too difficult to solve (Bandura, 1997). Newstead and Hoskins (2003) claimed that judiciously selected extrinsic motivators can be more effective in the pursuit of academic success than intrinsic motivation. This assertion is particularly apposite for Statistics where students admitted they neither prioritised work nor applied themselves fully to private study. Thoughtful Statistics assignments clearly focussed on required learning outcomes are likely to motivate most students as they aspire to particular degree classifications (Ramsden, 2003).

6.6.3 Statistics anxiety

Frank thought he was "THE slowest" student and exhibited signs of anxiety in both interviews and in class situations. By trying to memorise as much as possible Frank found that he did not "know much about Statistics and there's not much room in my head" (Frank 2.368). Frank's anxiety impaired memory because he was unable to control it (Onwuegbuzie and Wilson, 2003). Onwuegbuzie (2004) linked fear of failure to procrastination which adds a time pressure to learning. Under such circumstances students perceive memorising as quicker than conceptual development. Both Frank and Billy were anxious, mature, Sports Therapy students who described their learning in terms of "absorbing", "revising" and "reinforcing" whereas younger students used "interest" and "thinking"; words that suggested more active, experiential learning. Frank's and Billy's solitary learning strategies added to their difficulty. Billy valued group work in class situations, but personal study habits appeared to nullify the perceived benefits.

Donald explained how he used resources to assist learning as he built new knowledge onto an initial "mental image", "I've still got that diagram of um... that we did on the board... I've still got that and it's dead useful. Now I've got a kind of mental image in my head and I don't need it" (Donald 2.122). Donald had produced his "diagram" for himself during a seminar so it had meaning for *him*. Over-dependence on educational 'props' in the form of handouts can curtail learning. Participants gave many examples of what they would like tutors to do to help them to learn. More handouts, worked examples, annotated computer output and flow diagrams to help decision-making were all suggested as methods to support learning. However, students indicated they wanted these resources to use as 'recipes', an approach which is more likely to inhibit learning and increase anxiety as students quantify what they have yet to master (Onwuegbuzie and Wilson, 2003).

6.6.4 Assessment

Interviewees took a Statistics examination at the end of December 2006. Assessment anxiety resulted in greater attentiveness in the final week of the module, "people realised the exam is quite close and they've got to start listening" (Alan and Mark 2.257), "Crunch time...it was right near the exam" (Donald 2.191). Tim viewed the assessment mark as the goal of the module and thought teaching should reflect that focus, "just getting the best exam results for the greatest number of people. I think it's just important that the most effective method for the most people is used" (Jack and Tim 2.100).

Tim did not value statistical literacy; he sacrificed learning in the desire for the best possible grade. Senn (2007) cautioned that a 'course' should not "exist as a preparation for the examination. The examination is a means of assessing understanding of the course" (p.3). Unless an assessment is carefully designed to test conceptual learning rather than memory, a high mark or grade may be achieved with little or no learning (Ramsden, 2003; Jolliffe, 1997). Students limit learning to what *they* perceive an assessment to require, which will almost certainly not be the same as the *tutor's* perception. Therefore, assessment needs to be focussed carefully (Boud, 1995; Race, 1995). This is vital for Statistics. Interviewees reinforced the researcher's empirical observation that students take the fastest route to a pass mark in that subject. The Statistics marks analysed in Chapters Four and Five, together with information gathered from interviews, provided evidence that the efficacy of an examination to assess students' statistical literacy was questionable. The integration of these findings informed some recommendations for change articulated in Chapter Seven.

A very important and unforeseen finding was that students did not fully appreciate the aims of formative assessment. The lack of purposeful understanding diminished the potential for learning that was inherent in the work. Donald found that he had difficulty understanding the requirements of longer tasks but said that "it was only a few words that people needed to say and suddenly it all flooded in and it was very easy." (Donald 2.254). He experienced a similar problem in the Statistics examination, which indicated that he had not learned productively from his formative experiences.

Tim thought formative assessment was a 'knowledge audit' for the benefit of tutors, "the teachers or lecturers or seminar leaders or whatever would have a good idea of where everyone's at" (Jack and Tim 2.182). Jack added that "It's a bit late as well, when you find someone doesn't understand a small bit, it's a bit late at the exam time to find out" (Jack and Tim 2.191). Tim wanted short assessments every week in order to compare his progress with that of the rest of the group "When you get 80% then 80% is better than the person who gets 20%" (Tim 2.190). Tim demonstrated a desire for 'operant conditioned' learning with contiguous feedback on small, sequential tasks to influence his subsequent learning behaviour (Skinner, 1968). However, published evidence suggests that a grade alone does not promote further learning (Holmes, 2000). Freddy was the only interviewee to recognise formative assessment opportunities as useful because they, "acted as a test of situations to see what you don't know and what you do know and what you need to find out" (Freddy

2.190). Freddy's description indicated a quantitative audit of knowledge similar to his peers, but with the suggestion that he was prepared to act on feedback.

6.7 Conclusion

All students indicated that assessment was of vital importance to them and that statistics assessment was a particular source of anxiety. For some this was a pressure to make the 'right' decision quickly in a time constrained examination setting; for others, a perceived need to remember a large amount of information. Each manifestation of anxiety suggested that students considered Statistics to consist of large quantities of factual knowledge. Evidence of memorisation for examinations and poor use of formative feedback opportunities suggested that module assessment procedures did not enable students to develop effective statistical literacy for Sports Science. Results from Chapters Four and Five and interview responses provided evidence that the examinations for both Statistics One and Statistics Two tested and rewarded computational skills and adherence to algorithms. The examinations appeared to encourage students to adopt a surface approach to learning the procedural facets of statistical literacy and to overlook the need for statistical reasoning and thinking.

Some interview responses provided evidence of improved statistical literacy but not necessarily the ability to apply it. Hazel was very confident with Mathematics, gained 98% in the Statistics Two examination, understood the mathematical concepts behind the procedures but, "I could work with the figures, come out with results and everything, but I still wasn't quite sure why I was using each test." (Hazel 2.83). Freddy and Anna demonstrated a clear understanding of how Statistics applied to their field of expertise, "putting it into context really does help. The fact that it really does relate to sport so much definitely does help" (Anna 2.79). These students asked more questions in class situations, explained their need to know why they were using specific techniques and were better able to interpret statistical information. Several interviewees spoke of a desire to understand why they were using Statistics. However, most students explained that they simply learned enough to "get by" in assessment. This resonated with the findings of Lane, Dale and Horrell (2006).

Senn (2007) claimed statistical concepts of vital important to his students, however he was educating future statisticians. Understanding statistical procedures may be less important for Sports Science students than application and interpretational skills. Perhaps it is easy for academic statisticians in a Sports Science setting to attach greater importance to statistical techniques than they should. Students who have an ability to apply statistical reasoning meaningfully to their professional discipline should be better equipped than those who are mathematically talented. However, if this is the case, assessment must enable a student who can reason statistically to do as well, if not better, than those with high levels of mathematical competence. The insight into statistical thinking, given by Freddy, Anna and Hazel, suggested that assessment through examination did not differentiate in this way.

The assumption on the part of students that a score of right and wrong answers was adequate feedback for both formative and summative assessment limited the benefit gained from written feedback. Similarly, Boud (1995) and Race (1995 and 1993) claimed that student involvement in the formulation of assessment criteria or peer assessment of formative tasks should be considered, to raise awareness of the skills necessary to do well in a summative assessment. This involvement could be used to guide students away from a computational focus towards a recognition of the value of statistical literacy, reasoning and thinking. Crucially, the final assessment should not simply audit prior learning but require students to question, evaluate and interpret numeric data (Jolliffe 2007; Garfield, 1995). Students could succeed in Statistics Two because they knew what was expected of them, yet had serious misconceptions about Statistics. An assignment which requires an individual to make decisions and draw conclusions in a disciplinary field of personal interest is more likely to stimulate engagement with the statistical learning needed to enhance those decisions.

Quantitative evidence from Chapters Four and Five supported the hypothesis that the grade achieved at GCSE Mathematics affected Statistics marks. Higher grades did not necessarily equate to increased self-efficacy and greater confidence with statistical tasks. The diversity of student experiences that led to GCSE success indicated a need for statistical pedagogic strategies to provide a breadth of learning opportunities. Evidence from interviews demonstrated transmission models of teaching to be ineffective in such circumstance. Crucially, students perceived a transmission model of teaching to occur more frequently in the module than tutors planned. A structure that encourages students to share experiences and learn from each other through problems that have relevance to their disciplinary area is better able to be inclusive and supportive. These approaches help to combat the perception of Statistics as "daunting" and heighten awareness of the link with dominant Sports Science knowledge.

Students' accounts of their experiences in Statistics Two evidenced close links between motivation, confidence, and anxiety. These links resonated with previous quantitative findings (Chatzisarantis and Williams, 2006; Lane, Devonport and Horrell, 2004; Lane, Hall and Lane, 2004; Onwuegbuzie and Wilson, 2003; Onwuegbuzie, 2000b). Students who were less anxious found Statistics more interesting and were likely to have higher levels of motivation to engage with further statistical problems. Enjoyment was emphasised as a key component of such motivation. Students described the feeling of pleasure derived from completing a challenge or making a link between Statistics and developing Sports Science knowledge. These bonds between different parts of a modular course are essential to the professional development of the sports scientist. The motivated students developed statistical literacy without the angst expressed by those who saw Statistics as a series of numeric algorithms to be memorised and applied to order. For example, extrinsic motivators such as Donald's pleasure in solving a problem ahead of other students, or Yvonne's aspiration to an upper second degree classification, were more effective in the development of statistical literacy than Hazel's intrinsic motivation to indulge in her enjoyment of calculation, because she perceived Statistics as Mathematics. The identity of Statistics can be problematic.

The challenge levelled at the Statistics tutor is to provide learning experiences where students can develop confidence with the subject knowledge in a manner that has meaning for professional practice. A teacher-centred, transmission model caused students to disengage, they "switched-off". Problem-solving without tutor direction caused some students anxiety. Six interviewees preferred a 'controlled' constructivist approach to experiential learning through group work and small scale projects, as advocated by Holmes, (2003) and Mvududu (2005).

It is vitally important to develop pedagogic strategies to improve Sports Science students' experiences of learning Statistics, by addressing the key issues of motivation, confidence, assessment and anxiety. The evolving relationship between statistical literacy and the developing professional knowledge of the Sports Science student plays a crucial part in motivation. The central tenets of statistical literacy in academic settings must be clarified, particularly those for Sports Science. As this dominant professional expertise progresses from level four through to level six, it should be employed as a catalyst for the enhancement of statistical literacy. This strategy could effectively reduce anxiety as students work productively towards meaningful interpretations of numeric data. These areas are considered in detail in Chapter Seven which seeks to draw the quantitative and qualitative strands of this project together and relate them to learning theory and professional practice. Overarching conclusions will be drawn and recommendations made for evidence-based professional practice and further areas of research.

Chapter Seven

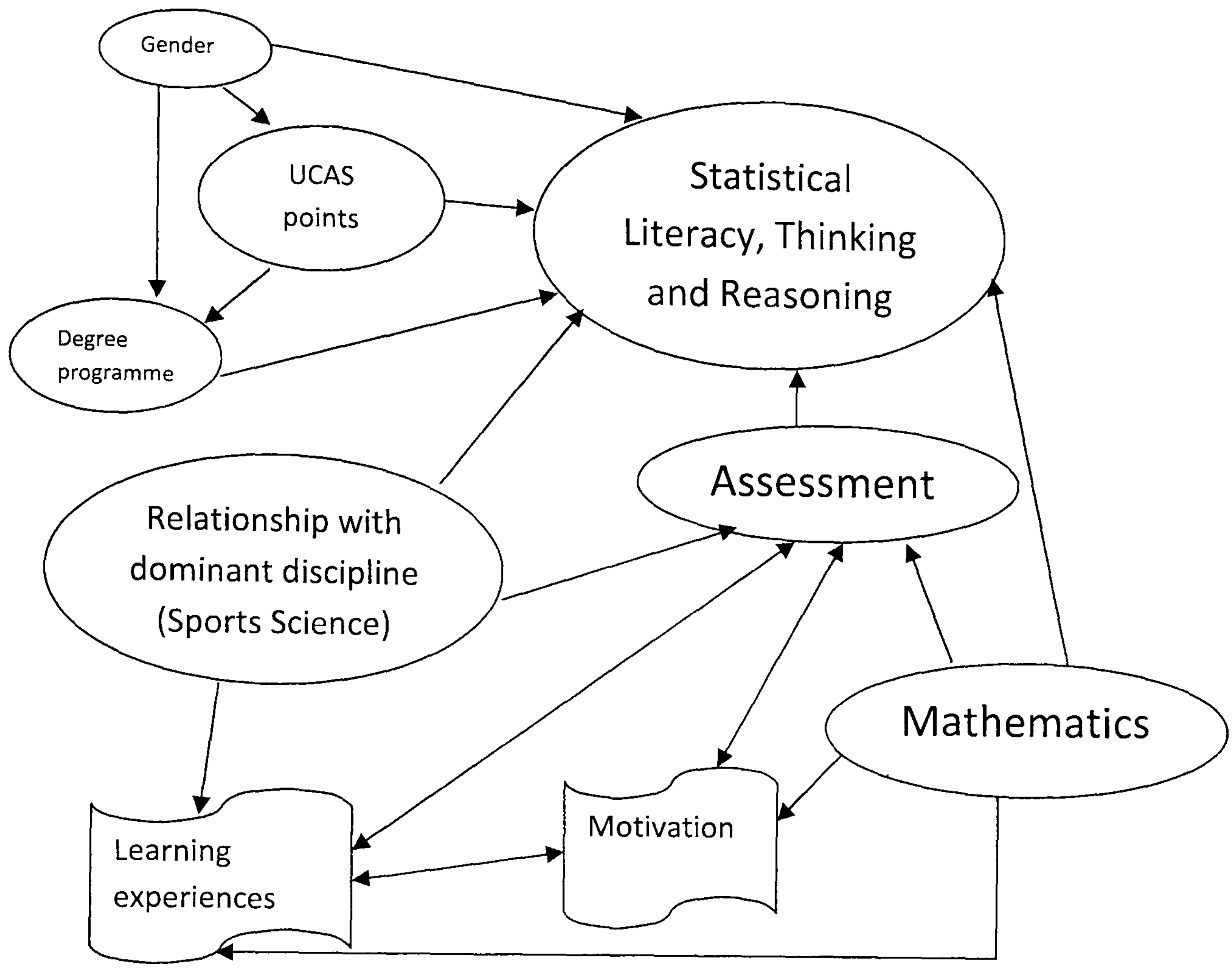
Conclusions

7.1 Introduction

This project investigated research questions that were, and continue to be, crucial to the professional role of the Statistics educator. This chapter integrates the findings from the quantitative analyses of a series of hypotheses developed from the research questions in Chapter One (section 1.2 and table 5.1) and the qualitative interpretation of interview data. The resultant rich description of Sports Science students' experiences in Statistics supports the main conclusions and recommendations at the end of the chapter.

This chapter begins with an analysis of the crucial roles of statistical literacy, reasoning and thinking in the evaluation of learning in Sports Science settings. Evidence from students' accounts of learning experiences clarified the interpretation of these three elements of statistical knowledge. Findings from Chapters Four and Five provided inconclusive information about the effects of gender, UCAS points and chosen degree programme on statistical achievement. There was an interrelationship between these three factors that produced contradictory results. These ambiguities are highlighted as potentially problematic, but do not form a part of the central focus of the chapter. Figure 7.1 demonstrates the linkages found between the factors that were analysed. The size of the ellipses represents the impact of the factor on statistical literacy, thinking and reasoning as evidenced by this project. The arrows indicate the probable direction of effects although this was not a part of the analysis. Motivation and the learning experiences described by students were added to the diagram because they had a crucial influence on students' accounts of the development of statistical literacy.

Figure 7.1 A representation of the factors arising from data analysis that impinge on statistical literacy



Statistics is dependent on data from other disciplines and contexts, and can be overshadowed to the point of invisibility. The separation of Statistics from Sports Science increased students' perceptions that it is a branch of Mathematics. The crucial implications of this problematic association are critically evaluated in the third section of the chapter. Students' motivation is diminished by the perceived importance of mathematical skill and the absence of an explicit link to Sports Science. The next major section contains an investigation of the empirical evidence of the influential effects of motivation on learning. An evaluation of the vital influence of assessment on students' motivation for statistical learning forms another main section. The final sections of the chapter assess the impact of the methodological choices on the findings and conclusions from this research project. A series of recommendations arise from an awareness of the limitations of this project and the key conclusions drawn from it. These suggestions signal areas of development for professional pedagogic practice and further research.

7.2 Statistical literacy, reasoning and thinking in Sports Science settings

Section 2.2 provided a critical evaluation of emergent literature that discussed statistical literacy, thinking and reasoning (for example, Ben-Zvi and Garfield 2004a; Gal, 2002; Rumsey, 2002). Garfield and Ben-Zvi (2004) recommended further research to position the demands of these concepts in particular educational contexts; a crucial activity as the literature indicated them to be situation specific. Pfannkuch and Wild's (2004) perspective of statistical thinking as an integration of statistical and contextual knowledge, combined with delMas's (2004) requirement that statistical reasoning should explain *why* results occur, provided a valuable structure to explore these conceptual applications in a specific Sports Science setting. This project therefore addressed the paucity of statistical literacy, reasoning and thinking research in the UK. It provided an insight to the "functional environment" and particular disciplinary culture of Sports Science that Gal (2002) and Garfield and Ben-Zvi (2004) deemed vital for development.

The interpretation of interview data revealed that most students possessed some statistical knowledge that could be described as statistical literacy. For example, Frank, a mature student, found the initial classes of Statistics One to be 'common sense'. Despite some prior statistical literacy, most interviewees experienced difficulty with the development of effective research designs for specific problems, the selection of appropriate samples of participants, and the identification of suitable analyses. Those who demonstrated a level of statistical thinking that enabled them to complete such tasks competently, for example, Anna, Freddy, and Donald, were not necessarily the most highly qualified students at entry to the university (see table 6.2). These students were more committed to individual study and to the development of Mode 2 knowledge through active questioning during class activities (Nowotny, Scott and Gibbons, 2003; Gibbons *et al.*, 1994). For example, Donald explained how he produced diagrams which he used to build a 'mental image in my head' to assist statistical decision-making. These diagrams were not algorithmic 'flow diagrams', which have been found to curtail critical inquiry because they contained his personal thoughts; instead, a 'mind-map' to produce further statistical questions. Students, like Donald, had reached a more advanced stage of statistical literacy that generated statistical thinking. These findings resonated with Garfield and Ben-Zvi's (2007) contention that diligence is a crucial ingredient in the development of statistical literacy; a characteristic which is more important than the mathematical and academic achievements that formed the focus of the research questions for this project.

Poor statistical thinking or reasoning appeared to constrain the progress of all interviewees. Most of them relied on Mode 1 knowledge to conduct statistical procedures in Sports Science settings (Gibbons *et al.*, 1994). This was unsurprising as the wider Sports Science community subscribed to this interpretation of statistical knowledge, and students were likely to absorb values from lecturers as a form of "hidden curriculum" (Becher and Trowler, 2001). Statistical thinking and reasoning require broader experiential knowledge, both personal and tacit. There is a need for reflexive interpretation and application in the appropriate setting, as well as the ability to compute and report statistical results. These attributes are characteristics of Mode 2 knowledge (Nowotny, Scott and Gibbons, 2005; Nowotny, Scott and Gibbons, 2003; Gibbons *et al.*, 1994). The transdisciplinary, applied nature of Statistics necessitates a Mode 2 production of knowledge that is counter to students' customary learning experiences through the lecture and laboratory based production of Sports Science knowledge, but is wholly appropriate to the professional setting.

Interview participants were invited to share their learning experiences during the Statistics Two module. Despite the inclusion of transmission/reception and constructivist models of learning and teaching in the module, students perceived their learning to be dominated by the computational content of the statistical procedures. Some students explained how they were daunted by large amounts of factual knowledge and this influenced both engagement with the module and preparation for assessment. Experiences of a transmission, teacher-centred, model of teaching afforded insufficient student activity to promote the deep learning necessary to develop statistical literacy towards statistical thinking and reasoning (Garfield and Ben-Zvi, 2007; Pfannkuch and Wild, 2004; delMas, 2004; Jarvis, 2002). Crucially, interview participants' accounts of the learning experience revealed transmission models of teaching to be more prevalent in the module than lecturers anticipated.

The disjuncture between the experiences of tutors and learners was partially explained by student interviewees' accounts of the method of teaching described as 'problem-solving'. A lack of initial classroom discussion and direction left students feeling insecure; they did not want to start work in case they were wrong. It was apparent that time was wasted waiting for advice, and lecturers over-supported student groups during discussion opportunities, through a desire to be helpful. This amounted to a 'concealed' transmission model of teaching. Some participants explained an over-reliance on lecturers which rendered them incapable of conducting any statistical work without considerable direction. Tutors should not do work *for* students or *with* students, but should facilitate them to think for themselves through judicious and reflexive guidance and questioning.

A reluctance to allow students to depart from standard statistical practices may result from lecturers' lack of confidence in their ability to guide students through unfamiliar territory. This situation could worsen due to a reduction in the number of Statistics places in UK HEIs (Smith and Staetsky, 2007). As a consequence, an increasing numbers of Sports Science specialists will be required to engage in teaching Statistics. These teaching staff will need support to develop their own skills of statistical thinking. The critical balance between autonomy and support, for both students, and lecturers inexperienced in Statistics, is a vital issue.

Students gave examples of situations in Sports Science modules where they were 'comfortable' with learning and expressed difficulties with the different demands of statistical learning. For example, Alan and Mark explained that the examination was hard to revise for because of the need to *do* Statistics rather than read lecture notes. Paradoxically, all students interviewed indicated that they 'switched off' if a transmission model was used to lecture about Statistics. The key issue for the statistics educator is that Sports Science students *want* to construct Mode 2 statistical literacy, but to do so they must operate in unfamiliar territory with uncustomary methods. Lecturers who contribute to course design should take this strangeness into account and balance module content with adequate time for reflection and interpretation. A course designed around a 'shopping list' of statistical techniques is unlikely to allocate sufficient time for the less tangible reflective, interpretive skills required to apply them with meaning and understanding. Less emphasis on computational complexity and greater attention to the desired learning outcomes could be informed by a clear picture of what characterises statistical literacy and thinking for Sports Science students. Further research to clarify these distinctive, discipline specific, features should be undertaken through dialogue within the Sports Science community, and elsewhere.

Evidence from interviews suggested level five to be too early a stage for the majority of students to reason statistically. None of the interviews addressed the interpretive evaluation of the impact of research design and sampling methods on the credibility of the statistical results and subsequent conclusions. This omission is unsurprising as the skills of statistical reasoning meet Masters level descriptors (QAA, 2001). Pedagogic strategies for undergraduate Sports Science programmes should aim to develop statistical literacy in all students, facilitate statistical thinking in those who ask suitable questions, and provide the opportunity to apply statistical reasoning for students who are capable of the abstract thought processes that delMas (2004) claimed to be a vital ingredient. Interview data suggested students who were challenged to develop statistical thinking demonstrated deeper engagement with the subject than those who experienced teaching that was focused on computational procedures. The outcome was not necessarily the ability to think statistically, but a tentative claim to higher levels of statistical literacy could be made.

Statistical thinking needs specific nurturing, because it is not an, "innate or community way of thinking" (Pfannkuch and Wild, 2004, p.37). In Sports Science, students most commonly encounter inferential hypothesis tests, such as *t*-tests and ANOVA, to analyse data from laboratory experiments. These statistical tests require students to take a Popperian, falsificationist perspective to disprove a negative statement through the use of probability theory (Popper, 1983 and 1977). The negativity inherent in these tests can inhibit understanding (delMas, 2004). Tim, Jack, Mark and Alan were reluctant for Statistics to be fully integrated into modules related to their dominant discipline, because the "space" to concentrate on learning specific statistical skills would be lost. These interpretations are particularly important to this project because they justify the need for a delicate balance between the statistical content and the Sports Science context of stand-alone modules. Statistics is dependent on the context to which it is applied, yet it must not be obscured by that dominant discipline. It is crucial that pedagogic strategies balance the need for Mode 1 knowledge about statistical techniques with the opportunity to assimilate and meaningfully apply Statistics to a Mode 2 construction of Sports Science knowledge, if students are to have the opportunity to develop statistical literacy and lay the foundations for statistical thinking and reasoning. Quantitative analysis in Chapters Four and Five found that Statistics marks became significantly worse than those for other core modules as students' Sports Science knowledge increased. These results supported the contention that there was insufficient opportunity for students to reflect on statistical literacy and apply statistical thinking.

7.3 The ambiguous gender effect and its relationship to degree programme and previous academic achievement

The researcher thought that gender, degree programme and prior academic ability (measured by UCAS tariff points and Mathematics experience) influenced Statistics marks, a perception based on published literature and empirical observation. When marks for Statistics One and Statistics Two were examined for differences between male and female students it was apparent that there was no meaningful difference, table 5.3. However, exploratory data analysis revealed small differences in patterns of Statistics marks between males and females, dependent on degree programme and highest Mathematics qualification. An investigation of the combined effects of these factors was worthwhile (section 4.7 and table 4.5). Gender was found to have a small but significant effect on Statistics Two marks although it did not affect Statistics One or Dissertation marks (sections 5.4-5.6). The limited reliability of these findings and the ambiguity of such inconsistent results meant that no specific recommendations could be made. Statistics lecturers need to be aware of the *potential* for gender differences and that these may be related to career aspirations, as reflected in the choice of degree programmes.

UCAS tariff points were included in this research project as an indicator of general academic ability. A weak relationship was found between these points and marks awarded for Statistics and the Dissertation modules. A more important finding was the extent of interaction between the variables thought to affect Statistics marks. Gender, previous academic achievement, and degree programme did not have large individual effects on Statistics marks but interacted to work in combination to differentiate between some subgroups of students. It was not possible to find significant interaction effects through statistical analysis in Chapter Five because the number of students in each group was very small; however, descriptive statistics in

Chapter Four and the interpretation of interview data from Chapter Six revealed some potential effects. For example, interview data suggested Coaching Science students' achievement in Statistics to be hampered by a vocational perspective on their studies.

7.4 The complex relationship with Mathematics

The contested relationship between Statistics and Mathematics was found to be of much greater importance than the other previous experiences and decisions that students made prior to university entry. One of the core research questions for this project sought to evaluate the effect of students' experiences with Mathematics on their ability to develop statistical literacy. The investigation of this question through both quantitative and qualitative methods provided unexpected and thought-provoking discoveries that extended beyond students' learning experiences to embrace the complex identity of Statistics as a distinct discipline.

Abstract thought is a component of both Mathematics and Statistics which partially explains why students often experience difficulties with *both* disciplines (delMas, 2004). However, statistical ability is not necessarily affected by mathematical aptitude. Quantitative results in sections 4.6, 5.4 and 5.5 confirmed Mathematics qualifications above GCSE grade C to positively influence the Statistics examination marks of Sports Science students. These findings appeared to support the work of Lane, Devonport and Horrell (2004), Lane, Hall and Lane, (2004) and Lane, Hall and Lane (2002) who claimed that self-efficacy influenced Statistics marks. Interviews revealed this situation to be more complex than the conclusions reached in Chapter Five. Although students who had gained grade B or higher in GCSE Mathematics *should* have more confidence in their numerical skill and therefore feel better able to learn Statistics, some interview participants with a grade C expressed greater belief in their numeric ability than those who appreciated the effort it had taken to gain a grade B.

Interviews confirmed students' diverse backgrounds in Statistics and Mathematics. Some participants compared themselves unfavourably with their peers, and were anxious about failure and computational self-concept (Onwuegbuzie 2004;

Onwuegbuzie and Wilson, 2003). Others explained how they used memorisation to take an algorithmic approach so that they made appropriate decisions but with insufficient understanding to be able to interpret and evaluate the final results. Computationally 'perfect' tasks enabled students like Hazel to do well because mathematical understanding enabled logical interpretation of the results. Kelly, Sloane and Whittaker (1997) described this as an "unjustified sense of mastery" (p.6) because such students cannot make decisions about the most suitable analyses to apply to a problem, nor can they contextualise findings meaningfully. delMas (2004) asserted that it is the situated contextual foundation of Statistics that distinguishes it from Mathematics. However, 'situating' Statistics in Sports Science produces a lack of disciplinary identity that is problematic. It is likely that stand-alone Statistics modules increase students' impression that Statistics is Mathematics, but embedding it in Sports Science modules renders it invisible.

Whether a strong background in Mathematics is *really* advantageous to statistical literacy may be less important than a student's *belief* that it is (Murtonen and Titterton, 2004). Murtonen *et al.* (2008) claimed that the "superficial similarity" between Statistics and Mathematics discourages many students from engaging in productive learning approaches; a situation apparent from Alan, Jack, Tim and Mark's accounts of their learning experiences (see sections 6.3.2, 6.3.12 and 6.6.4). Students who are demotivated by a perceived connection with Mathematics are probably disadvantaged by attitude rather than potential ability (Garfield and Ben-Zvi, 2007).

An exciting avenue for further development could be the clarification of Statistics as an autonomous discipline. delMas (2004) and others have begun this work, but more is needed to establish the Mode 2 characteristics of Statistics that set it apart from Mathematics. Its transdisciplinary nature could enable Statistics to be more comfortably aligned with the dominant disciplines on which it depends for data. However, student interviewees were clear that an element of separation appears to be necessary for students to absorb the Mode 1 statistical procedural knowledge. Difficulties arise in the consideration of pedagogic strategies to meet the three areas of procedural knowledge, application, and interpretation. The first emphasises the link with Mathematics and dominates students' perception of the subject as numerically demanding. Further work on these important interrelationships will enable the Statistics educator to guide students more effectively towards more autonomous statistical thinking.

7.5 The crucial influence of motivation

Antagonism towards Statistics at level five occurred as students' perceptions of developing professional knowledge diminished the importance of the subject. For example, the reluctance of Sports Therapy students to fully engage with Statistics was evident from findings which suggested that they did not gain significantly higher marks than Sport and Exercise Science or Exercise and Health Science students despite entering university with higher Mathematics qualifications and UCAS tariff points (see sections 4.2 and 5.3). Through the accounts of these students' learning experiences the effects of alienation to preserve self-identity could be better understood.

Students described how they employed memorisation as a means to "get by" in Statistics without the need to understand. A surprising finding from interview data, not hitherto available in the literature, was that students with a vocational focus, for example Sports Therapy and Coaching Science, also felt Physiology to be a peripheral discipline with which they struggled to engage. It had been the practice for lecturers to use data from Sports Physiology, Psychology and Biomechanics, to provide explicit links between Statistics and the dominant subjects. If some groups of students feel alienated from one or more of those disciplines, engagement with the statistical element of the activity is unlikely to occur. Students reading Sport and Exercise Science and Exercise and Health Science experienced Statistics as a means to understand laboratory data collected in other level five modules. This situation made them more aware of the need to develop statistical thinking and reasoning, although not necessarily more willing to do so. These students demonstrated greater openness to a variety of career options, did not have preconceived ideas about the content of a specific degree programme, and were more able to see a use for statistical literacy once they had entered employment.

Alienation effects of a different nature were exhibited by students who felt excluded by the language of Statistics. Interview participants explained difficulties which equated to the "stranger in a foreign land" that Mann (2001) had attributed to the culture change that many students experience on entry to university. Despite encounters with Statistics in Sports Science modules, students viewed it as outside the language of their Community of Practice (Becher and Trowler, 2001, Wenger, 1998). This was surprising as the association with Mathematics had been widely documented, but linguistic difficulties had not (Garfield and Ben-Zvi, 2007; Onwuegbuzie and Wilson, 2003; Schram; 1996). The multidisciplinary nature of Sports Science, demands the ability to understand Statistics from several disciplines, and therefore students encounter an extended vocabulary, unlike the academic contexts described by Gal (2002). There was evidence from several participants' interview responses, including Alan and Jack (sections 6.3.1 and 6.3.11) that these circumstances increased the likelihood that students did not understand the order and logic of Statistics teaching; alienation through estrangement (Mann, 2001). It is critical that Statistics educators develop pedagogic strategies which allow time for discussion and consolidation of learning activities so that students have the opportunity to reflect on the experience, ask questions and develop the deeper understanding necessary for statistical thinking (section 7.2).

Hazel, the only participant to demonstrate intrinsic motivation to engage with Statistics, did so because she saw it as a branch of Mathematics. Her interview provided evidence that she had not engaged deeply with statistical literacy, but with mathematical logic (delMas, 2004). It is likely that extrinsic motivators are necessary to encourage mathematically able students to engage with statistical literacy as well as those with a more obvious reluctance to learn. Professional Statistics lecturers must be aware that generic motivators are improbable. Methods of facilitating personalised learning should be sought, through pedagogic strategies that allow for the inclusion of previous experience and a range of learning styles.

The crucial importance of a careful balance between directed and autonomous learning environments was apparent from interviewees' accounts of the sessions described as 'problem-solving'. Pre-prepared data sets for problem-solving activity had detrimental effects on learning as they compromised students' ability to appreciate the research context. This partial knowledge made data analysis and interpretation difficult. Problem-solving is likely to be more successful if the student has initiated the problem, or it has been encountered during the course of project work. The latter approach decreases the likelihood that solutions can be reached by using memorised rules in response to 'clues' in a question, and should assist the development of statistical literacy. Constructivist project-based activities, without prescriptive constraint, give better preparation for the Dissertation and provide a closer link between research design and statistical analysis. Student involvement in all stages of quantitative research promotes an interest in the findings which should make learning Statistics more enjoyable (Davies, 2006; Jarvis, Holford and Griffin, 2003). Donald provided evidence of how powerful enjoyment can be for perseverance with difficult tasks. His enjoyment and motivation were interconnected and provided a route to greater engagement with Statistics.

Murtonen and Merenluoto's (2001) assertion that students who practise statistical techniques are not developing statistical literacy could be qualified. Students who practise examples in order to memorise statistical algorithms differ from those who use memory to support the development of statistical thinking. The importance of this differentiation was propounded by Webb (1997) and evidenced by Yvonne and Freddy during interviews (sections 6.3.8 and 6.3.9). These students demonstrated considerable extrinsic motivation to engage with Statistics, valued a good memory to provide the framework for subsequent deeper learning, and responded positively to teaching strategies that required thoughtful decision making.

The disciplinary frame does not support *intrinsic* motivation, but for some students, *extrinsic* motivators promoted engagement with Statistics. For example, the pursuit of particular degree classifications, or a desire to understand particular aspects of other modules, motivated some participants to devote considerable time to statistical work. A desire for good grades did not necessarily extend to Statistics modules. For example, a strategic approach to achievement within a modular degree structure was adopted by Jack and his friends, whereby sufficient work for a pass mark in Statistics was balanced against considerably higher goals for modules in the dominant discipline of Coaching Science (section 6.6.2). Students, such as Yvonne, Anna and Freddy, who engaged with Statistics to increase their understanding of Sports Science, could apply statistical reasoning to sporting contexts. Those who learned by rote, for example Mark, expressed a need for tutor support to select appropriate statistical analyses for specific laboratory experiments. These findings supported

Newstead and Hoskins's (2003) claim that extrinsic motivation could be a more powerful determinant of academic success than intrinsic motivation.

Pedagogic strategies that enhance the development of statistical literacy, reasoning and thinking through carefully chosen modes of assessment are likely to be the most likely to succeed. The students who were interviewed for this project identified assessment grades as the crucial extrinsic motivator to engage in statistical activity. Assessment is the focus of the following section.

7.6 The overarching impact of assessment

Statistics One marks were significantly lower than two out of three of the other level four compulsory modules and the mean mark was little above the pass boundary of 40% for Statistics Two (sections 4.3.1, 4.3.2 and 5.2). At level five students were required to make and justify statistical decisions and to interpret and evaluate the findings from statistical procedures. The analysis of Statistics Two marks, in Chapters Four and Five, implied that few students met the challenge of statistical thinking despite some evidence of statistical literacy. Ben-Zvi and Garfield's (2004b) contention that students perceive Statistics as a form of Mathematics, and expect to use a specific method to reach a definitive answer was pertinent here. Anxiety was increased by the presence of uncertainty, and the need to communicate it with precision. Students avoided the real issues and remained in the more familiar, deterministic, mathematical domain, which compromised the examination marks.

Interview responses revealed the vital importance that students attach to assessment. They illuminated the relationship between statistical learning and examination achievement. Most participants expressed a desire to succeed, although this varied from a motivation to do enough but no more and an ambition to gain the highest possible mark. Students adopted strategies to pass the examination rather than to learn Statistics; possibly two distinctly different outcomes. Interviewees, for example Anna, who demonstrated an appreciation of statistical concepts with which they could reason and draw conclusions did not necessarily obtain good marks in the examination. Mark passed Statistics examinations through memorisation and the application of algorithms, but he could not transfer the knowledge effectively to sport specific modules. Hazel could carry out statistical calculations, but her interview revealed poor statistical thinking. These findings coupled with Hazel's outstanding success in the Statistics examinations - 83% at level four and 98% at level five - demonstrated that examinations did not encourage the nature of learning necessary for statistical literacy. Innovative assessment practices should be sought, that allow students to demonstrate statistical literacy and thinking in real Sports Science settings.

Several interviewees thought the achievement of a pass mark for the module to be beyond their capabilities. This anxiety increased the likelihood of alienation from Statistics. Students were more inclined to delay or abandon statistical work as it increased in complexity, prioritising subjects which they found easier or more interesting. Similar effects were documented by Onwuegbuzie (2004). For some students examination anxiety had a positive short-term effect on motivation towards the end of the modules (section 6.6.4). The approaching examination motivated students to develop understanding; a constructive use of anxiety (Goleman 2004; McBride and Maitland (2002). It is probable that this engagement resulted in transitory learning for many students, and did not benefit statistical literacy. Billy's anxiety about assessments and poor statistical ability led him to abandon his preferred methods of learning in favour of memorisation (section 6.3.5). Mark's and Alan's enthusiasm for learning faded if they found understanding too difficult (sections 6.6.1 and 6.6.2) and Jack demonstrated a high dependence on lecturers (section 6.3.11). These insights obtained from interpretation of interview data highlighted some of the many manifestations of statistical anxiety experienced by interviewee participants. Motivation to engage with the discipline was reduced because of the perceived volume of knowledge and the necessity to remember it for assessment. The development of statistical literacy was curtailed as a result of this alienation. Crucially, students' anxiety and lack of confidence made them dependent learners, reliant on lecturers, despite the constructivist nature of the learning environment.

Teaching through project work that exposes students to the research design and the planning of analysis, employs Mode 1 knowledge to secure new experiential knowledge - Mode 2 construction. Assessment through a written project report or reflective research journal could enable students to demonstrate learning from this pedagogic strategy. Students would be better prepared for the Dissertation module at level six. Project work could alter the focus of statistical work to diminish the mathematical element and emphasise the Sport Science context. It is vitally important that the study of quantitative research methods, research design, sampling, statistical analysis, interpretation of results and final conclusions are not separated for teaching purposes if there is to be opportunity to develop statistical literacy and thinking (Murtonen, 2005a). Assessments that involve students in further learning, rather than auditing skills and competencies, encourage meaningful statistical activity in which there is sufficient emotional investment to maintain motivation and effort. This is important because in Sports Science, as in many other disciplines, the non-dominant skills of statistical literacy are developed in response to need rather than interest. Carefully constructed assessment can be a powerful extrinsic motivator for many students.

7.7 Key limitations of this research project

The mixed methodology employed in this project enabled an understanding of learning Statistics that would not otherwise have been achieved. The ability to substantiate quantitative findings through interviews, which provided further detailed information, strengthened the conclusions drawn from the results. Measurement or observation of learning remains problematic and the illumination of statistical learning was limited by the choice of methods and theoretical frameworks.

The self-selected sample of interview participants led to bias that must be accepted as a limitation of the research. The exploration of the differences between the four degree programmes was constrained by the heavy bias of volunteer participants from the more vocational programmes. Only one student reading Sport and Exercise Science, and two from Exercise and Health Science volunteered to participate in interviews. The effect of developing professional Sports Science knowledge on students' experiences of learning Statistics appeared to differ between degree programmes. The potential benefits and disadvantages of teaching students in groups defined by degree programme need further evaluation.

The choice of quantitative student profile variables limited the conclusions that could be reached by this research project. The factors included had been previously documented to affect statistical literacy, but regression analysis revealed the extent of this to be small for the 2006 Sports Science student sample at the university. The analysis served to emphasise the diverse experiences of students that resulted in the large number of small subgroups. These in turn compromised the reliability of the models. It is important to appreciate that learning is complex and multifaceted; it is unlikely that it can be explained adequately through measurement alone.

The data collection for this project was limited to one university and the findings informed the professional practice of the researcher. Nevertheless, similarities between modules in that university and others offering Sports Science degree programmes meant that findings from this research could resonate with the experiences of other Statistics educators and their students (section 1.3 and appendix *i*).

7.8 Final conclusions and recommendations

This research project sought to investigate six core research questions to evaluate whether statistical pedagogy encouraged Sports Science students to develop statistical literacy. The analysis of data exposed some surprising and informative patterns and perspectives. This section summarises and evaluates the outcomes to provide qualified conclusions and recommendations for evidence-based practice.

Attainment in Statistics was more variable and generally lower than in other compulsory modules[1]. It was surprising that the differences between module marks were more evident as students developed greater knowledge of Sport Science. Interviews emphasised the need to provide explicit justification of the vital role of Statistics in all areas of Sports Science, not only the research arena. Students had ambiguous understanding of the identity of Statistics. Therefore, their *developing professional awareness of the role of a Sports Scientist* did not place any importance on statistical literacy. Five of the twelve respondents explained that they did not necessarily want to learn Statistics, but wanted to 'know' sufficient information to reach a particular grade. There is clearly a tension between knowledge, identity and the desire to achieve the highest possible degree classification.

[1] Sentences which directly relate to the six core research questions are in italics. This is to assist with the identification of the source upon which conclusions and recommendations are based.

The only *factor that appeared to influence achievement in Statistics was students' previous Mathematics qualification.* Gender, prior academic achievement and the choice of degree programme contributed to the complex interplay of factors that determine student diversity, but the reliability of any conclusions based on these factors was compromised by the small group sizes. Many further potential variables were not selected for inclusion in this research project and these would further increase student diversity. Pedagogic planning that incorporates elements of individual learning would benefit statistical literacy as students bring a greater variety of previous experiences to Statistics modules than they do to the dominant subject disciplines within Sports Science. Advances in Information Technology, and e-learning in particular, lend themselves to the development of personalised learning. This area was explored as part of a previous assignment in the Ed.D. programme (Hale, 2005). Electronic resources need to be continually reviewed and improved to keep pace with advancements in the technologies available.

The perceived importance of Mathematics was evident in *students' descriptions of learning experiences in Statistics.* Additionally *Mathematics qualifications above GCSE grade C had a beneficial impact on Statistics marks.* These findings could be partially attributed to the examination mode of assessment and teaching strategies which contained a mathematical bias. The situated, contextual nature of Statistics as a distinct characteristic needs to be made more explicit for students if they are to appreciate that they are not in pursuit of definitive numerical answers. This difference from Mathematics is lost if students are confronted by a series of prepared data sets and required to use computational processes to reach a pre-determined solution. Statistics requires data from other disciplines, but its value is compromised if a dominant focus renders it invisible. There are three issues here. Firstly, there is a need to locate specifically what Statistics means, both in vocational settings, and more generally. If students are to develop the statistical literacy for "efficient citizenship" as identified by H.G. Wells then the necessary skills and competencies must be visible. Secondly, innovative pedagogic strategies need to be explored that emphasise the characteristics of Statistics that distinguish it from Mathematics. Involvement in the excitement of the successful application of statistical techniques to quantitative problems should engage students with Statistics and extend their skills to statistical thinking and reasoning. Finally, the rationale for assessment through examination should be considered carefully. Not only did examinations appear to strengthen the perceived relationship between Statistics and Mathematics, but they encouraged superficial memorisation of facts. This transient knowledge does not prepare students to assimilate the volumes of data that are a facet of modern society.

The researcher intends to employ the insights gleaned from this research project to work with students to explore a variety of teaching and learning opportunities to facilitate statistical literacy. Reflection on the unexpected discovery that students experienced a predominantly transmission mode of teaching revealed situations where the researcher recognised her tendency to assume the role of 'expert' and dictate a standard set of procedures, rather than guide students to a personal conclusion. The paradox, of the need for knowledge in an unfamiliar discipline and active involvement in data handling, is unlikely to be resolved, but can be better reconciled than it was when data were collected for this research project. It would be unrealistic to suggest that this is anything less than a continuous journey. The vital ingredient is sustained, reflexive evaluation of professional practice and willingness for dynamic pedagogic experimentation. Dialogue with colleagues and students is crucial for such development.

The core research questions aimed to investigate the key question: *How might the development of pedagogic strategies enhance Sports Science students' attainment of statistical literacy in Higher Education?* Statistical literacy appeared to be compromised by the transmission of knowledge. A critical element in the development of a more facilitative approach to statistical pedagogies is that of continuing professional development. As the number of Statistics specialists decreases (Smith and Staetsky, 2007), the burden of teaching Statistics falls to lecturers in the dominant disciplines.

There was evidence from students' interview responses that Sports Science tutors' lack of experience with Statistics limited learning opportunities to a Mode 1 interpretation. Tutors need to have sufficient confidence in their own ability to support students to develop the Mode 2 knowledge necessary for statistical thinking. Hencken (2005) claimed that most Sports Science lecturers lacked the confidence necessary to teach Research Methods and Statistics effectively. Confident, competent application of Statistics across all aspects of Sports Science degree programmes should increase the motivation to embed a Mode 2 construction of statistical literacy into students' developing professional knowledge. Dialogue between lecturers within the dominant Sports Science and the non-dominant Statistics disciplines needs to be enhanced through purposeful professional development opportunities that push the boundaries of modular degree structures. Students cannot be expected to connect knowledge from different modules if academic staff are unaware of the overall student experience.

Continuing professional development for tutors is vital if statisticians are to be aware of developments in Sports Science, and tutors from sports disciplines are to gain confidence with Statistics, not only the specific procedures, but the issues that have particular relevance to their own Community of Practice. This situation would be the case for any academic degree programme that includes Statistics modules. Professional development should be available to assist tutors to have the confidence to abandon teacher-centred, transmission modes of teaching and allow students to challenge their understanding.

This project employed a synthesis of quantitative and qualitative analysis to contribute to existing knowledge through a detailed exploration of a specific setting. For students firmly focussed on a dominant subject discipline Statistics requires careful integration with that discipline. It is crucial to allow space for statistical knowledge to be absorbed into the practice of that dominant discipline, and vital that the academic staff have the confidence and skills not to reduce statistical practice to a series of technical procedures that ignore context and application.

The need for statistical literacy that H.G.Wells and Florence Nightingale identified at the end of the nineteenth century has not been fulfilled satisfactorily by higher education in the twenty-first century. There is much still to be done if students are to develop statistical literacy, thinking and reasoning sufficient to understand the practical applications of specific subject disciplines and function as efficient citizens. The integration of lived experiences, dominant subject knowledge and statistical literacy needs to be presented in a meaningful manner to enhance students' appreciation of "the most important science in the whole world ..." (Florence Nightingale, 1820-1910).

Statistics Glossary

Analysis of variance (ANOVA)	An inferential statistical test which compares the means and variations of groups to ascertain whether there is evidence of differences between them. The test uses an F-ratio to evaluate the extent of difference. ANOVA in this thesis has been used 'one-way' to investigate differences between groups on one factor – to investigate degree programme differences for example – and 'two way' to look for differences between groups on two factors – eg degree programme and gender – and their potential interaction. ANCOVA results from the inclusion of a covariate – a continuous variable that is thought to affect the dependent, variable.
Assumptions of statistical tests	Conditions or parameters which should be fulfilled if a statistical test is to be applied with optimum effect.
Backward elimination regression	A regression procedure which employs statistical criteria to remove predictor variables from a full model. The variables are removed subject to the amount of variation in the dependent variable that they explain.
Cook's distances	A method of determining the influence of individual cases on a regression model.
Contrasts (simple)	A planned comparison of each group mean to a predetermined 'baseline' category. It usually follows ANOVA or ANCOVA.
Correlation	The strength of relationship between one variable and another. Measured on a scale from $^{+}1$ to $^{-}1$, correlation indicates the nature of relationship. A positive value represents a direct relationship; an increase in one variable is related to an increase in the other. A negative value represents a situation where an increase in one variable accompanies a decrease in the other.
Dummy variables	A way of coding nominal level data using only '0' and '1'.
Effect size	A way of measuring the size of an observed effect as a standardised quantity.
Fit (of a model)	The investigation of how well a regression model describes the behaviour of the original data set.

Forced entry regression	A method of regression where all selected variables are included in a model, whether or not they add value to the equation. The variables can be evaluated as entered simultaneously, or a hierarchical approach may be taken.
Games Howell *post hoc* test	A *post hoc* test that allows comparisons between groups when population variances differ. All possible paired comparisons are made.
Greenhouse-Geisser correction	An adjustment to the degrees of freedom in ANOVA to make the analysis less likely to reject the null hypothesis. It makes the test more conservative if the assumption of homogeneity within groups is violated.
Hierarchical regression	A method of forcing variables into a regression model in a predetermined order.
Interaction	The combined effect of two or more independent variables on a dependent variable.
Main Effect	Usually used to explain ANOVA or ANCOVA results. The influence of an individual factor on a dependent variable is a 'main effect'. The term is used to differentiate the effects of each factor from the interaction or combined effects that can also be identified.
Multicollinearity	When two or more variables have very close linear relationship.
Multilevel models	Regression models that enable interdependence to be described by the modelling procedure.
Multiple regression	A process of finding the multidimensional equivalent of a 'line of best fit' using more than one predictor variable to predict the dependent (outcome) variable.
Ordinary least squares models (OLS)	A method of regression that uses specific mathematical principles to position a line of best fit to minimise the residuals.
Reliability	The ability to measure the same phenomenon consistently when the conditions of measurement are kept constant.
Residual	The error in predicting from a regression model. For the data points that have been used to develop a model it is the amount by which a prediction from the model differs from the true, observed outcome.

Significance level (α level)	The predetermined level of probability that provides the rejection criteria for a null hypothesis. Education and Sports Sciences customarily set the significance level at 5% ($p<0.05$ results in the decision to reject a null hypothesis).
Statistical modelling	A term covering different types of regression analysis. The purpose of statistical modelling is to try to explain a 'real world' occurrence by explaining the pattern in data using an equation. If a good model can be found (the residuals are not large and do not contain systematic pattern) then the model can be used for prediction or to clarify the complex combination of variables that determine a particular outcome.
Validity	The ability of a variable to measure what one is setting out to quantify. In the context of this thesis it could be debated whether UCAS tariff points really measure 'general academic ability'.

Appendices

A Comparison of Statistics Content in Sports Science Degrees from Five Representative Universities

The five universities whose modules are detailed below were selected to represent the diversity of institutions (university and university college) as well as regional and more distant comparisons with the university in which data were collected.

	University A: City university college in south east England	University B: Town university in Wales	University C: City university in north east England	University D: university in the south of England	The university used for data collection, in the south of England
Level one content	**Research Methods** module : "Basic descriptive statistics"	**Research Methods and Statistics** module: χ^2, Mann-Whitney, Wilcoxon paired and independent t-tests, Spearman's Rank and Pearson's Product Moment correlation coefficients and simple linear regression.	**Research Methods** module: Describing and exploring data, Central Limit Theorem, one sample, paired and independent t-tests, χ^2 Mann-Whitney, Wilcoxon, Spearman's Rank and Pearson's Product Moment correlation coefficients and simple linear regression.		**Research Methods 1** χ^2, Mann-Whitney, Wilcoxon paired and independent t-tests. Qualitative methods, research design and philosophy
Assessment	Literature review (1000 words) Worksheets (1000 words) Group Poster (500 words)	1 ½ hr SPSS competency test – with notes Lab. Report (1000 words)	Assignment (50%) 1 hr examination with notes (50%)		1 hr statistics examination 1hr philosophy and research design examination

University C also had a 'Sports Mathematics' section in a module preceding Research Methods at level one

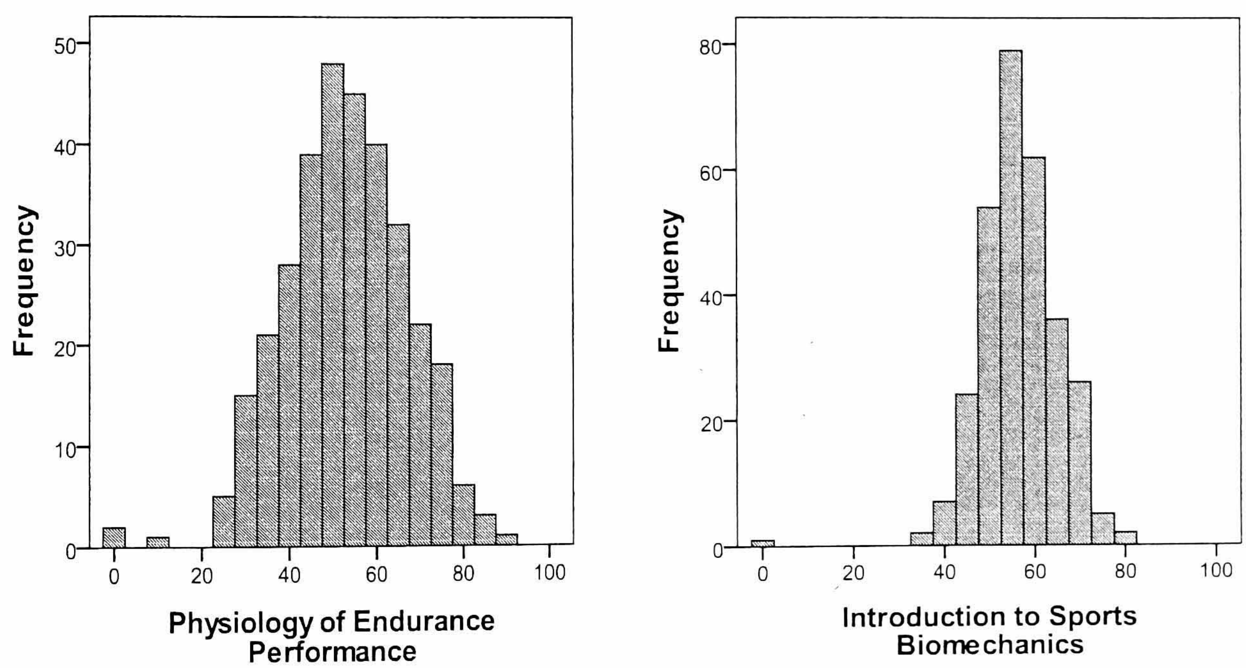
Level two content	**Interpreting Research** module: no specific statistical content specified	**Research Methods and Statistics 2** module: 1-way and 2-way ANOVA including within groups designs, Multiple Regression	**Research Methods 2 (A larger module worth more credit than in other universities)** module: 1-way and 2-way ANOVA including within groups designs, Multiple Regression	**Research Methods (Double unit at level 2)** Descriptive statistics, t-tests, ANOVA, MANOVA, χ^2 correlation and regression	**Research Methods 2** Spearman's Rank and Pearson's Product Moment correlation coefficients and simple linear regression. Multiple Regression 1-way and 2-way ANOVA including within groups designs
Assessment		Group Project Report Research Proposal	Critical evaluation of a research technique (1500 words, 25%) Statistical analysis (1500 words, 25%) Research proposal including a written submission and an oral presentation (50%)	Computer examination Written research proposal/protocol	1 hr Statistics examination 2500 word group project report
Level Three content	**Research Design** module contains "Parametric and nonparametric tests"				
Assessment	Viva voce (10 mins) Literature review (2000 words) Research Proposal (1000 words)				

Teaching at universities A-D was through a mixture of lectures and 'computer workshops'. Statistics 'practicals' and seminars provided the teaching and learning experiences n the university investigated through this research project.

An Example of Exploratory Data Analysis to Check Variables for Normality.

Visual inspection of the distribution of data is an important preliminary step to any statistical analysis. Histograms of two level four modules (shown below) illustrate the patterns of distribution followed by most variables. There was evidence of outliers in the histogram for Introduction to Sports Biomechanics which caused the distribution to be negatively skewed. The outliers warranted further investigation, although some were through the award of a 'penalty mark' of zero for academic malpractice.

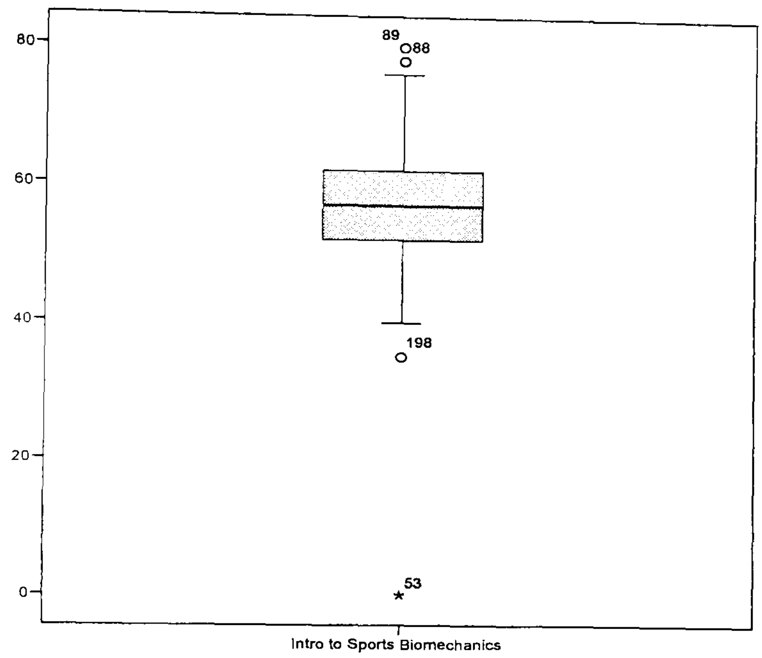
Histograms of examples of data distribution for level four module marks



Marks for the Physiology module extended further below 40% than those for the Biomechanics module, so those students with penalty marks were not so far removed from main body of data as the individual in Introduction to Sports Biomechanics, so the Biomechanics module is used to provide further examples of how outliers were evaluated.

Boxplots were drawn to assess the extent of outliers. The problem with the Biomechanics module stemmed from the close clustering of most of the marks with four student outliers or extreme outliers, this can be seen on the boxplot below. Outliers, denoted by 'O' are between 1.5-3.0 interquartile ranges (IQR) from the top or bottom line of the box part of the boxplot. Far outliers, denoted by '*', are over 3.0 IQRs from the ends of the box.

Boxplot of Introduction to Sports Biomechanics marks



Students 88 and 89 were outliers at the upper end and student 198 was an outlier at the lower end. Student 53 was an extreme outlier at the lower end of the marks because of the penalty mark of zero.

The individuals who were awarded penalty marks were not excluded from the analysis because they represented how the marking system of the university was applied in real situations. Further investigation using Shapiro-Wilk tests of normality indicated both Physiology modules and the Biomechanics module at level four to differ significantly from normality, highlighted results overleaf show $p < 0.05$.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Physiology of High Intensity Performance	.060	289	.013	.981	289	.001
Phys of Endurance Performance	.034	289	.200*	.988	289	.015
Statistics One	.050	289	.075	.990	289	.047
Intro to Sports Biomechanics	.050	289	.077	.948	289	.000

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

When sample sizes are larger than 100 Tabachnick and Fidell (1996) advised visual inspection of graphs together with calculations to evaluate the skewness (symmetry) and kurtosis (curvature) of the distributions. Additionally, if means and medians for a distribution are similar then the data are likely to be normally distributed. The highlighted sections of SPSS output below, and the following table, show the results of these checks and calculations for level four modules.

			Statistic	Std. Error
Physiology of High Intensity Performance	Mean		56.56	.862
	95% Confidence Interval for Mean	Lower Bound	54.87	
		Upper Bound	58.26	
	5% Trimmed Mean		56.94	
	Median		58.00	
	Variance		214.886	
	Std. Deviation		14.659	
	Minimum		0	
	Maximum		88	
	Range		88	
	Interquartile Range		20	
	Skewness		-.453	.143
	Kurtosis		.261	.286
Phys of Endurance Performance	Mean		52.97	.824
	95% Confidence Interval for Mean	Lower Bound	51.34	
		Upper Bound	54.59	
	5% Trimmed Mean		53.19	
	Median		53.00	

			Statistic	Std. Error
	Variance		196.221	
	Std. Deviation		14.008	
	Minimum		0	
	Maximum		89	
	Range		89	
	Interquartile Range		19	
	Skewness		-.316	.143
	Kurtosis		.746	.286
Statistics One	Mean		53.94	.957
	95% Confidence Interval for Mean	Lower Bound	52.06	
		Upper Bound	55.83	
	5% Trimmed Mean		54.16	
	Median		55.00	
	Variance		264.840	
	Std. Deviation		16.274	
	Minimum		5	
	Maximum		90	
	Range		85	
	Interquartile Range		25	
	Skewness		-.238	.143
	Kurtosis		-.405	.286
Intro to Sports Biomechanics	Mean		56.96	.504
	95% Confidence Interval for Mean	Lower Bound	55.96	
		Upper Bound	57.95	
	5% Trimmed Mean		57.04	
	Median		57.00	
	Variance		73.474	
	Std. Deviation		8.572	
	Minimum		0	
	Maximum		80	
	Range		80	
	Interquartile Range		10	
	Skewness		-.831	.143
	Kurtosis		5.949	.286

Standardised skewness and kurtosis values ($\frac{Skewness}{Standard\ error\ skewness}$ and $\frac{Kurtosis}{Standar\ error\ kurtosis}$) provided the following results.

Module	Standardised skewness	Standardised kurtosis
Physiology of High Intensity Performance	-3.168	0.913
Physiology of Endurance Performance	-2.210	2.608
Statistics One	-1.664	-1.416
Introduction to Sports Biomechanics	-5.811	20.801

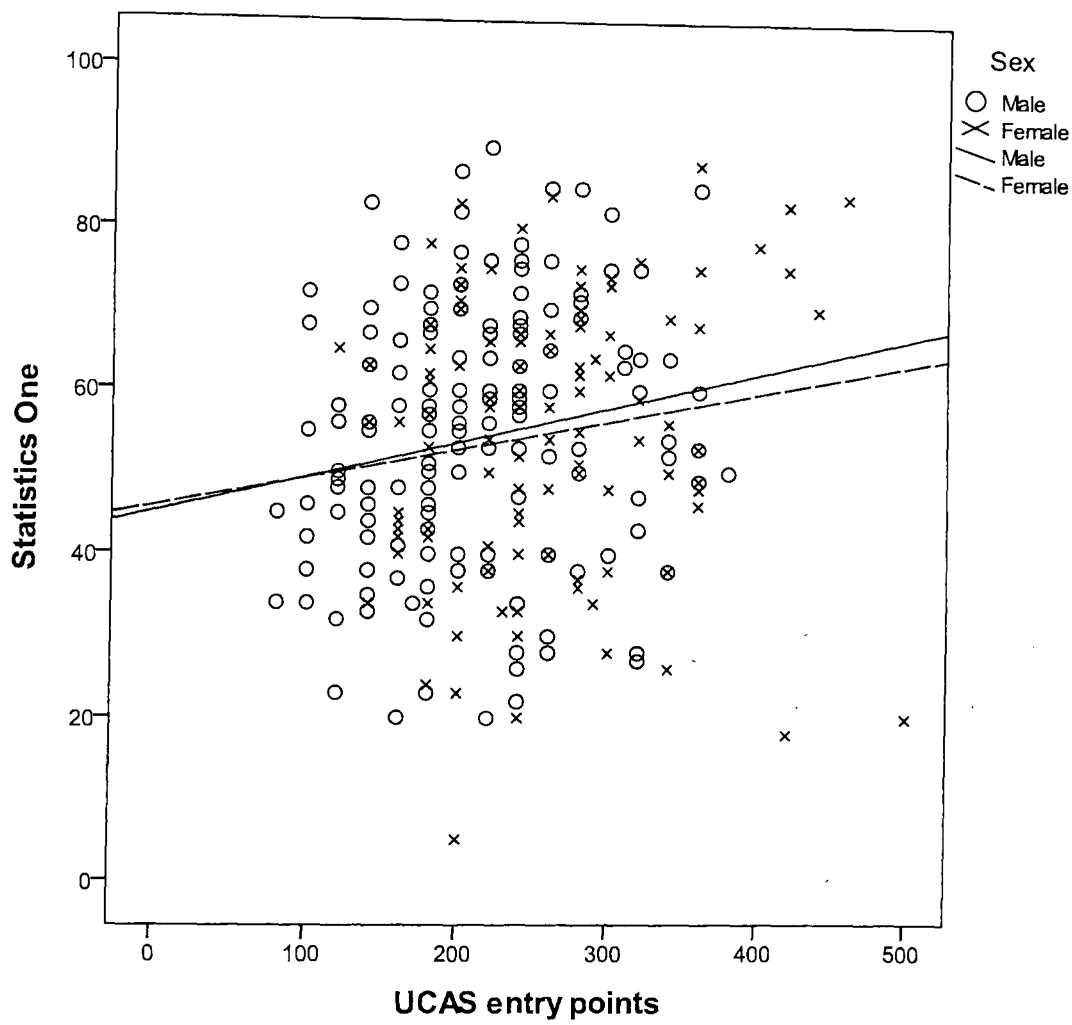
Standardised skewness and kurtosis values above +2 or below -2 indicate some departure from normality, with those values above +3 or below -3 providing cause for concern.

Small violations of the assumptions of ANOVA were found in many variables, but which were insufficient to prevent the use of ANOVA to investigate differences between groups (Tabachnick and Fidell, 1996: Stevens, 2009) particularly as sample sizes were deemed large enough for ANOVA to tolerate moderate departures from normality (Agresti and Finlay, 1997; Tabachnick and Fidell, 1996). The calculations indicated that Introduction to Sports Biomechanics was the only module to show large departures from normal distribution. The similarity of the mean and median for this module, together with the pattern of the histogram (predominantly bell-shaped) guided the researcher to use parametric testing in Chapter Five.

Tests of Homogeneity of Regression Slopes and ANCOVA Output for Statistics One Marks.

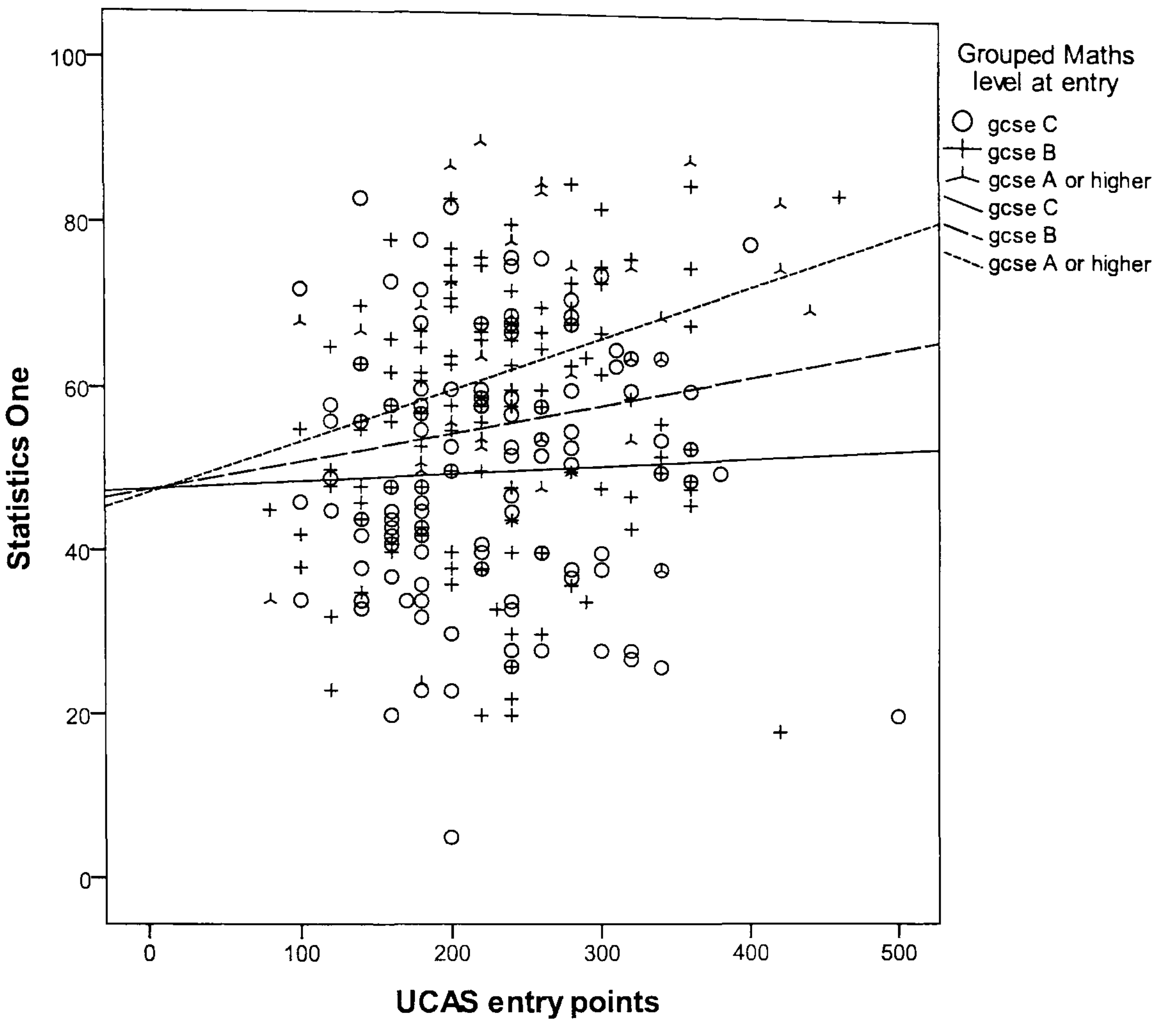
A variable can be considered a covariate if it bears a relationship to the dependent variable under analysis. Scatter diagrams for each variable, segregated by the factors to be included in the ANCOVA are a method of identifying potential covariates. The regression slopes for each factor should be similar if there is covariation.

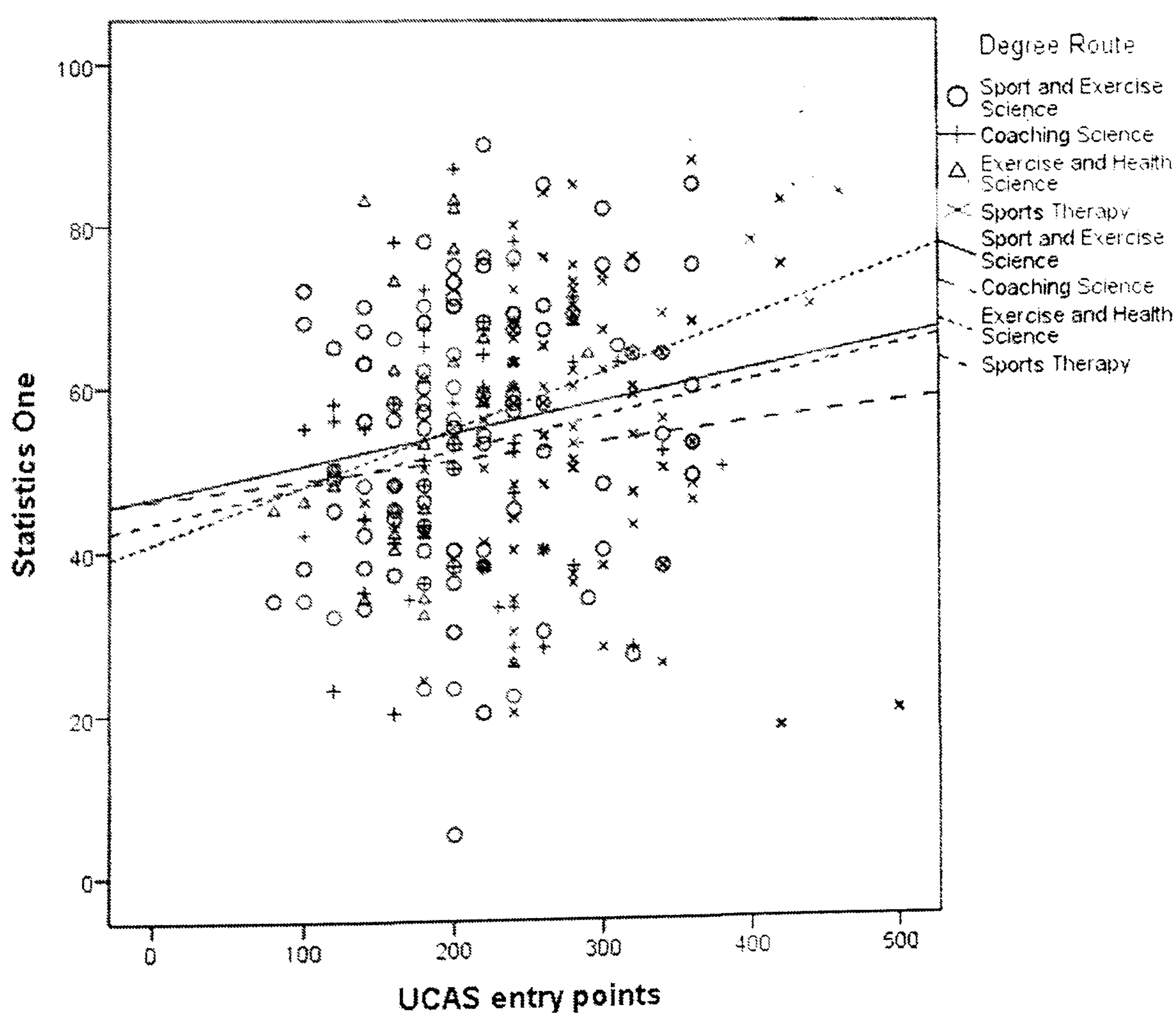
The scatter diagram to evaluate potential covariation between UCAS points and Statistics One marks between male and female students is shown below. There is a random scatter of points suggestive of little relationship between the two variables.



Regression lines for males and females did not fit the data well because of the poor relationship. However, the slopes for male and female students were very similar, suggesting that what little relationship may be present is similar for males and females.

Scatter diagrams for prior Mathematics qualification and degree route (overleaf) did not exhibit similarity between the regression slopes. Further tests were conducted to make sure the level of possible covariance did not differ significantly across these groups or their interactions.


Grouped Maths level at entry
gcse C
gcse B
gcse A or higher
gcse C
gcse B
gcse A or higher
Statistics One
UCAS entry points
0
20
40
60
80
100
0
100
200
300
400
500


Degree Route
Sport and Exercise Science
Coaching Science
Exercise and Health Science
Sports Therapy
Sport and Exercise Science
Coaching Science
Exercise and Health Science
Sports Therapy
Statistics One
UCAS entry points
0
20
40
60
80
100
0
100
200
300
400
500

Tests of Between-Subjects Effects

Dependent Variable:Statistics One

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11770.822[a]	28	420.386	1.758	.013
Intercept	13729.470	1	13729.470	57.405	.000
UCAS	1594.409	1	1594.409	6.666	.010
Mlevelcode * UCAS	791.821	2	395.910	1.655	.193
Prog * UCAS	96.916	3	32.305	.135	.939
Gender * UCAS	210.062	1	210.062	.878	.350
Mlevelcode * Prog * UCAS	2115.673	6	352.612	1.474	.187
Gender * Mlevelcode * UCAS	158.567	2	79.283	.331	.718
Gender * Prog * UCAS	224.735	3	74.912	.313	.816
Gender * Mlevelcode * Prog * UCAS	65.239	4	16.310	.068	.991
Gender	70.809	1	70.809	.296	.587
Mlevelcode	243.422	2	121.711	.509	.602
Prog	230.310	3	76.770	.321	.810
Error	60988.344	255	239.170		
Total	912717.000	284			
Corrected Total	72759.165	283			

a. R Squared = .162 (Adjusted R Squared = .070)

The highlighted values on the SPSS output above shows that none of the interactions between the covariate 'UCAS' and gender, degree programme (prog) or highest Mathematics qualification (Mlevelcode), are significant ($\alpha = 0.05$). This means that the little potential covariance evidenced by the data can be assumed to be homogeneous across the different interaction groups.

The preliminary analysis documented above confirmed that UCAS points *could* be included in an analysis as a potential covariate, but that it probably would not have a large effect on Statistics One marks. It was decided to complete the ANCOVA procedure because the exclusion of UCAS points at this stage would prevent an evaluation of some of the quantitative hypotheses of this project.

The SPSS output for the ANCOVA follows on the next three pages with interspersed commentary to indicate how the decisions were reached in section 5.4.

Between-Subjects Factors

		Value Label	N
Grouped Maths level at entry	2	gcse C	115
	3	gcse B	130
	4	gcse A or higher	39
Degree Programme	1	Sport and Exercise Science	112
	2	Coaching Science	52
	3	Exercise and Health Science	30
	4	Sports Therapy	90
Gender	0	Male	162
	1	Female	122

The table of factors (above) indicates how the data were spread between groups. The group sizes are large for the analysis of main effects, but tables 4.1 and 4.2 demonstrated that some interaction groups were very small. This affected the reliability of interaction results.

Tests of Between-Subjects Effects

Dependent Variable:Statistics One

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10579.340[a]	22	480.879	2.018	.005
Intercept	34595.095	1	34595.095	145.213	.000
UCAS	1759.021	1	1759.021	7.383	.007
Mlevelcode	1585.336	2	792.668	3.327	.037
Prog	570.788	3	190.263	.799	.496
Gender	249.774	1	249.774	1.048	.307
Mlevelcode * Prog	1457.086	6	242.848	1.019	.413
Mlevelcode * Gender	644.004	2	322.002	1.352	.261
Prog * Gender	228.154	3	76.051	.319	.811
Mlevelcode * Prog * Gender	101.175	4	25.294	.106	.980
Error	62179.826	261	238.237		
Total	912717.000	284			
Corrected Total	72759.165	283			

a. R Squared = .145 (Adjusted R Squared = .073)

The highlighted values in the table at the bottom of the previous page provided the evidence for the significant results documented in section 5.4. Only the results for the main effects of UCAS points and Mathematics qualifications had probabilities below the 5% significance level.

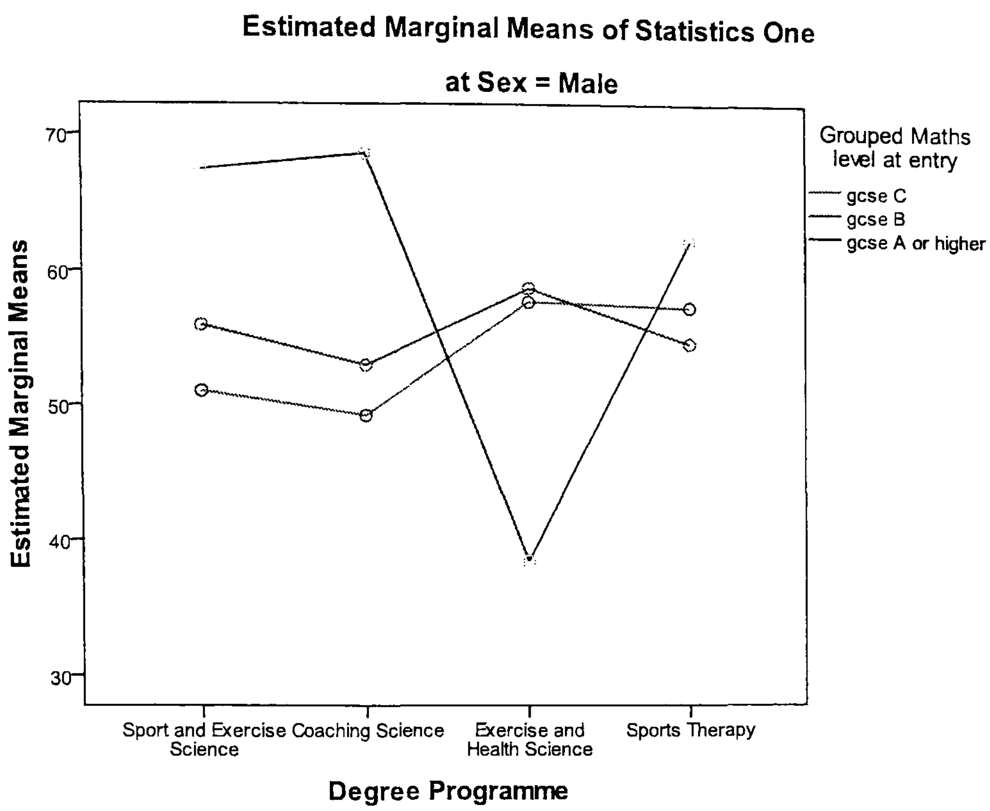
Contrast Results (K Matrix)

Grouped Maths level at entry Simple Contrast[a]			Dependent Variable Statistics One
GCSE B vs. GCSE C	Contrast Estimate		4.046
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		4.046
	Std. Error		2.498
	Sig.		.107
	95% Confidence Interval for Difference	Lower Bound	-.873
		Upper Bound	8.965
GCSE A vs. GCSE C	Contrast Estimate		7.954
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		7.954
	Std. Error		4.162
	Sig.		.057
	95% Confidence Interval for Difference	Lower Bound	-.242
		Upper Bound	16.150

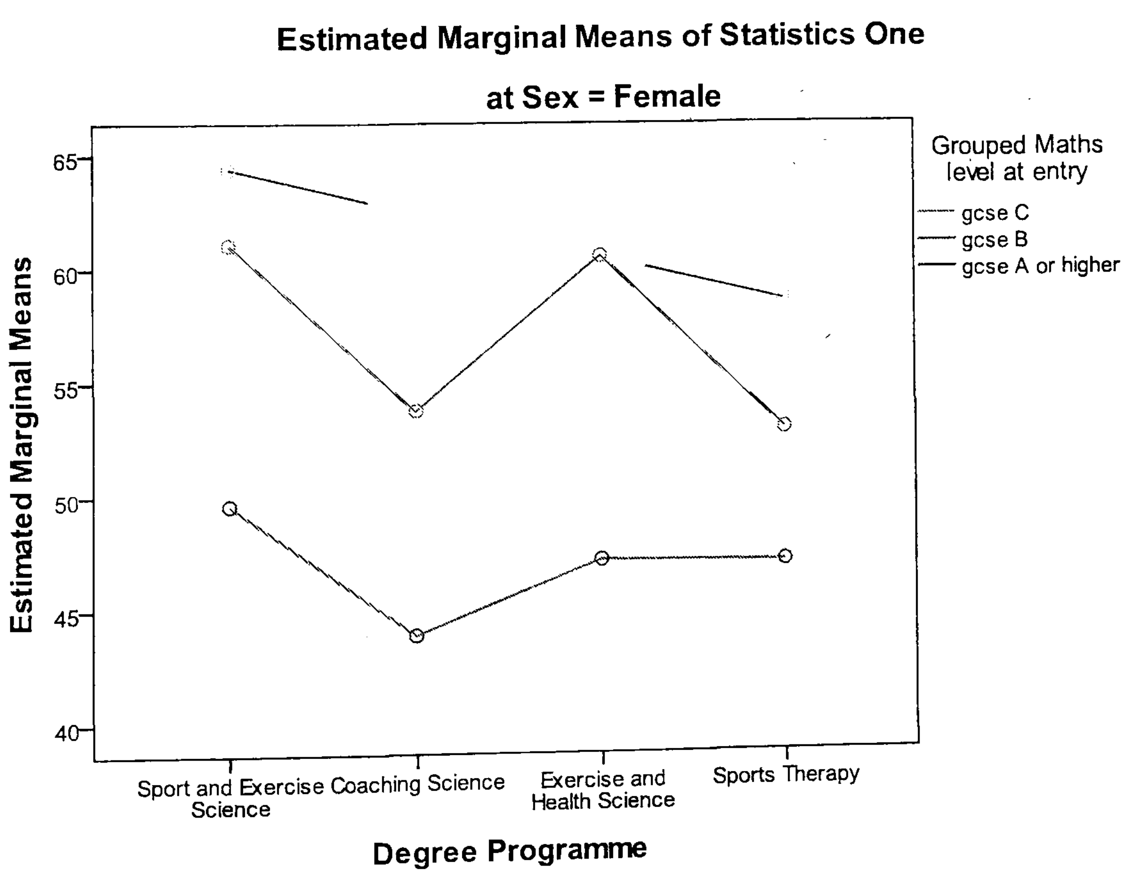
a. Reference category = GCSE C

Simple contrasts and reference to table 4.4 found GCSE grade A or higher to be significantly different from GCSE grade C at the 10% level of significance ($p = 0.057$) and to result in an increased mean mark. There was no evidence that a GCSE grade B was significantly better than a grade C ($p = 0.107$).

The profile described by the line for GCSE grade A differed from the other grades in the graphs on the following page, and it is consistently higher than the other lines. The graphs illustrate why Mathematics qualification was found to have a significant effect, although manually calculated effect sizes reported in section 5.4 were small, so the differences detected may not be reliably attributed to UCAS points and Mathematics qualifications.



Covariates appearing in the model are evaluated at the following values: UCAS entry points = 231.62



Covariates appearing in the model are evaluated at the following values: UCAS entry points = 231.62

Non-estimable means are not plotted

Participant Information Sheet

A study into Sports Science students' experiences of learning statistics

Participants will be selected from students studying SPL201 (Research Methods for Sport and Exercise Sciences 2) this semester. Students need to respond to an e-mail (sent to all students registered on the module) indicating that they would be willing to participate and selection will be from this list of volunteers.

Participants will be required to take part in an interview near the commencement of the module where their experiences of learning statistics will be explored using unstructured interview techniques. This interview could be fairly lengthy. Further short interviews will be conducted at middle or end points of the module for participants to be able to review their experiences of learning specific statistical processes. A final short retrospective interview will be conducted after Christmas once students have undertaken the assessment process and have received feedback on their results.

Interviews will be taped and transcribed, rather in the way you learned in the level four research methods module. Each participant will have the opportunity to verify and adjust his or her individual transcript before it is used as part of the final thesis.

The exploration of students' experiences is one part of a larger study into statistical teaching and learning. Analysis of examination and assignment marks across all three years of undergraduate modules will form another large component of my work.

The purpose of the whole study is to look for indicators of how statistics teaching can be improved to support student learning.

All information gathered will be anonymised and kept in a locked cabinet on the university campus. Spreadsheets of statistical data will be coded so that no names are stored on any computer. Participants have the right to withdraw from the study at any time and to request that no data collected from them be used for analysis.

Volunteering, or not volunteering, to take part in this study will not affect the way you are treated as part of the module teaching for SPL201. I will not mark any assessments for students who take part in the study. Knowledge I have about those students that is beyond knowledge I have of other students on the module will not affect marks. (Thus the possibility of me recognising individual students' work during the marking process will be removed.)

In writing the final thesis no information will be included that will identify individuals or the institution in which the study took place.

Bev Hale.

Participant Consent Form

I ____(print name)

Have read and understood the information sheet about the study into

Students'experiences of learning Statistics.

- I understand what my involvement will entail.
- I have asked, and obtained satisfactory answers to questions and concerns I had about participating.
- I understand that I can withdraw from the study at any time without prejudice.
- I understand that all data gathered will be anonymised, kept in a secure location and will remain confidential.
- I understand that I will have the opportunity to see, and if necessary adjust, the outcomes of analysis of the data I provide.
- I understand that tapes and transcripts of interviews become the property of the University of [redacted].
- I agree that findings following analysis of data may be published provided that I cannot be identified as a participant.
- I have the means of contacting the researcher should I wish to seek further information during the course of my participation in the study.

Participant's signature ____________________________ Date ________________

I, Beverley Hale, have explained the project and the implications of participation to

____ .

I believe that consent is informed, and demonstrates understanding of the implications of the investigation.

Signature ______________________________________ Date ________________

Semi-Structured Interview Schedule November/December 2006

Over the course of the module statistics has been taught using three main approaches

Problem solving approach – where we have given you a problem and asked you to solve it with support from us on an individual and group basis.

Directed approach – where most of the session has been tutor led and you have followed instructions throughout

Front loaded approach – where you have had a 'lecture' style introduction to a topic and then you have carried out work on your own or in groups

1. Explain how you felt about each of those types of sessions

   How did each type affect your learning?

   Did you learn some things better one way and other things a different way? Can you give some examples?

   Do you think that one model was better for your learning than the others? Other students might not have liked your choice, could they be disadvantaged? What are your thoughts on this?

   What impact do any/each of the models have on the assessment of your abilities?
   and other people's abilities?

   Is there a different way that you can think of that you would have found more beneficial?

2. You will be aware in class that other students are not at the same level as you because of prior experiences. Some will be faster, others slower. What do you think should be done about this?

   What would you find helpful for your progress?

3. I observed in weeks 11 and 12 that most people were very attentive in the revision sessions that dealt with the concepts of ANOVA and regression. In previous weeks some students had indicated that they preferred to work on the computers and not have to consider the conceptual side of statistics.

   Why do you think you were all more attentive in those weeks?

   Do you think the computers are distracting if we try to explain the concepts in S9?

   How did you feel about those revision sessions?

   Do you think that the location of the revision classes (in seminar rooms) or the timing of them was important?

How do you think the revision sessions would have worked if I had delivered the material as a lecture to all of you rather than in 5 smaller seminar groups?

4. Explain how you went about completing the readings, Portia tasks and formative assessments that were provided over the course of the module.

   What would have made you engage more fully with these?

Do you have anything to add about your experiences of studying this particular module that we haven't considered?

Conversion of Entry Qualifications to UCAS Tariff Points

UCAS tariff points were generated from two different forms of qualification. 79% of the students had completed AS and A-level studies which transferred directly to UCAS tariff points using the grade to point conversion shown in table 1.

Table 1 A/AS-level conversion from grade awarded to UCAS tariff points

A level grade	A level UCAS points		AS level grade	AS level UCAS points
A	120		A	60
B	100		B	50
C	80		C	40
D	60		D	30
E	40		E	20

20% of students entered with BTec diplomas in Sports Science (5.7%) or Sports Studies (14.3%). Sports Science BTec provided outcomes for 3 modules of study. The possible combination of awards and their UCAS tariff point equivalents are shown in table 2. Three distinction modules were deemed equivalent to 3 A levels at grade A, 3 merit modules equivalent to 3 A levels at grade C.

Table 2. BTec Sports Science conversion from grade awarded to UCAS tariff points

Possible grade combinations of D = Distinction, M = Merit, P = Pass	UCAS points (D = 120, M = 80, P = 40)
DDD	360
DDM	320
DMM	280
MMM	240
MMP	200
MPP	160
PPP	120

Sports Studies BTec profiles were sent to the University as a transcript of unit grades typically over fourteen to sixteen 'units' of study. Students with such profiles amounted to 14.3% of the total group for whom UCAS tariff points were applicable. Quantification of UCAS tariff points from BTec Sports Studies 'unit' outcomes was not transparent. A translation system, supplied by a local further education college, enabled conversion of these students' achievements onto the standard UCAS tariff point scale. This involved grouping units of study under generic subject areas and converting unit marks into Pass Merit or Distinction grades for those subject areas. Pass, Merit and Distinction grades could then be converted using the system outlined in table 2.

Example of SPSS Output - for Regression Equation 5.2

›r to regression analysis the categorical variables of gender, degree programme and thematics qualification needed to be coded as dummy variables (that is using only the ıes one and zero). The method used by Agresti and Finlay (1997) was used following able SPSS coding as explained by Field (2009a). For gender this is simple because the ɩable is dichotomous. Males were assigned the value of zero and females were coded as . The method for coding more than two categories is outlined below for the degree gramme variable.

- Subtract one from the total number of groups to be recoded in order to determine how many dummy variables are needed – this corresponds to the number of columns needed in an SPSS spreadsheet. There were four degree programmes so three columns were needed.
- Select a comparative group. The Sport and Exercise Science degree programme was selected as all the other programmes included some compulsory modules from this programme. It was assigned '0' for all three dummy variables.
- For the next group the Coaching Science degree programme was assigned a value of '1' in the first dummy variable but zero in all the others.
- The next group - Exersise and Health Science was assigned '1' in the second dummy variable, but zero in all others.
- Finally, Sports Therapy was assigned a '1' in the final column only.

ɗings in SPSS columns for each degree programme were as in the table below.

	SPSS variable headings		
	DummyCS	DummyEH	DummyST
Degree programme			
Sport & Exercise Science	0	0	0
Coaching Science	1	0	0
Exercise & Health Science	0	1	0
Sports Therapy	0	0	1

› coding enabled the regression equations to be interpreted with reference to baseline ›gories. For the example above equations that included a coefficient for Coaching ›ence, Exercise and Health Science, or Sports Therapy could be interpreted as indicating : those degree programmes would contribute additional marks to the outcome of Statistics ɗule compared to a similar Sport and Exercise Science student. If the coefficients were ative, then students on that particular programme would have lower marks than similar ɭents on the Sport and Exercise comparative programme.

The analysis that resulted in equation 5.2 is reproduced below as an example. That equation was chosen because the SPSS output for it was shorter than that for the backwards elimination model that resulted in equation 5.1, but the explanation of the output is similar.

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	GCSE B, UCAS entry points, GCSE A or more[a]		Enter

a. All requested variables entered.

b. Dependent Variable: Statistics One

The backwards elimination procedure retained all three variables entered for equation 5.2 (UCAS points, Dummy GCSE A and Dummy GCSE B). Therefore, SPSS specified the model as a simultaneous entry method.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.313[a]	.098	.088	15.310

a. Predictors: (Constant), GCSE B, UCAS entry points, GCSE A or more

b. Dependent Variable: Statistics One

The fit of the model was poor, as it only accounted for 9.8% of the data variation (R Square = 0.098). The estimated ability of the model to predict Statistics One marks for future cohorts was only 8.8% (Adjusted R Square value = 0.088).

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	46.14	69.03	54.38	5.018	284
Std. Predicted Value	-1.643	2.919	.000	1.000	284
Standard Error of Predicted Value	1.343	3.668	1.759	.456	284
Adjusted Predicted Value	45.63	68.98	54.39	5.025	284
Residual	-44.131	35.665	.000	15.229	284
Std. Residual	-2.882	2.329	.000	.995	284
Stud. Residual	-2.896	2.345	.000	1.002	284
Deleted Residual	-44.726	36.156	-.008	15.465	284
Stud. Deleted Residual	-2.935	2.365	-.001	1.006	284
Mahal. Distance	1.181	15.245	2.989	2.329	284
Cook's Distance	.000	.100	.004	.009	284
Centered Leverage Value	.004	.054	.011	.008	284

a. Dependent Variable: Statistics One

Statistics from the table above indicate some problems with the regression model. The residuals, or errors, for prediction ranged from 46% to 69%. This would be unacceptable on a scale of percentage marks where crucial parameters are a pass mark of 40% with associated 10% grade boundaries.

There are other values included in the table which provide useful diagnostic tools if a model does appear to fit the data set. That is not the case here, so further analysis of the fit of the model to the data concentrated on the way the model predicted estimates of the known Statistics One marks.

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7124.933	3	2374.978	10.132	.000[a]
	Residual	65634.233	280	234.408		
	Total	72759.165	283			

a. Predictors: (Constant), GCSE B, UCAS entry points, GCSE A or more

b. Dependent Variable: Statistics One

The ANOVA evaluated the regression model to explain a significant amount of data variation. This was unsurprising as the criteria for the model meant that only variables that had significant predictive ability could be included.

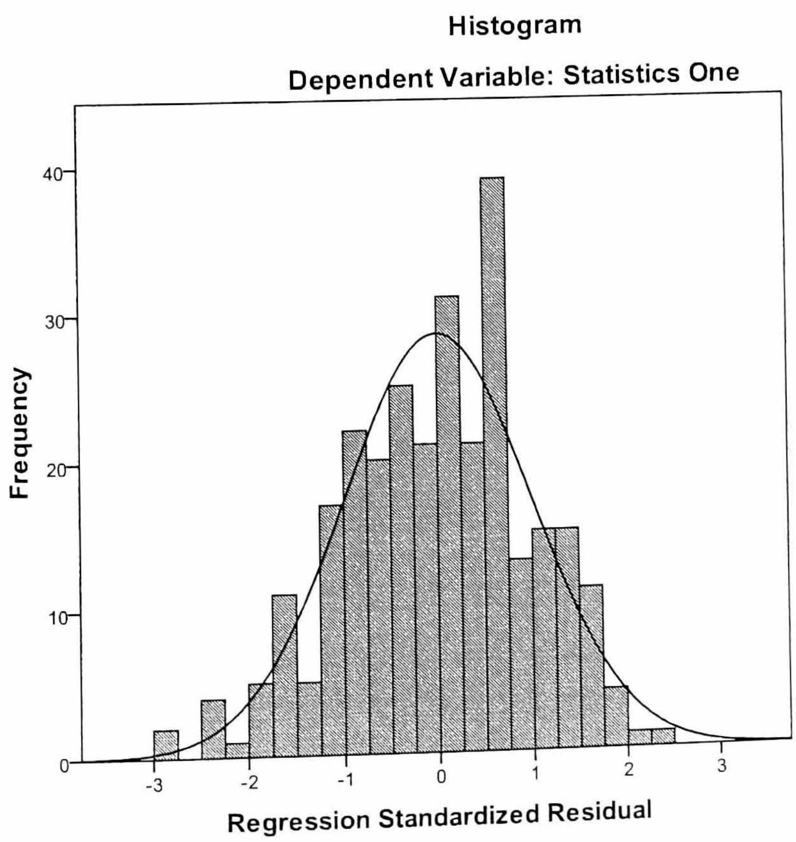
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	43.144	3.145		13.718	.000
	UCAS entry points	.030	.012	.139	2.422	.016
	GCSE A or more	12.713	2.862	.273	4.442	.000
	GCSE B	5.593	1.960	.174	2.853	.005

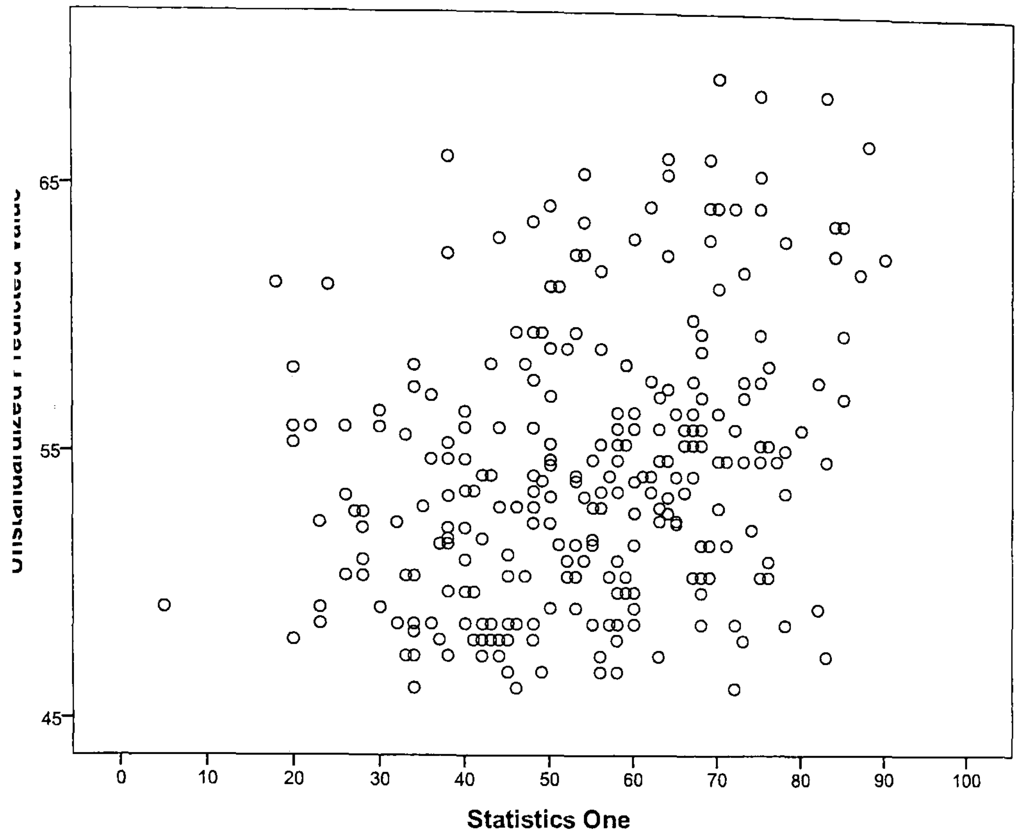
a. Dependent Variable: Statistics One

The unstandardised coefficients column provided the values that generated equation 5.2. The value of 12.713 next to 'GCSE A or more' indicates that a student with that grade would expect to get a mark approximately 12% higher than a student with a grade C for GCSE Mathematics.

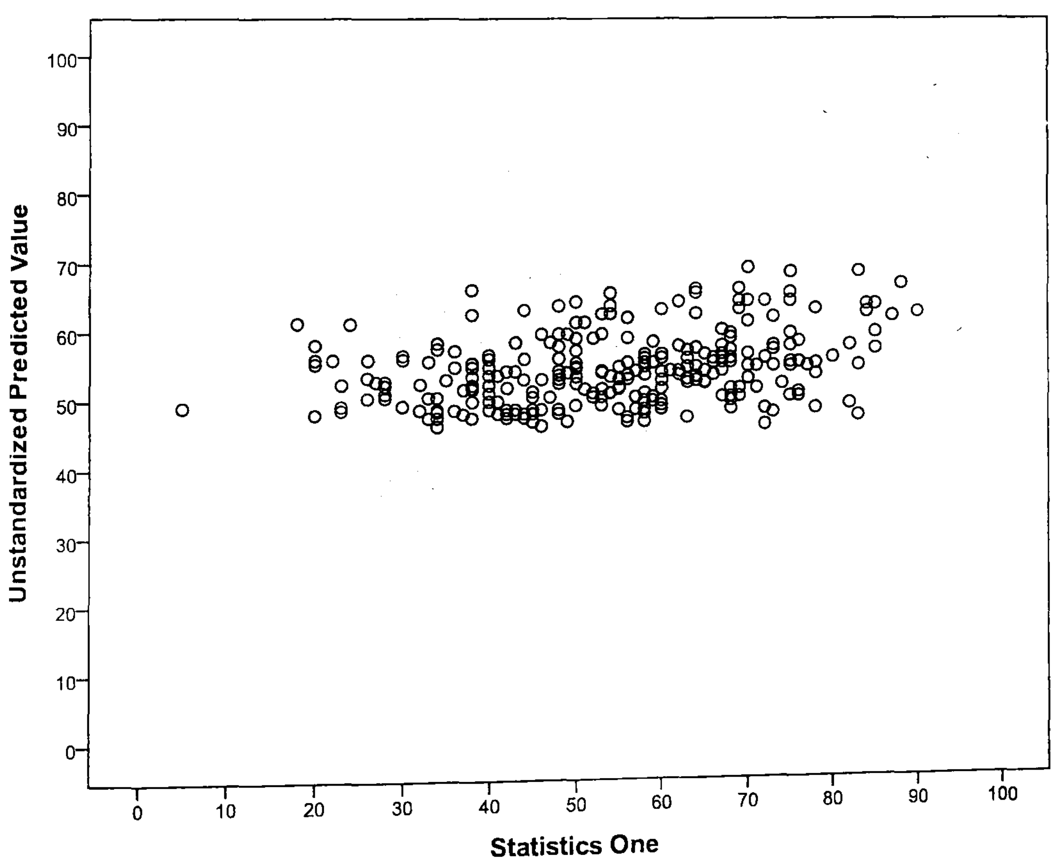
The standardised coefficients enabled a comparison of the three variables included in the equation. This comparison could not be made from the unstandardised coefficients because the variables were not measured on the same scale.



Standardised residuals were between three standard deviations (the x-axis scale) and mirrored the normal curve fairly well. Although the histogram suggested that equation 5.2 fitted the data adequately, it missed potential patterns in the residuals which gave cause for concern.



first glance the relationship, for the sample of students, between the actual Statistics One ırk and the prediction from the model appeared to be better than the R^2 value suggested. A ;caling of the y-axis to make it match that of the x-axis revealed how the predictions ıtched the possible range of the data.



ıe adjusted scale on the scatter diagram above revealed how equation 5.2 predicts marks tween 46% and 69% for everybody. It fails to discriminate adequately between students.

Poster

Presented at the annual international conference of The Royal Statistical Society

Edinburgh September 2009

(Poster was preceded by a two minute 'speed-dating' style presentation)

This appendix is not referred to in the main document. It is included here as evidence of dissemination of some of the findings from the research project.

What's Statistics got to do with my Degree: Is relevant context useful in the enhancement of students' understanding of statistical concepts?

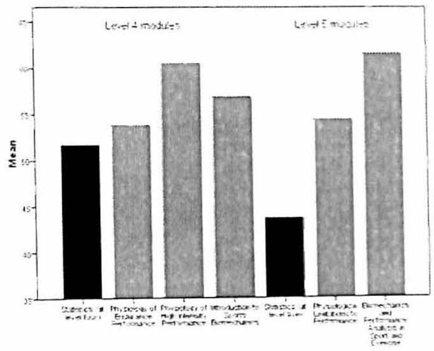
Beverley Hale

University of , UK

Statistics is perceived to be difficult and irrelevant by Sports Science students.

Students do not achieve marks for statistics that are commensurate with other core modules.

Statistics marks compared to other compulsory modules (Mean % marks)



utors used data generated from sports science laboratory tudies to introduce statistics to students. From tutor erspective the problem, the data and the analysis link into coherent whole that enables interpretation of results.

One-way ANOVA found the differences in mean module marks to be significant at both level four ($F_{(2,250,648.131)}$ = 12.265, p<0.001) and level five ($F_{(1,357,264.663)}$ = 161.940, p<0.001).
Effect sizes for the ANOVA at level four was medium (*f* = 0.326) while at level five it was large (*f* = 0.454).

Student interviews (n=12) demonstrated little contextual comprehension resulting in inability to see the logical progression of work.

CONCLUSION

The introduction of relevant context to stand-alone statistics modules is insufficient to establish connections between statistics and sports science.

BUT

"Putting it into context of something we had to do that was important for us..everything gets kind of clearer…it

just gets a bit 'oh wow I'm actually using this!'" (a level five student)

The crucial point. Statistics educators must not forget the student perspective.

References

Agresti, A. and Finlay, B. (1997) *Statistical methods for the social sciences.* 3rd (International) edn. New York: Pearson, Prentice-Hall.

Altman, D.G. and Bland, J.M. (1991) 'Improving doctors' understanding of statistics', *Journal of the Royal Statistical Society Series A, Statistics in Society,* 154(2), pp.223-267.

Arksey, H. and Knight, P. (1999) *Interviewing for social scientists.* London: Sage.

Atkinson, P. and Delamont, S. (2005) 'Analytical perspectives', in Denzin. N.K. and Lincoln, Y.S. (eds.) *The Sage handbook of qualitative research.* London: Sage, pp. 821-840.

Bandura, A. (1997) *Self-efficacy: the exercise of control.* New York: W.H. Freeman and Company.

Barnett, R. (1997) *Higher education: a critical business.* Buckingham: SRHE/Open University Press.

Barnett, V. (2007) 'Statistics teaching in higher education', *RSS News,* 34(8), pp.1-3.

Beaty, L. (2003) 'Supporting learning from experience', in Fry, H., Ketteridge, S. and Marshall, S. (eds.) *A handbook for teaching and learning in higher education: enhancing academic practice.* 2nd edn. London: Kogan Page, pp. 134-147.

Becher, T. and Trowler, P.R. (2001) *Academic tribes and territories: intellectual enquiry and the culture of disciplines.* 2nd edn. Buckingham: SRHE/Open University Press.

Ben-Zvi, D. and Garfield, J. (eds.) (2004a) *The challenge of developing statistical literacy, reasoning and thinking.* Dordrecht: Kluwer Academic Publishers.

Ben-Zvi, D. and Garfield, J. (2004b) 'Statistical literacy, reasoning and thinking: goals, definitions and challenges', in Ben-Zvi, D. and Garfield, J. (eds.) *The challenge of developing statistical literacy, reasoning and thinking.* Dordrecht: Kluwer Academic Publishers, pp. 3-15.

Bessant, K.C. (1992) 'Instructional design and the development of statistical literacy', *Teaching Sociology,* 20(2), pp.143-149.

Biggs, J. and Tang, C. (2007) *Teaching for quality learning at university.* 3rd edn. Maidenhead: SRHE/Open University Press.

Birkhead, T. (2009) 'Superficiality breeds contempt', *Times Higher Education,* 10-16 September, pp.38-43.

Blair, A. (2009) 'University Challenge: can you find a job afterwards?', *Times2, Times Newspaper*, 22 September, p. 3.

Boud, D. (1995) 'Assessment and learning: contradictory or complementary?', in Knight, P. (ed.) *Assessment for learning in higher education*. London: KoganPage, pp. 35-48.

Brannen, J. (2005) 'Mixing methods: the entry of qualitative and quantitative approaches into the research process', *International Journal of Social Research Methodology,* 8(3), pp.173-184.

Brogan and Kutner (1986) 'Graduate statistics service courses', *The American Statistician,* 40(3), pp.252-254.

Bryson, C. (2009) *The nature of student engagement and why it matters so much.* available at:
http://www.gla.ac.uk/service/learningteaching/seminarsandsymposia/colinbryson (Accessed: 19 June 2009).

Bryson, C. and Hands, L. (2007) 'The role of engagement in inspiring teaching and learning', *Innovations in Education and Teaching International,* 44(4), pp.349-362.

Carey, T.A. (2006) 'Maths and stats', *The Psychologist,* 19(4), p.209.

Carnell, E. and Lodge, C. (2002) *Supporting effective learning.* London: Paul Chapman.

Carr, W. and Kemmis, S. (1986) *Becoming critical: education, knowledge and action research.* London: Falmer Press.

Case, J.M. (2008) 'Alienation and engagement: development of an alternative theoretical framework for understanding student learning', *Higher Education,* 55(3), pp.321-332.

Case, J. and Gunstone, R. (2003) 'Going deeper than deep and surface approaches: a study of students' perceptions of time', *Teaching in Higher Education,* 8(1), pp.55-69.

Case, J. and Marshall, D. (2004) 'Between deep and surface: procedural approaches to learning in engineering education contexts', *Studies in Higher Education,* 29(5), pp.605-615.

Chalmers, D. and Fuller, R. (1996) *Teaching for Learning at University.* London: Kogan Page.

Chatzisarantis, N.L.D. and Williams, C. (2006) 'The impact of Schmidt's teaching method on motivation to study statistics', *The Higher Education Academy Hospitality, Leisure, Sport and Tourism Network* [Online]. Available at: http://www.hlst.heacademy.ac.uk/projects/r5_chatzisarantis_report.pdf (Accessed: 7 March 2006).

Clarke, A. and Erickson, G. (2003) 'Teacher inquiry: a defining feature of professional practice', in Clarke, A. and Erickson, G. (eds.) *Teacher inquiry: living the research in everyday practice.* London: RoutledgeFalmer, pp. 1-6.

Cobb, G.W. and Moore, D.S. (1997) 'Mathematics, statistics and teaching'. *American Mathematical Monthly,* 104(9), pp.801-823.

Coffield, F., Moseley, D., Hall, E. and Ecclestone, K. (2004) 'Learning styles and pedagogy in post-16 learning: A systematic and critical review', *Learning and Skills Research Centre.* [Online]. Available at: http://www.lsneducation (Accessed: 24 July 2008).

Cohen, J. (1988) *Statistical power analysis for the behavioral sciences.* 2nd edn. New Jersey: Lawrence Erlbaum Associates.

Cowan, J. (2006) *On becoming an innovative university teacher: reflection in action.* 2nd edn. Maidenhead: SRHE/Open University Press.

Crang, M. and Cook, I. (2007) *Doing ethnographies.* London: Sage.

Cullingford, C. and Crowther, K. (2005) 'Student learning and mathematics in higher education', *Higher Education Review,* 37(3), pp.33-43.

D'Andrea, V. and Gosling, D. (2005) *Improving teaching and learning in higher education: a whole institution approach.* Maidenhead: SRHE/Open University Press.

Davies, N. (2006) 'Real data, real learning and the London Olympics', *Significance,* 3(2), pp.94-96.

Deci, E.L. and Ryan, R.M. (1985) *Intrinsic motivation and self-determination in human behaviour.* New York: Plenum Press.

DeCesare, M. (2007) '"Statistics anxiety" among sociology majors: a first diagnosis and some treatment options', *Teaching Sociology,* 35, pp.360-367.

delMas, R.C. (2004) 'A comparison of mathematical and statistical reasoning', in Ben-Zvi, D. and Garfield, J. (eds.) *The challenge of developing statistical literacy, reasoning and thinking.* Dordrecht: Kluwer Academic Publishers, pp. 79-95.

Dewey, J. (1966) *Democracy and education.* Toronto: First Free Press.

Drever, E. (2003) *Using semi-structured interviews in small-scale research: a teacher' guide.* Revised edn. Glasgow: SCRE Centre, University of Glasgow.

Eisner, E. (1992) 'Objectivity in educational research', *Curriculum Inquiry,* 22(1), pp.9-15.

Elliott, J. (2005) *Using narrative in social research: qualitative and quantitative approaches.* London: Sage.

Entwistle, N.J. (1981) *Styles of learning and teaching.* New York: Wiley.

Entwistle, N. (2000) 'Promoting deep learning through teaching and assessment: conceptual frameworks and educational contexts', *Paper presented at the Teaching and Learning Research Programme (TLRP) conference, Leicester*, November 2000. [Online]. Available at: http://scholar.google.co.uk/scholar?hl=en&as_sdt=2000&as_ylo=1981&q=%22types+of+learning%22+author%3AEntwistle (Accessed: 29 November 2009).

Field, A. (2009a) *Discovering statistics using SPSS,* 3rd edn. London: Sage Publications Ltd.

Field, A. (2009b) 'Can humour make students love statistics?', *The Psychologist,* 22(3), pp.210-213.

Foucault, M. (1977) *Language, counter-memory, practice.* Ithaca: Cornell University Press.

Furedi, F. (2005) 'I refuse to hand it to students on a plate', *The Times Higher Education Supplement,* 25 March p.46.

Gal, I. (2002) 'Adults' statistical literacy: meanings components, responsibilities', *International Statistical Review,* 70(1), pp.1-25.

Gardner, H. (1993) *Frames of mind: the theory of multiple intelligences.* 2nd edn. London: Fontana Press.

Garfield, J. (1995) 'How students learn statistics', *International Statistical Review,* 63(1), pp.25-34.

Garfield, J. and Ben-Zvi, D. (2004) 'Research on statistical literacy, reasoning and thinking: issues, challenges and implications', in Ben-Zvi, D. and Garfield, J (eds.) *The challenge of developing statistical literacy, reasoning and thinking.* Dordrecht: Kluwer Academic Publishers, pp. 397-409.

Garfield, J. and Ben-Zvi, D. (2007) 'How students learn statistics revisited: a current review of research on teaching and learning in statistics', *International Statistical Review,* 75(3), pp.372-396.

Geertz, C. (1993) *The interpretation of cultures: selected essays.* London: Fontana.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and Trow, M. (1994) *The new production of knowledge: the dynamics of science and research in contemporary societies.* London: Sage.

Gigerenzer, G., Gaissmaier, W., Kurz-Milcke, E., Schwartz, L.M. and Woloshin, S. (2008) 'Helping doctors and patients make sense of health statistics', *Psychological Science in the Public Interest,* 8(2), pp.53-96.

Goldstein, H. (2003) *Multilevel Statistical Models.* 3rd Edn. London: Arnold.

Goleman, D. (2004) *Emotional intelligence; why it can matter more than IQ, and Working with emotional intelligence.* Omnibus edn. London: Bloomsbury.

Gough, H. and Gaine, C. (2002) *Minority Ethnic Experience in the Chichester District.* Chichester: University College Chichester.

Graham, A. (2006) *Developing thinking in statistics.* London: Paul Chapman Publishing.

Great Britain. Department for Education and Skills (2003) *The future of higher education.* (White paper) [Online]. Available at: http://www.dius.gov.uk/higher_education/~/media/publications (Accessed: 19 June 2009).

Great Britain. Department for Education and Skills (2006) *Widening participation in higher education.* [Online]. Available at: http://www.dius.gov.uk/higher_education/~/media/publications (Accessed: 19 June 2009).

Great Britain. *Higher Education Act 2004.* [Online]. Available at: http://www.opsi.gov.uk/acts/acts2004/ (Accessed: 21 June 2009).

Gregory, J. (2002) 'Facilitation and facilitator style', in Jarvis, P. (ed.) (2004) *The theory and practice of teaching.* London: RoutledgeFalmer, pp. 79-93.

Haggis, T. (2002) 'Exploring the "black box" of process: a comparison of theoretical notions of the 'adult learner' with accounts of postgraduate learning experience', *Studies in Higher Education,* 27(2), pp.208-220.

Haggis, T. (2003) 'Constructing images of ourselves? A critical investigation into 'approaches to learning' research in higher education', *British Educational Research Journal,* 29(1), pp.89-104.

Haggis, T. (2004) 'Meaning, identity and 'motivation': expanding what matters in understanding learning in higher education?', *Studies in Higher Education,* 29(3), pp.335-352.

Haggis, T. and Pouget, M. (2002) 'Trying to be motivated: perspectives on learning from younger students accessing higher education', *Teaching in Higher Education,* 7(3), pp.323-336.

Hale, B.J. (2004) *The place of the applied statistics lecturer as a professional within an academic community.* Unpublished EdD assignment: University of Surrey.

Hale, B.J. (2005) *The use of e-learning as a mode of learning within a small HEI.* Unpublished EdD assignment: University of Surrey.

Halpern, D.F. (2000) *Sex differences in cognitive abilities* 3rd edn. New Jersey: Lawrence Erlbaum Associates Inc.

Hanton, S. and Jones, G. (1999) 'The acquisition and development of cognitive skills and strategies: 1. Making the butterflies fly in formation', *The Sports Psychologist*, 13, pp.1-21.

Hencken, C. (2005) 'Making research methods more "attractive" to sport and exercise science students', *The Sport and Exercise Scientist*, 3(Mar), pp.10-11.

Higher Education Policy Institute (HEPI) (2009) *Male and female participation and progression in higher education*. Available at: http://www.hepi.ac.uk/pubs (Accessed: 19 August 2009).

Higher Education Statistics Agency (HESA) (2007). Available at: http://www.hesa.ac.uk (Accessed: 20 July 2007).

Higher Education Statistics Agency (HESA) (2008). Available at: http://www.hesa.ac.uk (Accessed: 20 July 2008).

Holmes, P. (2000) *Some issues in teaching statistics at university level*. [Online] Available at: http://www.mathstore.ac.uk (Accessed: 28 July 2008).

Holmes, P. (2003) '50 years of statistics teaching in English schools: some milestones', *The Statistician*, 52(4), pp.439-474.

Honey, P. and Mumford, A. (1982) *The manual of learning styles*. Maidenhead: Peter Honey.

Hopf, C. (2000) 'Qualitative interviews: an overview', in Flick, U., von Kardorff, E., and Steinke, I. (eds.) *A companion to qualitative research* (Translation B. Jenner, 2004). London: Sage, pp. 203-208.

Howell, D.C. (1997) *Statistical Methods for Psychology*. 4th edn. London: Duxbury Press.

Jarvis, P. (2002) 'Teaching styles and teaching methods', in Jarvis, P. (ed.) (2004) *The theory and practice of teaching*. London: RoutledgeFalmer, pp. 22-30.

Jarvis P., Holford, J. and Griffin, C. (2003) *The theory and practice of learning*. 2nd edn. London: Kogan Page.

Jolliffe, F. (1997) 'Issues in constructing assessment instruments for the classroom', in Gal, I. and Garfield, J. (eds.) *The assessment challenge in statistics education*. [Online]. Available at: http://www.stat.auckland.ac.nz/~iase/publications/assessbkref. pp. 191-204. (Accessed: 27 June 2008).

Jolliffe, F. (2007) *The changing brave new world of statistics assessment*. [Online]. Available at: http://www.stat.auckland.ac.nz/~iase/publications/sat07/joliffe.pdf (Accessed: 27 October 2008).

Kelly, A.E., Sloane, F. and Whittaker, A. (1997) 'Simple approaches to assessing underlying understanding of statistical concepts', in Gal, I. and Garfield, J (eds.) *The assessment challenge in statistics education.* [Online]. Available at: http://www.stat.auckland.ac.nz/~iase/publications/assessbkref. pp. 85-90. (Accessed: 27 June 2008).

Kolb, D.A. (1984) *Experiential learning: experience as the Source of learning and development.* New Jersey: Prentice-Hall Inc.

Kolb, D.A. (1999) *The Kolb learning styles inventory version 3.* Boston: Hay Group.

Kreft, I. and de Leeuw, J. (1998) *Introducing Multilevel Modeling.* London: Sage Publications Ltd.

Lane, A.M., Dale, C. and Horrell, A. (2006) 'Differentiating work for statistics modules in sports degrees', *Journal of Further and Higher Education,* 30(3), pp.295-302.

Lane, A.M, Devonport, T.J. and Horrell, A. (2004) 'Self-efficacy and research methods', *Journal of Hospitality, Leisure, Sport and Tourism Education,* 3(2), pp.25-37. [Online]. Available at: http://www.hlst.heacademy.ac.uk/johlste (Accessed: 5 January 2006).

Lane A.M., Devonport, T.J., Milton, K.E. and Williams, L.C. (2003) 'Self-efficacy and dissertation performance among sports students', *Journal of Hospitality, Leisure, Sport and Tourism Education,* 2(2), pp.59-66. [Online]. Available at: http://www.hlst.heacademy.ac.uk/johlste (Accessed: 6 July 2007).

Lane, A.M., Hall, R. and Lane, J. (2002) 'Development of a measurement of self-efficacy specific to statistics courses in sport', *Journal of Hospitality, Leisure, Sport and Tourism Education,* 1(2), pp.47-56. [Online]. Available at: http://www.hlst.heacademy.ac.uk/johlste (Accessed: 5 January 2006).

Lane A.M., Hall, R. and Lane J. (2004) 'Self-efficacy and statistics performance among sports studies students', *Teaching in Higher Education,* 9(4), pp.465-448.

Lane, J. and Lane, A. (2001) 'Self-efficacy and academic performance', *Social Behaviour and Personality,* 29(7), pp.687-694.

Lave, J. and Wenger, E. (1991) *Situated learning: legitimate peripheral participation.* Cambridge: Cambridge University Press.

Learning and Teaching Support Network for Mathematics Statistics and OR (LTSN MSOR) (2001) *Teaching statistics in higher education.* One day conference at The Royal Statistical Society, 14th November.

Legard, R., Keegan, J. and Ward, K. (2003) 'In-depth interviews', in Ritchie, J. and Lewis, J. (eds.) *Qualitative research practice: a guide for social science students and researchers.* London: Sage, pp. 138-169.

Lyons, K. (1992) 'Telling stories from the field? A discussion of an ethnographic approach to researching the teaching of physical education', in Sparkes, A.C. (ed.) *Research in physical education and sport: exploring alternative visions*. London: Falmer Press, pp.248-270.

Maas, C.J.M. and Hox, J.J. (2004) 'Robustness issues in multilevel regression analysis', *Statistica Neerlandica,* 58(2), pp.127-137.

Malcolm, J. and Zukas, M. (2001) 'Bridging pedagogic gaps: conceptual discontinuities in higher education', *Teaching in Higher Education,* 6(1), pp.33-42.

Mann, S.J. (2001) 'Alternative perspectives on the student experience: alienation and engagement', *Studies in Higher Education,* 26(1), pp.7-19.

Marshall, D. and Case, J. (2005) ''Approaches to learning' research in higher education: a response to Haggis', *British Educational Research Journal,* 31(2), pp.257-267.

Marton, F. and Säljö, R. (1976) 'On qualitative differences in learning I – outcome and process', *British Journal of Educational Psychology,* 46, pp.4-11.

Matt, E. (2000) 'The presentation of qualitative research', in Flick, U., von Kardorff, E. and Steinke, I. (eds.) *A companion to qualitative research* (Translation B. Jenner, 2004). London: Sage, pp. 326-330.

M^c^Bride, P. and Maitland, S. (2002) *The E.I. advantage. Putting emotional intelligence into practice.* Maidenhead: M^c^Graw-Hill Professional.

Merricks, L. (2002) 'Assessment in post compulsory education', in Jarvis, P. (ed.) (2004) *The theory and practice of teaching.* London: RoutledgeFalmer, pp.159-170.

Mitchell, P.D. (1994) 'Learning style: a critical analysis of the concept and its assessment', in Hoey, R. (ed.) *Design for learning: aspects of educational and training technology.* London: Kogan Page Ltd, p. xxvii.

Munro, B.H. and Page, E.B. (1993) *Statistical methods for health care research.* 2nd edn. Philadelphia, J.B. Lippincott Company.

Murphy, P. (2008) 'Concepts instead of computation: enhancing statistical literacy'. (Paper presented at the ICOTS7 conference sponsored by the International Association for Statistics Education). *The Pantaneto Forum,* 29. [Online]. Available at: http://www.pantaneto.co.uk/issue29 (Accessed: 28 May 2008).

Murtonen, M. (2005a) *Learning of quantitative research methods – university students' views, motivations and difficulties in learning.* PhD thesis, Turku University, Finland. [Online]. Available at: http://www.statauckland.ac.nz/~iase/publications/dissertations (Accessed: 21 May 2009).

Murtonen, M. (2005b) 'University students' research orientations: do negative attitudes exist towards quantitative methods?', *Scandinavian Journal of Educational Research,* 49(3), pp.263-280.

Murtonen, M. and Lehtinen, E. (2003) 'Difficulties experienced by education and sociology students in quantitative methods courses', *Studies in Higher Education,* 28(2), pp.171-185.

Murtonen, M. and Merenluoto, K. (2001) 'Novices' and experts' knowledge on statistics and research methodology', *Proceedings of the 25th Psychology of Mathematics Conference* 3, pp.391-398.

Murtonen, M., Olkinuora, E., Tynjälä, P. and Lehtinen, E. (2008) '"Do I need research skills in working life?": university students' motivations and difficulties in quantitative methods courses', *Higher Education,* 56(5), pp.599-612.

Murtonen, M. and Titterton, N. (2004) 'Earlier mathematics achievement and success in university studies in relation to experienced difficulties in quantitative methods courses', *Nordic Studies in Mathematics Education,* 9(3), pp.3-13.

Mvududu, N. (2005) 'Constructivism in the statistics classroom: from theory to practice', *Teaching Statistics,* 27(2), pp.49-54.

Newstead, S.E. and Hoskins, S. (2003) 'Encouraging student motivation', in Fry, H., Ketteridge, S. and Marshall, S. (eds.) *A handbook for teaching and learning in higher education: enhancing academic practice.* 2nd edn. London: Kogan Page, pp. 62-74.

Nowotny, H., Scott, P. and Gibbons, M. (2003) ''Mode 2' revisited: the new production of knowledge', *Minerva* 41, pp.179-194.

Nowotny, H., Scott, P. and Gibbons, M. (2005) *Re-thinking science: Mode 2 in societal context.* [Online]. Available at: http://iccppss.ull.es/tersaweb/investigacion/doctorado/novotny.pdf (Accessed: 12 April 2010).

Onwuegbuzie, A. J. (2000a) 'Attitudes towards statistics assessment', *Assessment and Evaluation in Higher Education,* 25(4), pp.321-339.

Onwuegbuzie, A. (2000b) 'Statistics anxiety and the role of self-perceptions', *The Journal of Educational Research,* 93(5), pp.323-330.

Onwuegbuzie, A.J. (2004) 'Academic procrastination and statistics anxiety', *Assessment and Evaluation in Higher Education,* 29(1), pp.3-19.

Onwuegbuzie, A.J. and Wilson, V.A. (2003) 'Statistics anxiety: nature, etiology, antecedents, effects and treatments – a comprehensive review of the literature', *Teaching in Higher Education,* 8(2), pp.195-209.

Orton, A. (2004) *Learning mathematics: issues, theory and classroom practice.* 3rd edn. London: Continuum.

Pajares, F. (1996) 'Self-efficacy beliefs in academic settings', *Review of Educational Research,* 66(4), pp.543-578.

Pallant, J. (2005) *SPSS survival manual: a step by step guide to data analysis using SPSS for Windows (version 12).* 2nd edn. Maidenhead: Open University Press.

Parsons, H.M. (1974) 'What happened at Hawthorne? New evidence suggests the Hawthorne effect resulted from operant reinforcement contingencies', *Science,* 183(4128), pp.922-932.

Perks, R. (1992) *Oral history: talking about the past.* Dorset: Blackmore Press.

Pfannkuch, M. and Wild, C. (2004) 'Towards an understanding of statistical thinking', in Ben-Zvi, D. and Garfield, J. (eds.) *The challenge of developing statistical literacy, reasoning and thinking* Dordrecht: Kluwer Academic Publishers, pp.17-46.

Polkinghorne, D.E. (1988) *Narrative knowing and the human sciences.* Albany: State of New York Press.

Popper, K.R. (1977) *The logic of scientific discovery.* 9th impression. London: Hutchinson and Company (Publishers) Ltd.

Popper, K.R. (1983) *Realism and the aim of science.* London: Hutchinson and Company (Publishers) Ltd.

Pring, R. (2000) 'The 'false dualism' of educational research', *Journal of Philosophy of Education,* 34(2), pp.247-260.

Pring, R. (2004) *Philosophy of Educational Research.* 2nd edn. London: Continuum.

Prosser, M. and Trigwell, K. (1999) *Understanding learning and teaching: the experience in higher education.* Buckingham: SRHE/Open University Press.

Quality Assurance Agency (QAA) (2001) *The framework for higher education qualifications in England, Wales and Northern Ireland – January* 2001. [Online]. Available at: http://www.qaa.ac.uk/academicinfrastructure/fheq/EWNI (Accessed: 1 October 2008).

Quality Assurance Agency (QAA) (2008) *Hospitality, leisure, sport and tourism 2008.* [Online]. Available at: http://www.qaa.ac.uk/academicinfrastructure/benchmark/statements/HLST08.pdf (Accessed: 1 October 2008).

Race, P. (1993) 'Quality of assessment', in *Never Mind the Teaching, Feel the Learning* SEDA paper 80. [Online]. Available at: http://www.londonmet.ac.uk/deliberations/seda-publications (Accessed: 25 October 2008).

Race, P. (1995) 'What has assessment done for us – and to us?', in Knight, P. (ed.) *Assessment for learning in higher education.* London: SEDA/KoganPage, pp.61-74.

Ramsden, P. (2003) *Learning to teach in higher education.* 2nd edn. London: RoutledgeFalmer.

Rasbash, J., Steele, F., Browne, W. and Prosser, B. (2004) *A user's guide to MLwiN.* London, Institute of Education: University of London.

Reay, D., David, M.E. and Ball, S. (2005) *Degrees of choice: class, race, gender and higher education.* Stoke on Trent: Trentham Books Limited.

Richardson, L. and St Pierre E.A. (2005) 'Writing: a method of inquiry', in Denzin, N.K. and Lincoln, Y.S. (eds.) *The Sage handbook of qualitative research.* 3rd edn. London: Sage, pp. 959-978.

Ridgway, J., McCusker, S. and Nicholson, J. (2004) *Uncovering and developing student statistical competences via new interfaces.* [Online]. Available at: http://www.statlit.org/pdf/2004RidgwayNicholson/IASE.pdf (Accessed: 18 October 2009).

Riessman, C.K. (2008) *Narrative methods for the human sciences.* London: Sage.

Ritchie, J., Spencer, L. and O'Connor, W. (2003) 'Carrying out qualitative analysis', in Ritchie, J. and Lewis, J. (eds.) *Qualitative research practice: a guide for social science students and researchers.* London: Sage, pp. 219-262.

Robson, C. (2002) *Real world research.* 2nd edn. Oxford: Blackwell Publishers.

Rumsey, D.J. (2002) 'Statistical literacy as a goal for introductory statistics courses', *Journal of Statistical Education,* 10(3) [Online]. Available at: http://www.amstat.org/publications/jse (Accessed: 4 October 2008).

Ryan, R.M. and Deci E.L. (2000a) 'Self-determination theory and the facilitation of intrinsic motivation, social development and well-being', *American Psychologist,* 55(1), pp.68-78.

Ryan, R.M. and Deci E.L. (2000b) 'The darker and brighter sides of human existence: basic psychological needs as a unifying concept', *Psychological Inquiry,* 11(4), pp.319-338.

Schield, M. (1999) *Statistical literacy: thinking critically about statistics* [Online]. Available at: http://www.augsburg.edu/ppages/schield (Accessed: 13 March 2009).

Schmidt, C. (2000) 'The analysis of semi-structured interviews', in Flick, U. von Kardorff, E. and Steinke, I. (eds.) *A companion to qualitative research* (Translation B. Jenner, 2004). London: Sage, pp.253-258.

Schmidt, F.L. (1996) 'Statistical significance testing and cumulative knowledge in psychology: implications for training of researchers', *Psychological Methods,* 1(2). pp.115-129.

Schram, C.M. (1996) 'A meta-analysis of gender differences in applied statistics achievement', *Journal of Educational and Behavioural Statistics,* 21(1), pp.55-70.

Seeman, M. (1959) 'On the meaning of alienation', *American Sociological Review,* 24(6), pp.783-791.

Senn, S. (2007) 'On thinking and learning', *RSS News,* 35(4), pp.1-3.

Simonite, V. (2000) 'The effect of aggregation method and variations in the performance of individual students on degree classifications in modular degree courses', *Studies in Higher Education,* 25(2), pp.197-208.

Skinner, B.F. (1968) *The technology of teaching.* New York: Appleton-Century-Crofts.

Smith, T.M.F. and Staetsky, L. (2007) *The teaching of statistics in UK universities* [Online]. Available at: http://www.rsscse.org.uk/activities/tsukuniversitiesprojrep.asp (Accessed: 24 June 2008).

Snee, R.D. (1993) 'What's missing in statistical education?', *The American Statistician,* 47(2), pp.149-154.

Snijders, T.A.B. and Bosker, R.J. (1999) *Multilevel analysis: an introduction to basic and advanced multilevel modeling.* London: Sage Publications Ltd.

Spencer, L., Ritchie, J. and O'Connor, W. (2003) 'Analysis: practices, principles and processes', in Ritchie, J. and Lewis, J. (eds.) *Qualitative research practice: a guide for social science students and researchers.* London: Sage, pp. 199-218.

Stevens, J.P. (2009) *Applied multivariate statistics for the social sciences.* 5th edn. Hove: Routledge Taylor and Francis Group.

Tabachnick, B.G. and Fidell, L.S. (1996) *Using multivariate statistics.* 3rd edn. New York: HarperCollins.

Tabachnick, B.G. and Fidell, L.S. (2007) *Using multivariate statistics.* 5th edn. (Pearson International Edition). Boston: Pearson, Allyn and Bacon.

University Central Admissions Service (UCAS) [Online]. Available at: http://www.ucas.com (Accessed: 21 June 2007 and 30 September 2008).

Vere-Jones, D. (1995) 'The coming of age of statistical education', *International Statistical Review,* 63(1), pp.3-23.

Waghid, Y. (2002) 'Knowledge production in higher education transformation in South Africa: towards reflexivity in university teaching, research and community service', *Higher Education,* 43(4), pp.457-488.

Wallman, K.K. (1993) 'Enhancing statistical literacy: enriching our society', *Journal of the American Statistical Association,* 88(421), pp.1-8.

Warhurst, C. (2001) 'Using debates in developing students' critical thinking', in Walker, M. (ed.) *Reconstructing professionalism in university teaching: teachers and learners in action.* Buckingham: SRHE/Open University Press, pp. 81-104.

Webb, G. (1997) 'Deconstructing deep and surface: towards a critique of phenomenography', *Higher Education,* 33, pp.195-212.

Wenger, E. (1998) *Communities of practice: Learning, meaning and identity.* Cambridge: Cambridge University Press.

Wengraf, T. (2001) *Qualitative research interviewing: biographic narrative and semi-structured methods.* London: Sage.

Wilson, V.A. (1999) 'Student response to a systematic program of anxiety-reducing strategies in a graduate-level introductory educational research course'. Paper presented at the annual meeting of the *American Educational Research Association.* Montreal. Cited in Onwuegbuzie, A.J. and Wilson, V.A. (2003) 'Statistics anxiety: nature, etiology, antecedents, effects and treatments – a comprehensive review of the literature', *Teaching in Higher Education,* 8(2), pp.195-209.

Yilmaz, M.R. (1996) 'The challenge of teaching statistics to non-specialists', *Journal of Statistics Education,* 4(1). [Online]. Available at: http://www.amstat.org (Accessed: 22 March 2006).

Yin, R.K. (2006) 'Mixed methods research: are the methods genuinely integrated or merely parallel?', *Research in the Schools,* 13(1), pp.41-47.