

# Igniting the statistical spark in the social sciences

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## Abstract

Several investigations have concluded that there is a quantitative deficit within the social sciences in the UK (Fonow and Cook, 1991; Lincoln and Denzin, 2003; Payne *et al.*, 2004; Williams, *et al.*, 2008; MacInnes, 2009; Platt, 2012; Payne, 2014; Williams *et al.*, 2015). Reasons for this are potentially rooted within the societal negative attitudes towards mathematics.

Societal negative attitudes towards mathematics could be a product of the traditional teaching approaches of mathematics education. In particular, teaching methods have potentially contributed to the subject identity as being right or wrong, perceived as a difficult discipline (Porkess, 2013; Donaldson, 2015). Significant changes have been made to mathematics education (years 7-13) more recently to encourage greater student uptake post-16, within England and Wales (Porkess, 2013; Donaldson, 2015). Statistics has gained an increasingly important voice within mathematics education. Statistics also cuts across many disciplines, becoming a core subject. In addition, employers are increasingly requesting employees acquire data analysis skills, underpinned by statistical and scientific principles.

In relation to the quantitative deficit, the Q-Step initiative was created across 15 British universities to develop a range of undergraduate social science degree courses to improve quantitative methods skills. The Q-Step centre within Cardiff University invested in the development of a range of school and further education activities, to highlight the importance of these quantitative skills. The development of a QCF level 3 course in Social Analytics (investigation of social

processes using statistical analysis and techniques) involved the creation of the Pilot Scheme in Social Analytics (SA). This course was developed with a group of secondary school teachers and FE lecturers, delivered over a series of 21 weeks to a mixture of year 12 and 13 students in Cardiff in 2014/15 (44 students) and 2015/16 (29 students).

To investigate the effectiveness of the Pilot Scheme in SA, a series of research questions were developed. A quasi-experimental design was used to operationalise these research questions to measure the impacts on student attitudes and attainment in statistics (in year 12 and 13) on an experimental group who received a contextualised statistics course in 2015/16 (Pilot Scheme in SA), compared to two control groups.

Results suggest the course did lead to changes in the students' attitudes, becoming more positive. In addition, their statistical abilities also seem to have improved, in comparison to the two control groups. Although the positive impacts of the course are somewhat tentative, and in places it is difficult to make unequivocal inferences, there is no evidence to suggest the course had a negative impact on the experimental group. In comparison, students in both control groups who didn't receive the treatment, showed negative differences in their attitudes and abilities with respect to mathematics and statistics.

In light of the findings and discussion, recommendations have been made with reference to professional practice and also future research. These include expanding the Pilot Scheme in SA to be made available for more schools in Wales and developing teacher training support to deliver these courses.

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# Chapter 1 Introduction

This chapter will provide an overview of the rationale for the study, the projects research questions, a summary of the main findings, and the structure of the thesis.

## 1.1 Introduction

The main focus of this study is an evaluation of a contextualised statistics course called the Pilot Scheme in Social Analytics (SA). A quasi-experimental approach was utilised for the evaluation. The study investigated attitudes to mathematics, statistics and critical thinking of the students who took the SA course. Impacts on students' statistical abilities were also explored.

The Pilot Scheme in SA course was developed with a group of secondary school teachers and FE lecturers, from a range of disciplines and delivered at Cardiff University School of Social Sciences. Participants on this course came from two local educational institutes, Cardiff and the Vale College (CAVC) and St David's Sixth Form College (St David's). As part of the quasi-experiment design, two control groups were created, with participants selected from CAVC and St David's. Students on the Pilot Scheme SA course attended the same A' Level classes as students in the control groups.

The main findings from the study include; that by engaging year 12 and 13 students with a contextualised statistics course (Pilot Scheme in SA course), their attitudes and abilities with respect to mathematics, statistics and critical thinking (an important component of statistics) led to a series of measurable changes. The course has potentially contributed to increases in their mathematical and statistical confidence, ability and views on the importance of the subject both in an

academic context, and also in everyday life attitudes becoming more positive.

Although the positive impacts of the course are somewhat tentative, and in places it is difficult to make unequivocal inferences, there is no evidence to suggest the course had a negative impact on the experimental group.

In comparison, students in both control groups who didn't receive the treatment, showed negative differences in their attitudes and abilities with respect to mathematics, statistics and critical thinking. These included decreases in their mathematical and statistical confidence, and also decreases in ability. However, both control groups revealed an increase in their views relating to the importance of mathematics and statistics, both in an academic context and also in its uses for everyday life.

## **1.2 Reasons for undertaking the study**

The social sciences (sociology in particular) have seen radical shifts in terms of the primary methodological tools used to generate new knowledge, especially in the UK (Lincoln and Guba, 1985, 1988; Morgan, 2007). The so-called Paradigm shift towards the use of predominantly qualitative methods has had significant implications for the discipline (Lincoln and Guba, 1985, 1988; Morgan, 2007).

After decades of social science researchers investigating these implications, many have come to the conclusion that there is a quantitative deficit within the social sciences in the UK (Fonow and Cook, 1991; Payne *et al.*, 2004; Williams, *et al.*, 2008; MacInnes, 2009; Platt, 2012; Payne, 2014; Williams *et al.*, 2015). Several recent initiatives within the UK have attempted to reverse this trend, namely the Q-Step project.

Since quantitative methods focus on the analysis and manipulation of data sets and numerical values, statistical techniques form core elements within quantitative modules in social science courses. In addition statistics, a branch of mathematics, requires users to engage with mathematical techniques and procedures.

Mathematics phobia is well documented within the UK, with mathematics anxiety being widespread throughout society (Harrison, 2014; National Numeracy, 2017).

In addition, public perception behind the differences between mathematics and statistics suggest they elide them together, imprinting negative mathematical attitudes onto statistics (Gal and Ginsberg, 1994; National Numeracy, 2017).

Reasons to explain some of the antipathy towards quantitative methods within the social sciences are potentially rooted within this societal negative attitude.

There is an overwhelming consensus that mathematics is of central importance to modern society (Smith 2004). It provides the vital foundations of the “knowledge economy” (Smith, 2004; Swan, 2005; Porkess, 2013). There are clear disadvantages for individuals who struggle numerically with respect to success in the labour market (Smith, 2004; National Numeracy, 2017). Competency in mathematics can therefore be seen as a crucial component in the development and success of both the individual and of the society in which they hope to prosper both economically and socially.

To add to the pressures highlighted above, there is an increasing demand for teachers across many subject areas to be competent in both numerical and statistical skills. This presents an enormous challenge for both the current teaching workforce, and teacher training courses (RSS and ACME, 2015). In

particular subjects not normally associated with statistics, such as sociology and geography, have increasing numerical and statistical content (RSS and ACME, 2015). New forms of statistical content and associated pedagogical guidance could help to facilitate the essential changes needed to support teachers across disciplines.

The Royal Statistical Society (RSS) and the Advisory Committee on Mathematics Education (ACME) have stated that evidence needs to be collected to help direct these suggested initiatives, especially with reference to the overlaps in statistical education:

“A research study is needed to understand perceptions in schools and colleges about the learning, teaching and assessment of statistics. This could be designed to interview learners and teachers in schools and colleges. It would also be illuminating to look at the various routes that learners take through their education, considering what statistics they encounter and the skills and experience gained during compulsory education.”

(RSS and ACME, 2015, p.11)



The need for clear evidence to review students' perceptions of and abilities in mathematics and statistics provides the rationale for this study. This rationale constitutes the main aims of this research project.

### **1.3 Research questions**

This study is concerned with exploring the impacts of delivering a contextualised statistics course (Pilot Scheme in SA), on year 12 and 13 students' attitudes to and abilities in mathematics and statistics. The following research questions will aim to explore these impacts:

1. What are the attitudes of year 12 and 13 students to mathematics and statistics, before participating in a contextualised statistics course (Pilot Scheme in SA)?
2. What are the attitudes of year 12 and 13 students to critical thinking, before participating in a contextualised statistics course (Pilot Scheme in SA)?
3. What are the impacts of a contextualised statistics course (Pilot Scheme in SA) on year 12 and 13 student attitudes towards mathematics/statistics and critical thinking?
4. What are the student outcomes of participating in a contextualised statistics course (Pilot Scheme in SA course), in relation to mathematical and statistical abilities, in years 12 and 13?

#### **1.4 Structure of the thesis**

The thesis is presented in eight chapters, beginning with this introduction outlining the reasons for undertaking the study, through to conclusions and recommendations for further study.

Chapter two focuses on the quantitative deficit in the social sciences, drawing on relevant literature to support this claim. Initiatives aimed at reversing this trend will also be described: the Q-Step programme, including the Cardiff Q-Step and Cardiff FE Q-Step initiatives (Pilot Scheme in SA).

Chapter three presents the second part of the literature review, highlighting the current state of mathematics and statistics education in England and Wales. This chapter aims to provide potential reasons for the quantitative deficit described in chapter two. In particular, chapter three focuses on policy changes to mathematics and statistics education, mathematics pedagogy and interdisciplinary mathematics and statistics.

Chapter four describes the creation of the Pilot Scheme in SA, including the curriculum development stages, course content, student recruitment strategies and delivery. This chapter ends by presenting the research questions, derived from the literature review and also as a tool to evaluate the Pilot Scheme in SA.

Chapter five describes the research methodology and methods and explains the choice of a quasi-experimental approach. The research instruments and process of analysis are also described. The ethical issues are also discussed, particularly with

respect to working with 16-18 year old students and my position as an insider researcher.

Chapter six presents the data gathered during the quasi-experiment through a series of graphs and tables. The data is described in detail, which includes identification of trends and differences.

Chapter seven provides a detailed discussion of the research findings, to answer the research questions posed in chapter four. In addition, an evaluation of the Pilot Scheme in SA is explored, culminating with an exemplification of the main limitations from the study.

Chapter eight presents a series of recommendations for practice and also for future research, as well as the contribution of the thesis to the current educational literature.



# Chapter 2 – Quantitative deficit in the social sciences

## 2.1 Introduction

The social sciences (sociology in particular) within the UK have seen radical shifts in terms of the primary methodological tools used to generate new knowledge. The so-called Paradigm shift towards the use of predominantly qualitative methods has had significant implications for the discipline (Lincoln and Guba, 1985, 1988; Morgan, 2007). This chapter will explore potential reasons for the social sciences becoming less quantitatively orientated, drawing on a range of political and philosophical stances. In particular, evidence from a number of researchers will be presented, concluding that there is a quantitative deficit within the social sciences, in the UK. Several recent initiatives will also be summarised, that attempt to reverse this trend.

## 2.2 A brief history of quantitative methods in the social sciences within the UK

Social sciences degree courses within British higher education institutes (HEIs) expanded dramatically in the 1960s (Campbell and Naulls, 1987). These courses offered a cost effective programme to educate students in higher education (HE). For example, social sciences courses allocated no laboratory time compared with bioscience or chemistry degree programmes. There was little emphasis placed on students, 'doing,' social science. In addition, they were perceived to be an inexpensive way of expanding student numbers in the HE sector, with no specialised equipment required to facilitate the teaching of the subject (Campbell and Naulls, 1987). The Robbins report of 1963 showed only 6% of young adults

participated (i.e. enrolled on degree courses) within the UK HE sector, one of the lowest in the Organisation for Economic Co-operation and Development (OECD) (Barr and Crawford, 2005). The need for higher participation rates in HE is cited as a factor in the rapid expansion of social science degrees across the UK, providing an attractive, cost effective solution. The Robbins report also led to the formation of the Social Science Research Council (SSRC), which resulted in the creation of the SSRC data bank at the University of Essex in 1967 (Barr and Crawford, 2005). This data bank provided a centralised repository for researchers and policy makers to access.

Social science research within universities, as well as the development and utilisation of quantitative methods, rapidly expanded during the 1970s, receiving significant government funding (UK Data Archive, 2010). The need for more quantitatively trained social science graduates led to the incorporation of statistical content across British universities. Statisticians often taught the quantitative methods modules. This is thought to have contributed to a decline of interest in quantitative methods (Campbell and Naulls, 1987).

Government spending from the 1980s saw a significant reduction in university funding, especially for the social sciences. The Rothschild enquiry was set up to assess the impact of the SSRCs research output. The enquiry highlighted the importance of the SSRCs work, although suggested that it should focus on empirical social science research, related to public concern. This led to the formation of the Economic and Social Research Council (ESRC) in 1984 (UK Data Archive, 2010).

The increasing importance of social science research, in particular empirical social science, resulted in a plethora of funding streams from the SSRC and later the ESRC. This led to an increased demand for social science courses to produce graduates with the appropriate analytical skills (Barr and Crawford, 2005).

Government initiatives to rapidly expand HE participation probably contributed to the mass expansion of social science degree courses across British universities.

However, the movement towards the social sciences becoming more qualitative in the 1980s can be partly attributed to the poor quantitative teaching during the expansion of the subject in the 1960s into the 1970s (Campbell and Naulls, 1987).

During the 1980s, the social sciences (sociology in particular) experienced a resurgence of qualitative research methods. Academics began to question the perceived lack of validity of quantitative research methods (Morgan, 2007).

Quantitative research was also criticised on several philosophical levels. Empirical anomalies were highlighted which led to a reinterpretation of methodological issues in the social sciences (Morgan, 2007). Lincoln and Guba developed a system for comparing different paradigms in the social sciences, reviewing the philosophy of knowledge, ontology, epistemology and methodology (Lincoln and Guba, 1985; 1988). They compared positivism with naturalist enquiry, which later became better known as constructivism (or interpretivism). Their work, drawing on the concept suggested by Thomas Kuhn (1966), often referred to them as competing paradigms, giving the impression that they were incompatible (Lincoln and Guba, 1985, 1988). Qualitative research methods were increasingly popular, becoming the dominant paradigm across the social sciences within the UK.

Proponents of qualitative research methods favour the rich, descriptive data, which is said to accurately represent research subjects or groups (Eisner, 1981; Fonow and Cook, 1991; Lincoln and Denzin, 2003; Tashakkori and Teddlie, 2003). In addition, there is a philosophical argument that questions the external validity of an experimental or laboratory model to investigate and explain sociological phenomena (Eisner, 1981; Fonow and Cook, 1991; Lincoln and Denzin, 2003; Tashakkori and Teddlie, 2003). In addition, approaching sociological research with an objective scientific approach has also been questioned, stating one can never achieve complete objectivity. One should adopt a reflexive state of awareness, and tease out subjective biases that are inherent with sociological research that explore issues such as gender, sexuality, and education (Eisner, 1981; Fonow and Cook, 1991).

The emergence of mixed methods has become increasingly popular within the social sciences more recently, enabling the strengths of both methodological tools to be utilised to produce robust data that accurately measures and explains sociological phenomena (Tashakkori and Teddlie, 2003; Lincoln and Denzin, 2003). The need to prepare future social scientists in both qualitative and quantitative methods could help to facilitate mixed methods approaches that are not confined to a certain type of methodological research (Tashakkori and Teddlie, 2003; Williams, *et al.*, 2008).

An exploration of the expansion of social science degrees across the UK, as well as the emerging dominant paradigms within the discipline, provides a useful explanation to some of the resultant attitudes towards quantitative methods. To further probe the impacts of these changes, we can draw on recent investigative



evidence from several academics across the UK who have come to the conclusion that a quantitative deficit exists within the social sciences (Fonow and Cook, 1991; Payne *et al.*, 2004; Williams, *et al.*, 2008; MacInnes, 2009; Adeney and Carey, 2011; Taylor and Scott, 2011; Platt, 2012; Payne, 2014; Williams *et al.*, 2015).

Evidence suggests that there is a lack of quantitatively orientated journal papers submitted and subsequently published within British based Journals (Payne *et al.*, 2004; Platt, 2012; Payne, 2014). A common mantra across British HEIs, particularly research-intensive universities, encompasses a commitment to research-led teaching (Cardiff University, 2016). With a clear orientation towards qualitative research within British HEIs (and many research centres), and a lack of quantitative research papers published, this would reduce the numbers of individuals who could competently deliver quantitative methods courses. There are however perfectly valid philosophical reasons why researchers choose to engage with qualitative methods (Lincoln and Denzin, 2003; Tashakkori and Teddlie, 2003), although the inequity of quantitative papers published in British based Social Science journals is questionable. And with more social science researchers and academics engaged with qualitative methods, other questions are raised such as, who teaches the quantitative methods in social sciences degree courses across the UK? Williams *et al.*, (2004) also highlighted the “Cinderella” status of teaching quantitative methods across social science degree courses, with the responsible staff members being sidelined or even alienated for teaching a necessary evil. It follows that the majority of social science lecturers, engaged with qualitative research methods publishing and indeed monopolising the British Journal outputs, would have a preference in engaging with their own qualitatively

orientated research-led teaching. In addition, Williams *et al.*, (2004) showed evidence of bias against quantitative methods in general social science teaching.

This apparent negative attitude of quantitative methods in general social science teaching will undoubtedly have a profound impact on student attitudes towards the subject. Williams *et al.*, (2008) conducted a national survey of student attitudes towards quantitative methods in sociology. Unsurprisingly there was an overall negative attitude, coupled with a lack of confidence in learning the subject. MacInnes (2009) conducted a national review of quantitative methods teaching across British HEIs. His results echoed the findings of Williams *et al.*, (2004) and revealed an isolation of quantitative methods courses within social science degree courses, the teaching of which was often dumped on junior colleagues.

Surprisingly, mathematics anxiety and bad experiences with mathematics at earlier stages of education were not as high as expected by Williams *et al.*, (2004). Williams *et al.*, (2008) showed that 50% of university students on social sciences courses surveyed reported a good experience of mathematics at school (N=650). The authors do state however, that without having comparative data for those studying other subjects, there is no way to know if this value is high or low (Williams *et al.*, 2008).

The lack of confidence of social science students towards quantitative methods is not isolated to the social sciences. Williams *et al.*, (2015) suggest the problem is widespread across disciplines in the sciences (Richardson and Woolfolk, 1980; Marsh, 1988; Swan, 2005). Drawing again on the national study of student attitudes in 2006/07 conducted by Williams *et al.*, (2008), 71% (N=650) of respondents regarded sociology as closer to the arts and humanities than science.

In addition 71% also stated they had a preference for essay writing over data analysis. These findings were explored further using focus group interviews, which overwhelmingly indicated a humanistic inclination and antipathy toward quantitative methods (Williams *et al.*, 2008). Subject identity within the social sciences has also had an impact on student attitudes towards the usefulness of quantitative methods. For example, Williams *et al.*, (2008, p.1013) presented a student statement on their views of quantitative methods:

“Quantitative research is boring ... numbers and stuff . . . that’s the nitty gritty isn’t it? Do you really want to sit on the street and count how many people are wearing blue jumpers or whatever (laughing)? I’d rather go up and ask them why they’re wearing a blue jumper than just tick a box if they are, do you know what I mean?”

This difference in self-identity, aligned to their perceptions of the subject being studied, could have a profound impact on their attitudes towards the use of quantitative methods.

The complex interplay between changing government priorities, funding streams to influence research, the emergence of dominant paradigms post 1980, and the changes to social science degree courses has provided useful explanations to the current student negative attitudes towards quantitative methods within the social sciences.

### **2.3 Q-Step initiative**

The conclusion reached by several investigations of a quantitative deficit in British sociology (and areas of the social sciences, educational research for example) resulted in widespread concern, leading to significant investment of resources to remedy the situation (Williams, *et al.*, 2008; MacInnes, 2009; Adeney and Carey, 2011; Taylor and Scott, 2011). Several key initiatives to tackle the problem emerged during the mid-2000s, mainly funded by the ESRC. For example, strategies were developed to encourage social science students to engage with quantitative methods during their dissertations, which included guidance to make more use of secondary data sets. In addition, Professor John MacInnes from the University of Edinburgh was appointed as the strategic lead for the teaching of quantitative methods, and oversaw two funding initiatives in 2012 (Curriculum Innovation and Researcher Development Initiatives (Williams *et al.*, 2015)).

These preliminary initiatives led to the Nuffield Foundation, a charitable foundation established in 1943, securing government matched funding in 2013 to launch the Q-Step initiative.

The Nuffield Foundation has two aims:

1. Funding research and innovation in education and social policy.
2. Building research capacity in science and social science.

The rationale for creating the Q-Step initiative builds on the Foundation's general aims as an organisation, with a more specific summary to address the quantitative deficit outlined below:

“The UK has a shortage of social science graduates with quantitative skills to evaluate evidence, analyse data, and design and commission research. Yet these skills are increasingly in demand from employers across all sectors - academia, government, business and charities. Q-Step's funders believe that this skills deficit, caused primarily by market failure to attract students and teachers in quantitative social science training, cannot be improved without targeted investment.”

(Nuffield Foundation, 2016a, p.1)

The Q-Step initiative was an investment in excess of £19.5 million, and began in 2013. The main aim of this programme is to promote a sustainable change in quantitative social science training in the UK. Funded by the Nuffield Foundation, Economic and Social Research Council (ESRC) and Higher Education Funding Council England (HEFCE), Q-Step was developed as a strategic response to the shortage of quantitatively skilled social science graduates. Q-Step is currently funding fifteen universities across the UK, supporting the continued development and delivery of specialist undergraduate programmes, including new courses, work placements and pathways to postgraduate study. Stronger links between HEIs and Further Education (FE) colleges/secondary schools will hopefully provide a range of benefits to include; smoother transitions for students into university and the collaborative development of teaching resource, related to quantitative social science (Nuffield Foundation, 2014).

Several interim reports have been compiled to assess the sustainability of the programmes being created as well as the level of embedding of quantitative

methods content across existing courses aligned to the social sciences. The outcomes from these reports (currently being prepared to be published) suggest the initiative has been well received by employers and HEI's across the sector. Employer engagement is especially high on the Foundations agenda, to ensure graduates are securing valuable work placements to embed their quantitative methods skills developed into professional practice. In terms of wider dissemination, the Foundation is keen to develop a support programme for the initiative:

“Although targeted at undergraduates, Q-Step aims to promote quantitative skills training across the course of the education system, from recruitment of school students to specialist training for those going on to postgraduate work.”

(Nuffield Foundation, 2016b, p.1)

The network of 15 UK based Q-Step centres are situated in mostly Russell group universities. The centres offer a range of undergraduate degree courses in the social sciences and several humanities subject areas, aimed at developing quantitative skills. The undergraduate degree courses available are listed in Table 2.1.

Table showing the fifteen Q-Step Centres alongside the disciplines that will be included in their programmes of activity													
Q-Step Centres	Disciplines												
	Area studies	Criminology	Education	Environmental Planning	Human Geography	Linguistics	Business studies	Political studies	Social Anthropology	Social Policy	Social Work	Social-Legal studies	Sociology
University of Bristol			✓		✓			✓		✓			✓
Cardiff University		✓	✓						✓				✓
City University London		✓						✓					✓
University of Edinburgh			✓			✓		✓	✓		✓	✓	✓
University of Exeter	✓	✓	✓					✓	✓				✓
University of Glasgow			✓					✓	✓				✓
University of Kent		✓					✓	✓	✓		✓	✓	✓
Manchester Metropolitan University													✓
University of Manchester		✓				✓		✓	✓				✓
University of Oxford								✓					
Queen's University Belfast		✓						✓		✓	✓		✓
University of Sheffield				✓	✓		✓	✓				✓	✓
University of St Andrews					✓								
University College London					✓			✓	✓				
University of Warwick								✓					✓

**Table 2. 1 Overview of current undergraduate degree course available across the Q-Step network (Nuffield, 2017).**

An overview of the aims and objectives of all 15 Q-Step centres have been summarised by the Nuffield Foundation (Q-Step, 2017 available at:

[http://www.nuffieldfoundation.org/sites/default/files/files/Aims%20and%20Activities%20of%20the%20Q-Step%20Centres\(1\).pdf](http://www.nuffieldfoundation.org/sites/default/files/files/Aims%20and%20Activities%20of%20the%20Q-Step%20Centres(1).pdf)). Several Q-Step centres have

included schools and FE engagement activities (Manchester Metropolitan

University (MMU) and Edinburgh University for example), which tend to include

summer school activities and school visits from Q-Step centre staff (Q-Step, 2017). There are also dedicated work placement modules that exist in Q-Step centres such as those at Manchester University, MMU and also Cardiff University. These modules aim to provide learning opportunities for students to apply their theoretical knowledge of quantitative methods into the work place (Q-Step, 2017). In addition, the training and upskilling of sociology staff in the MMU Q-Step centre for example, have focused on developing complex strategies to increase confidence in lecturers teaching quantitative research methods (Scott-Jones and Goldring, 2015). These strategies have addressed issues related to the development of effective pedagogies, departmental resourcing and strategy and infrastructure (Scott-Jones and Goldring, 2015).

#### **2.4 Cardiff Q-Step Initiative**

The Q-Step Centre for Excellence in Quantitative Methods is based in the Cardiff School of Social Sciences, at Cardiff University (SOCSI). Over the past eight years, the School has made significant investments to develop the quality of undergraduate skills in quantitative methods. This centre is beginning to consolidate and develop this work, enabling Cardiff to become a leading centre of quantitative pedagogy nationally.

The Cardiff Q-Step Centre has currently two leading areas of development:

- Embedding of quantitative methods modules into existing social science degree programmes at SOCSI and the creation of a BSc in Social Analytics



- FE college and schools engagement work across the UK (including the development of Qualifications and Credit Framework (QCF) level 2 and level 3 qualifications in Social Analytics)

Social Analytics is defined as the scientific investigation of social processes using statistical techniques and critical thinking.

The two degree programmes, BSc Social Analytics, and a joint degree programme, BSc Social Analytics and Politics, both have a mixture of core and optional modules. The optional modules across QCF levels 4-6 (i.e. years one, two and three of a degree scheme) are available for the majority of students studying at undergraduate level in SOCSI.

The rationale for creating these new qualifications rests on evidence from a number of studies that indicate relatively small numbers of undergraduates are likely to enter social science programmes with A' Level mathematics, which could potentially make these students underprepared for these courses (Williams, *et al.*, 2008; Payne, 2014; Platt, 2012). Most enter social science programmes with sociology/ humanities A' Levels and are at times unaware that they will be studying quantitative methods (Williams, *et al.*, 2008; Payne, 2014; Platt, 2012). In addition, A' Levels in sociology have marginal quantitative methods content, which severely underprepares students when they encounter them at university (Williams *et al.*, 2015). Students applying to social science undergraduate degree programmes with the QCF level 3 qualification in Social Analytics should be better prepared for the quantitative methods training they will receive.

The FE and schools engagement work, as well as the development of the QCF level 3 course in Social Analytics will be explored in greater detail in chapter four.

## **2.5 Conclusion**

The origins of the quantitative deficit within the social sciences are complex and currently ongoing, with recent initiatives (Q-Step for example) attempting to address the situation. Reasons to explain some of the antipathy towards quantitative methods within the social sciences are potentially rooted within the societal negative attitudes towards mathematics. An exploration of mathematics education, as well as clarification on where statistics sits within this domain, could provide answers to elucidate elements of the quantitative deficit. The next chapter will outline potential reasons to explain the above, reviewing mathematics and statistics education in England and Wales.



# Chapter 3 – Mathematics and statistics education in

## England and Wales

### 3.1 Introduction

This study is concerned with the changing nature of mathematics and statistical education across a number of disciplines, and also the quantitative deficit in specific areas of the social sciences. Statistics education, a branch of mathematics education, will be discussed using several recent research projects as illustrations. These projects suggest statistics is often perceived to be the most boring and theoretically abstract component of mathematics education, post-16. Since statistics is underpinned by mathematical principles, the chapter will explore the current state of mathematics education, with a particular focus on post-16 mathematics within England and Wales.

The view that a numerate society is essential for the prosperity of a nation is clearly articulated by Donaldson (2015) below:

“Mathematics helps children and young people to make sense of the world around them and to manage their lives. It gives them skills they need to interpret and analyse information, solve problems and make informed decisions. Taught well through relevant contexts, mathematics can engage and fascinate children and young people of all interests and abilities. It provides strong support for the development of wider skills, particularly critical thinking and problem solving, planning and organisation, and creativity and innovation. It enables people to communicate ideas in a concise, unambiguous and rigorous way, using numbers

and symbols. A high level of numeracy and mathematical competence is important for the prosperity of the country.”

(Donaldson, 2015, p.49).

To unpick these statements more closely, an analysis of traditional mathematics pedagogical practices will be presented, arguing the case that these practices need to be adapted to change the inherent negative attitudes towards the subject.

Statistics embedded across post-16 curriculum areas will also be explored.

### **3.2 Current state of mathematics and statistics education (internationally and within England and Wales)**

The measurement of numeracy levels across countries within the Organisation for Economic Cooperation and Development (OECD) involves the testing of 15-16 year old students, through the Programme of International Student Assessment (PISA). PISA assesses the extent to which students nearing the end of compulsory education have acquired some of the essential knowledge and life skills to fully participate in society. In all testing cycles of PISA, the domains of reading, mathematics and scientific literacy are covered not only in terms of mastery of the school curriculum (heavily prescribed by the Department for Education and Skills – DfES), but also in terms of important knowledge and skills needed in adult life (ACER, 2016). With reference to mathematical skill, PISA usually involves students answering abstract mathematical questions, demanding high levels of literacy skills (Tanner and Jones, 2013). This is in stark contrast with GCSE mathematics style questions, which usually involve students answering similar style questions to those that have been covered in their mathematics lessons. Students are almost coached or taught to the test, regurgitating content covered in mathematics classes

(Tanner and Jones, 2013). Wales often falls below the OECD average scores in mathematics, as well as placing last in the UK (Bradshaw *et al.*, 2010; BBC News, 2016). Results for GCSE mathematics in Wales and the UK continue to rise every year, whereas the PISA results for numeracy are relatively constant for 2006, 2009 and 2012 (OECD, 2012; Tanner and Jones, 2013). These differences could be due to targeted government initiatives to raise standards in GCSE mathematics, focusing more on national rather than international priorities (Tanner and Jones, 2013). This paints a complicated and somewhat conflicting picture of the current mathematics levels in secondary students, in England and Wales.

Standards of numeracy in Wales, as well as other western countries, are a cause for concern with 51% of students aged 16-19 possessing numeracy skills that are below GCSE level mathematics (WG, 2011). According to the PISA results, Wales has the lowest numeracy levels within the UK; suggesting current initiatives are inadequate to address these poor levels of mathematical skills (Tanner and Jones, 2013; BBC News, 2016). Even with the mismatch in numerical testing regimes highlighted above, PISA results reflect global standards that directly, and perhaps unfairly, compare all OECD countries together, politically forcing governments to review current teaching practices and curriculum content.

The poor PISA ranking for Wales and the UK has resulted in the commissioning of national reports to assess the reasons for these poor outcomes. For example, the Donaldson review points to current teaching strategies as well as the curriculum structure of mathematics education being inadequate and insufficient in Wales (Donaldson, 2015). Traditionally, mathematics teaching within UK primary and secondary schools has been described as repetitive, procedural and laborious

(Porkess, 2013; Swan, 2005). Porkess exemplifies this by stating nothing actually happens within a mathematics lesson in secondary school, with very little context or relevance incorporated and limited imagination in the delivery (Porkess, 2013). Several researchers in mathematics education suggest mathematics is widely regarded as being boring and irrelevant (Smith, 2004; Noyes, 2007), with Noyes (2007, p.18) suggesting that, “many learners are not well served by their mathematics education... and in the actual learning processes in the classroom.” The views of Tanya, a year 10 pupil, described by Boaler (2009, p.163) are sadly not uncommon - describing mathematics lessons as, “a whole hour of silence.” The point being, mathematics lessons should encourage more discussion and debate, which could help to bring the subject to life and make it more interesting.

Mathematics phobia is well documented within the UK, with mathematics anxiety being widespread throughout society (Harrison, 2014; National Numeracy, 2017). In addition, public perception in relation to the differences between mathematics and statistics suggest they elide them together, imprinting negative mathematical attitudes onto statistics (Gal and Ginsberg, 1994; Jordan *et al.*, 2014; Gibbison, 2017; National Numeracy, 2017).

The differences between statistics and mathematics are often contested, and as already described, they are often amalgamated together (Gal and Ginsberg, 1994; Fitzmaurice, 2014; Gibbison, 2017; National Numeracy, 2017). Franklin (2013) presents an account of the origins of statistics, developed as a discipline to solve real world problems. She goes on to suggest that statistics has become mathematised, due to advances in technology being able to carry out complex calculations on large data sets (2013). Franklin also states that the two disciplines

are mutually supportive, however there are distinct differences that should not be ignored (Franklin, 2013). Misunderstandings between the two disciplines persist, with Gibbison reporting widespread confusion of statistical concepts specifically within the UK medical profession, particularly with anesthesiologists (Gibbison, 2017). Gibbison (2017) defines statistics and probability as valuable instruments to underpin the science of uncertainty and also to provide tools to deal with uncertainty in a structured manner. He suggests that the reported difficulty with statistics is often due to it being labelled as a mathematical subject. These findings call for an exploration of both mathematics and statistics education in this study.

Critical thinking is also an essential analytical tool that mutually supports the disciplines of mathematics and statistics. The ability to objectively evaluate evidence and make judgments is of central importance to enable relational understanding of mathematics (Skemp, 1976; Landers, 1999). However, the negative image of mathematics persists, perceived as a right or wrong subject (Landers, 1999).

A UK government inquiry led by Sir Adrian Smith reported the negative image that mathematics has in many areas of society. At the same time it suggested that mathematics is an essential part of that same society. It exemplifies mathematics as being of central importance to modern society, which provides the vital foundations of the knowledge economy (Smith, 2004). The report also confirms that problems with numeracy lead to the greatest disadvantages for individuals in the labour market and in terms of general social exclusion (Smith, 2004).

Competency in mathematics can therefore be seen as a crucial component in the



development and success of both the individual and of the society in which they hope to prosper both economically and socially.

Attitudes towards statistics in particular have been identified as causing angst and fear among pre-university students in many disciplinary areas in the UK (Richardson and Woolfolk, 1980; Marsh, 1988). For example, areas that have increasing levels of statistical content (e.g. psychology, geography and sociology) can come as a surprise, creating anxiety (Marsh, 1988; Swan, 2005). And when students reach university, these anxieties continue to persist and even magnify in many cases (Musch and Broder, 1999; Vigil-Colet and Condon, 2008). In particular, certain populations of students, those with dyslexia for example, have been reported to suffer from high levels of mathematical and statistical anxiety (Jordan *et al.*, 2014). The differences between these two types of anxieties are still difficult to ascertain, with Gibbison (2017) suggesting perceptions of statistics and probability correlate strongly with those of mathematics. Jordan *et al.*, (2014) reported difficulties in their participants being able to distinguish between statistics and mathematics, which could have led to inaccuracies in their findings.

With the advent of big data, expansions in quantitative methods within the social sciences, and technological advances across the sciences, students with good statistical ability are essential (Dolphin, 2015). For example, students live in an increasingly data driven world, which has facilitated technological advances in improved methods to collect and analyse data (social media for example) (Porkess, 2013; Donaldson, 2015). The need for quantitative skills to be adequately prepared for HE is becoming increasingly important (Dolphin, 2015; Donaldson, 2015).

A recent review of post-16 mathematics in England mirrored many of the concerns highlighted above (Smith, 2017). In his report, Smith makes a series of recommendations urging the government to encourage more people to take some form of mathematics, post-16. In particular, he describes the increasing importance of quantitative reasoning skills as valuable preparation for HE across a range of subject areas, including; psychology, geography and sociology, as well as the sciences (Smith, 2017). He also calls for universities to be more explicit in asking for QCF level-3 mathematics qualifications, since this can drive student subject choice post-16 (Smith, 2017).

### **3.3 Policy changes to mathematics and statistics education**

As a result of the poor student PISA performance in mathematics within the UK, and Wales in particular, an exploration of the UK and Welsh Government's responses will provide an insight into the proposed trajectory for mathematics and statistics education. This trajectory also helped to inform several of the underlying objectives for the contextualised statistics course, described in chapter four.

The performance of Wales in the PISA study of 2009 and 2012 created a climate in which political intervention was required to deal with the poor standards of numeracy. This led to a previous Welsh education minister, Leighton Andrews, setting an ambitious target for Wales to be in the top 20 countries in the OECD, during the 2015 PISA study (Tanner and Jones, 2013). The Andrews 20-point plan (Andrews, 2011) demanded that PISA-style assessments be introduced to year 8-10 students across Wales, during mathematics lessons. As mentioned above, PISA and GCSE mathematics style questions are very different, which leads to many

practical challenges to implement these changes. Tanner and Jones carried out action research across six secondary schools in Wales, from 2011-2012, evaluating the implementation of Andrews' 20-point plan (Tanner and Jones, 2013). Their results suggest teachers struggled to facilitate such a radical change in mathematics pedagogy, with little training and guidance from Welsh Government. In addition, students revealed poor levels of attainment when engaging with PISA style numerical questions (Tanner and Jones, 2013). The Welsh Government's response to the poor PISA mathematics outcomes resulted in the speedy implementation of an initiative that had underestimated the magnitude of the task set for mathematics teachers across Wales.

There has been an increase in the number of A' Level mathematics student entries across England and Wales over the last five years, although these could decrease with the proposed changes to the curriculum structure of the A' Level in England (MEI, 2015; Henry, 2014). The divergent education systems have resulted in the decoupling of A' Level subjects (enforced by the UK government), where students in England now have to decide whether they want to study a subject as an Advanced Subsidiary (AS) (one year of study) or the full A' Level (two years of study) (Gov.UK, 2015). Currently, students initially choose A' Level mathematics as an AS choice, with many deciding to study through to the full A' Level (MEI, 2015). Since students can no longer choose to convert an A' Level to an AS level qualification, there are grave concerns from head teachers, mathematics teachers and HE lecturers across the country that this could lead to a severe drop in A' Level mathematics entries (MEI, 2015; Henry, 2014). These concerns are founded on data that reveal increasing numbers of AS Level mathematics students converted to the full A' Level between 2008 and 2014 (MEI, 2015). Since students in England

no longer have this option, they must decide before they embark on their post-16 study whether they want to AS or A' Level mathematics (MEI, 2015).

Current Welsh government initiatives to tackle these poor educational outcomes, and potential threats to student numbers studying mathematics, include changes to the literacy and numeracy framework (LNF), from the Foundation phase (3-7 years old) through to Key Stage 3 (year 9) (WG, 2013). These changes to the national curriculum, which include substantial differences in curriculum content, are currently being implemented. In addition, GCSE and A' Level mathematics curricula are also being developed, alongside other curriculum areas such as the sciences and humanities. As stated above, frequent changes to mathematics curriculum across several qualification types across the whole spectrum of age groups can leave teachers feeling overwhelmed, underprepared and unable to implement changes effectively (Tanner and Jones, 2013).

The Welsh Government has set out an ambitious plan, to reform the National Curriculum, across all Key Stages. These changes are to be implemented by 2021. Below is an overview of the proposed elements, including a timeline for implementation:

<b>4 purposes</b>
The 4 purposes will be at the heart of our new curriculum. They will be the starting point for all decisions on the content and experiences developed as part of the curriculum to support our children and young people to be:
<ul style="list-style-type: none"> <li>• Ambitious, capable learners ready to learn throughout their lives</li> </ul>
<ul style="list-style-type: none"> <li>• Enterprising, creative contributors, ready to play a full part in life and work</li> </ul>
<ul style="list-style-type: none"> <li>• Ethical, informed citizens of Wales and the world</li> </ul>
<ul style="list-style-type: none"> <li>• Healthy, confident individuals, ready to lead fulfilling lives as valued members of society.</li> </ul>
<b>Key elements</b>
The new curriculum will include:
<ul style="list-style-type: none"> <li>• 6 Areas of Learning and Experience from 3 to 16</li> </ul>
<ul style="list-style-type: none"> <li>• 3 cross curriculum responsibilities: literacy, numeracy and digital competence</li> </ul>
<ul style="list-style-type: none"> <li>• Progression reference points at ages 5, 8, 11, 14 and 16</li> </ul>
<ul style="list-style-type: none"> <li>• Achievement outcomes, which describe expected achievements at each progression reference point.</li> </ul>
The curriculum will be organised into 6 Areas of Learning and Experience:
<ul style="list-style-type: none"> <li>• Expressive arts</li> </ul>
<ul style="list-style-type: none"> <li>• Health and well-being</li> </ul>
<ul style="list-style-type: none"> <li>• Humanities (including RE which should remain compulsory to age 16)</li> </ul>
<ul style="list-style-type: none"> <li>• Languages, literacy and communication (including Welsh, which should remain Compulsory to age 16, and modern foreign languages)</li> </ul>
<ul style="list-style-type: none"> <li>• Mathematics and numeracy</li> </ul>
<ul style="list-style-type: none"> <li>• Science and technology (including computer science)</li> </ul>
<b>Timeline</b>
High-level key milestones for the proposed changes:
2015 - 2016: Pioneer Network established
2015 - 2018: Design and development phase of the new curriculum
September 2016: Digital Competence Framework available
2017 - 2021: Practical support to schools to prepare for the new curriculum
September 2018: New curriculum and assessment arrangements available
September 2021: New curriculum and assessment arrangements in place

**Table 3. 1 Proposed National Curriculum reforms (WG, 2015).**

These key changes were heavily informed by the Donaldson review, stating the current Welsh education system is failing students in several key areas, including mathematics and digital literacy (Donaldson, 2015). Donaldson and Porkess have

expressed support for the proposed National Curriculum reforms (Donaldson, 2015; Porkess, 2013), although their reports suggest the need for pedagogical innovation within mathematics education. Porkess in particular has mapped statistics content across the majority of curriculum areas in the UK, which emphasises the importance of these skills for nearly all students (Porkess, 2013). His report provided a rationale behind embedding statistical education through nearly all curriculum areas in the UK. His report emphasises the importance of students acquiring these skills, in a variety of contexts, which should not be ignored.

The removal of Key Stages, and introduction of reference points (implementing the new LNF stated above) is an attempt to give greater freedom to education providers, with a drive on skills development rather than focusing too much on prescriptive curriculum content (WG, 2015). To support the allocation of greater teacher freedom and a drive on skills development, interviews with students across Wales from both secondary and primary schools suggested a preference to learn skills for life, employment, and higher education (Donaldson, 2015). These students were also less concerned with learning prescribed curriculum content that was similar to students from other schools (Donaldson, 2015). In addition, teachers across Wales supported the introduction of a skills focused national curriculum, supporting the development of digital literacy, numeracy and literacy that had real world contexts (Donaldson, 2015). The skills for life and employment rhetoric also echo the voices of a multitude of employers and educational organisations (ACME, 2011; MEI, 2015; RSS and ACME, 2015). In terms of the Donaldson report, it is difficult to ascertain the extent to which the student voice was utilised. In addition, these opinions are from a sample of students across

Wales and do not necessarily represent or perhaps even capture all relevant opinions in relation to the current education system in Wales.

With increasing pressure to raise Wales' game in mathematics educational outcomes, the Welsh Government recently commissioned the creation of a Mathematics Task and Finish Group led by Michael Griffiths. His recent report was published in November 2015, and drew on several sources that echo the current state of mathematics education presented here. The report presented 14 recommendations for the Welsh Government to consider, several of which are shown below. These recommendations link directly to mathematical pedagogy, and post-16 mathematics education, both of which are key elements of this thesis.

<p><b>Recommendation 3:</b> Considers establishing a National Centre of Excellence for Mathematics that would be responsible for identifying and promoting excellent mathematics pedagogy, for developing resources, for coordinating professional training and for undertaking best practice, evidence-based research into mathematics and mathematics teaching.</p>
<p><b>Recommendation 4:</b> Considers establishing school based mathematics hubs across all education settings, which would work collaboratively and in partnership with the Centre of Excellence for Mathematics in considering needs and identifying priorities, developing and delivering courses and resources and in undertaking research.</p>
<p><b>Recommendation 6:</b> In collaboration with the proposed Centre of Excellence for Mathematics, establishes a recognised national programme of training for all teachers and support staff of mathematics in Wales. As a first step, the Welsh Government should map existing mathematics professional development opportunities available to teachers in Wales, and make that information readily available electronically.</p>
<p><b>Recommendation 14:</b> Monitors the numbers for both post 16 and graduate level mathematics study in Wales in order to inform future recruitment and training needs.</p>

**Table 3. 2 Mathematics Task and Finish Group report (Griffiths, 2015).**

The recommendations made by the Griffiths review provided practical solutions to tackle many of the concerns described in section 3.2 of this chapter, although it is perhaps disappointing that the report focuses on pre-16 mathematics education. There seems to be a missed opportunity to address the numbers of students progressing onto university courses that require a pre-requisite level of numerical skills. In particular, the report should have highlighted the increasing numbers of university courses that require students to have covered statistical concepts and techniques at A' Level (RSS and ACME, 2015). However focusing on numeracy initiatives earlier on could help raise standards in the PISA exercise and GCSE mathematics for example. Improving mathematics pedagogy and teacher training (as suggested by Donaldson (2015) and the RSS and ACME (2015)) could also raise student interest and awareness of applying numerical and statistical skills to a variety of subject areas that are perhaps less obvious; sociology for example.

### **3.4 Mathematics and statistics A' Level curriculum**

In its current state, A' Level mathematics is offered by all exam boards within England and Wales. The full A' Level comprises of a combination of six modules, with three being taken in each year (AQAa, 2017; Edexcel, 2017; OCR, 2017; WJECa, 2017). Each of the exam boards requires students to complete two compulsory units each year in core or pure mathematics, with space for one optional unit each year. Most exam boards offer optional units in statistics or mechanics modules, with all except WJEC (the main exam board in Wales) offering decision mathematics as well. An overview of the content of each of these options is highlight in Table 3.3 (Edexcel, 2017).



Unit	Summary of unit content
C1	Algebra and functions; coordinate geometry in the (x, y) plane; sequences and series; differentiation; integration.
C2	Algebra and functions; coordinate geometry in the (x, y) plane; sequences and series; trigonometry; exponentials and logarithms; differentiation; integration.
C3	Algebra and functions; trigonometry; exponentials and logarithms; differentiation; numerical methods.
C4	Algebra and functions; coordinate geometry in the (x, y) plane; sequences and series; differentiation; integration; vectors.
M1	Mathematical models in mechanics; vectors in mechanics; kinematics of a particle moving in a straight line; dynamics of a particle moving in a straight line or plane; statics of a particle; moments.
M2	Kinematics of a particle moving in a straight line or plane; centres of mass; work and energy; collisions; statics of rigid bodies.
M3	Further kinematics; elastic strings and springs; further dynamics; motion in a circle; statics of rigid bodies.
M4	Relative motion; elastic collisions in two dimensions; further motion of particles in one dimension; stability.
M5	Applications of vectors in mechanics; variable mass; moments of inertia of a rigid body; rotation of a rigid body about a smooth axis.
S1	Mathematical models in probability and statistics; representation and summary of data; probability; correlation and regression; discrete random variables; discrete distributions; the Normal distribution.
S2	The Binomial and Poisson distributions; continuous random variables; continuous distributions; samples; hypothesis tests.
S3	Combinations of random variables; sampling; estimation, confidence intervals and tests; goodness of t and contingency tables; regression and correlation.
S4	Quality of tests and estimators; one-sample procedures; two-sample procedures.
D1	Algorithms; algorithms on graphs; the route inspection problem; critical path analysis; linear programming; matching's.
D2	Transportation problems; allocation (assignment) problems; the travelling salesman; game theory; further linear programming, dynamic programming; rows in networks.

**Table 3. 3 An overview of the A' Level mathematics modules available**

(Edexcel, 2017). C=core, M=mechanics, S=statistics and D=decision. All C modules are compulsory.

Ward-Penny *et al.*, (2013) have investigated mathematics teachers' perceptions of the applied mathematics streams, in a variety of secondary schools across England and Wales. Mechanics was considered the most difficult due to the modelling, problem solving and high algebraic content, but the most interesting. Statistics was described as the least engaging for both students and teachers. Mechanics and statistics could be easily related to real-world experiences, more so than decision mathematics. Many teachers appreciated the values of the various applied modules to different careers and noted that certain modules would assist students' wider education. For example, studying mechanics was beneficial to A' Level physics students. The authors reported that statistics was the most commonly offered stream of applied mathematics; they expressed disappointment that this position has arisen due to strategic considerations with statistics seen as easier for the weaker students to access (Ward-Penny *et al.*, 2013).

An earlier review of A' Level mathematics (QCA, 2007) had already highlighted that much strategic selection of applied maths modules exists, with the decisions almost always made by teachers rather than students. There was a clear view that M1 and M2 are the most challenging combination and S1 and D1 are the easiest modules. The most difficult combination (M1 and M2) had the highest proportion of A grades and S1 and D1 the lowest proportion (Edexcel results, Summer 2006), attributed to the more able pupils taking M1 and M2 and less able pupils tending to pursue S1 and D1 (QCA, 2007).

Lee *et al.*, (2007) investigated why schools did not offer both modules of an applied maths stream in England and Wales. For both the mechanics and statistics streams, timetable constraints was a dominant concern but the most common

reason for not offering M1 and M2 was that mechanics was the most difficult of the applied topics. Despite this perception, others praised the importance and value of mechanics in that, unlike statistics and decision maths, it offers opportunities to practise and develop skills in the use of algebra, calculus and trigonometry (Kitchen *et al.*, 1997).

Minards (2013) explored teachers' perceptions of their students' experiences of the pure maths modules. The most common reason given by teachers for difficulties in A' Level maths was novelty – unfamiliar wording or structure of questions and therefore the need to make a decision, rather than the mathematics itself, caused the difficulty. The author states that this unpreparedness for unfamiliar questions suggests a lack of critical thinking and also relational understanding (defined by Skemp (1976) as knowing both what to do and why) and comments that many students with good grades in maths are not confident in problem solving.

Research conducted by Cole (2015) in 27 grammar schools in Northern Ireland investigated the attitudes of mathematics school teachers views on the different streams of applied mathematics in A' Level mathematics. The curriculum content is identical to A' Level content in England and Wales. Their results showed that the teachers found statistics to be the least popular topic for pupils; while the learning of methods and number crunching can be tedious and uninteresting. However, S1 is recognised to be relatively elementary and straightforward and pupils realise they can boost their overall result through it. It was suggested that statistics modules within A' Level mathematics should be made more meaningful. Analysis

of a large data set, as proposed for the new A' Level specifications, might be a way to achieve this (Cole, 2015).

These findings suggest statistics in its current state, within mathematics A' Level, is the least engaging component, with students performing less well compared to mechanics modules (Kitchen *et al.*, 1997; QCA, 2007; Ward-Penny *et al.*, 2013). In addition, the qualification as a whole is seen to leave students underprepared and lacking confidence in problem solving, critical thinking and relational understanding (Skemp, 1976; Minards, 2013).

Changes to A' Level mathematics have taken the longest time to implement, in relation to the new A' Level curricula being rolled out across all subjects in England and Wales (ACME, 2011). The Advisory Committee to Mathematics Education (ACME) board has developed guidelines to inform the compulsory requirements needed for the new A' Level in mathematics content being launched by all exam boards in September 2017. Changes include the compulsory inclusion of mechanics and statistics modules, alongside the Core Mathematics modules (ACME, 2011). With regards to statistical content, changes include greater use of large data sets as well as the need to use more information technologies (IT) to analyse the data (ACME, 2011). Sadly what is meant by the use of large data sets is open to interpretation (the sample size can be as small as 300 for example) and the use of IT was only a recommendation, due to access and cost of certain software packages (ACME, 2011).

### **3.5 Mathematics pedagogy**

Government initiatives to adapt mathematics and statistics education aim to influence the way it is taught as a subject. These changes require an examination of several key issues with mathematics pedagogy, drawing on a variety of predominantly negative student experiences.

The recent Welsh Government (WG) document *Effective Practice in Learning and Teaching - A Focus on Pedagogy*, describes how teachers from all subject areas should be prepared to try new approaches as well as wanting, "to enable learners to become more engaged, effective and motivated and thus able to achieve better quality outcomes" (DCELLS, 2009, p.4). It is evident from the literature that traditional didactic teaching methods in mathematics do not adequately meet the demands of this report or indeed the needs of the learner (Swan, 2005; Donaldson, 2015). Swan reports that even students who have sufficient interest to have chosen A' Level mathematics may lack satisfaction in their learning, with some sixth form students describing their most frequent behaviours in maths lessons as:

"I listen while the teacher explains."

"I copy down the method from the board or textbook."

"I work on my own"

"I try to follow all the steps of a lesson."

"I practise the same method repeatedly on many questions."

(Swan, 2005, p.3)

Traditional styles of teaching mathematics fail to include discussion and debate.

Introducing more interaction in the classroom may serve to spark students' interest in the subject (Swan, 2005).

There is a clear opportunity to create a transformative pedagogy that could challenge and reverse negative attitudes to the subject. Sadly, there are engrained

societal attitudes that make it acceptable to openly admit to being useless at maths, whereas few would admit that they are useless at reading (Harrison, 2014; National Numeracy, 2017).

By being aware of and reflecting on some of the negative aspects of students learning experiences in mathematics and statistics, it should be possible to modify, create and identify pedagogical practices that produce an excellent experience, even in schools which may have different 'classroom cultures' to those being promoted by current research (Swan, 2005; Noyes, 2007, p.69).

There are however excellent examples of teaching practice in mathematics and statistics education, with increasing numbers of web based resources available online from a variety of the examination boards and other educational charities across the UK. For example, Mathematics in Education Industry (MEI) have excellent banks of free teacher resources, video clips of exemplar mathematics and statistics lessons for a variety of age groups and also examinations tips for students (MEI, 2016). MEI also holds a national conference for teachers to share best practice, delivered in a series of workshops and keynote speeches. The event also showcases a variety of instruments to accompany the teaching of mathematics and statistics, for example: incorporating scientific/graphical calculators and data analysis software packages using quantitative data sets (MEI, 2016).

Unfortunately, these events are expensive and require schools and FE colleges releasing their teaching staff for up to four days. As a consequence, the conference delegates tend to be teachers from privately maintained schools, and independent colleges, where student numeracy levels tend to be higher than the national average (Swan, 2005; Bradshaw, 2010). Schools in deprived areas with limited

funding, which usually present with student numeracy levels that are below the national average, are unfortunately less likely to be able to send their staff on training courses like the MEI provide (Swan, 2005; Bradshaw, 2010).

The national numeracy campaign also offers assistance to teachers, to help make their mathematics teaching more engaging. This is offered as an online support package in the form of resources, some of which are free while others require payment (National Numeracy, 2017).

### **3.6 Interdisciplinary mathematics and statistics**

As previously discussed, mathematics and statistics education has a history of difficulties in creating distinct and engaging pedagogical methods (Swan, 2005; Noyes, 2007, p.69; Porkess, 2013). This section will draw on evidence that provides an opportunity to develop creative teaching strategies (including the curriculum development and evaluation of the course created and described in chapter four), to help change the negative identity of mathematics and statistics.

In an increasingly data-rich world, there is a growing consensus that young people should leave compulsory education able to understand, analyse and critique data in their lives: as learners, as employees and as citizens (Prime Minister's Office, 2014). The quantitative demands of university courses are increasing (Hodgen *et al.*, 2014) yet many learners arrive underprepared for these courses (ACME, 2011). Many jobs now require problem solving skills and greater confidence in using data (CBI, 2010). Understanding statistical methods and approaches is crucial for informed analysis in many contexts.

The reformed A' Levels in England (closely mirrored in Wales) reveal an increased requirement for students to apply mathematical and in particular statistical skills, across a range of subjects (Table 3.4). These changes necessitate the need to better prepare students for the increasing levels of mathematics and statistics they will encounter across many subject areas. In addition, the application of mathematics and statistics across a range of subjects places a greater demand on the need for context rich examples, to facilitate subject knowledge acquisition.

<b>Statistical skills in selected A Levels</b>
<p><b>Biology</b> Various statistical skills are listed under mathematical skills. These include learners selecting and using a statistical test, and identifying uncertainties in measurements using simple techniques to determine uncertainty when data are combined.</p>
<p><b>Business</b> Quantitative skills in business list broad competencies, including using and interpreting quantitative information in order to make decisions.</p>
<p><b>Chemistry</b> Some statistical skills are listed under mathematical skills. These include identifying uncertainties in data using simple techniques.</p>
<p><b>Geography</b> Geographical skills developed throughout the course are listed and include an equal balance of quantitative and qualitative methods and skills. The skills listed are comprehensive, including collecting, analysing and interpreting data and demonstrating skills in descriptive, inferential and relational statistics.</p>
<p><b>Psychology</b> Extensive statistical skills are listed under mathematical skills, including selecting and using a statistical test, using statistical tables to determine significance, and understanding the difference between qualitative and quantitative data.</p>
<p><b>Sociology</b> The guidance is broad, with statistical skills listed under skills. Learners must collect, record, interpret and evaluate evidence, which is understood to include both qualitative and quantitative data.</p>

**Table 3. 4 Statistical skills in selected A' Levels (RSS and ACME, 2015)**



The challenge of integrating mathematics and statistics into other curriculum areas links to several interconnected issues, which appear to be overlooked by the proposed changes associated with the LNF. For example, these subjects contain a specialised set of knowledge, uses a specific lexicon, with a pedagogic tradition that emphasises singular facts and precise tools to solve mathematical problems over broad concepts and generalisable ideas (Nikitina and Mansilla, 2003; Roth, 2014). These issues can also be said for the sciences, where Nikitina and Mansilla (2003) suggest these subjects have maintained subject boundaries for decades, or as C.P. Snow puts it, the divide between the, 'two cultures,' referring to the sciences versus the humanities. Creating opportunities to link mathematics and statistics to social science for example could lead to disciplinary incongruence, perhaps due to the traditional incompatibilities in which the different subjects are taught (Roth, 2014). Social science subjects often include broad facts and generalisable ideas to explain social phenomena for example, which is the complete opposite to mathematics and statistics (Roth, 2014). These differences will have a profound impact on the way these subjects are taught, for example humanities subjects lend themselves well to more discursive classroom activities, whereas mathematics and statistics subjects have traditionally been delivered through didactic approaches and individual problem solving tasks (Swan, 2005; Noyes, 2007; Roth, 2014).

The increasing demand for teachers across many subject areas to develop numerical and statistical skills along with their own subject specialism knowledge, presents an enormous challenge for both the current teaching workforce, and teacher training courses (RSS and ACME, 2015). In particular, subjects not normally associated with statistics at Key Stage 5 (perhaps for the above reasons) such as sociology and geography will require teachers to upskill in this area (Table

3.4) (Porkess, 2013; RSS and ACME, 2015). New forms of applied mathematical and statistical content and associated pedagogical guidance could help to facilitate the essential changes needed to support teachers across disciplines.

### **3.7 Mathematics for life, mathematical reasoning, critical thinking and statistical education (Core Mathematics)**

The opportunity to make mathematics and statistics education more accessible to pre-university students is an area that is being explored by government and educational organisations across the UK. This section will begin to draw on recent developments that focus on these areas, in the UK.

With only 20% of students choosing to study mathematics beyond GCSE, the UK government commissioned the Core Mathematics programme as a key initiative to increase student numbers, post-16 (Core Mathematics, 2015). Core Mathematics was designed to maintain and enhance real life mathematics skills, to include mathematical reasoning, critical thinking, statistics and financial mathematics. Currently all major examination boards in England offer a Core Mathematics qualification, with the Department for Education (DfE) sanctioning the approval of such courses for English schools only. The newly created Qualifications Wales, who have a similar role to the DfE in England, have yet to comment on introducing Core Mathematics for Welsh schools (WG, 2015). The initiative is currently being rolled out across England, with funding available for English schools.

Mathematics as a discipline has experienced radical shifts in both applied and theoretical aspects (Nunez, 2006, pp.160-181; Walshaw and Anthony, 2008; Durrand-Guerrier, 2015, pp.453-457). Proponents for more applied forms of

mathematics argue procedural mathematics; mathematical induction and proof should be limited to higher education, with a greater focus placed on mathematical reasoning, critical thinking and context at the pre-university level (Gal, 2002; Nunez, 2006, pp.160-181; Schleppegrell, 2007; Walshaw and Anthony, 2008; Durrand-Guerrier, 2015, pp.453-457). In a mathematical context, critical thinking will be treated as a form of relational understanding in this thesis, as Skemp puts it, 'knowing what to do and why,' (Skemp, 1976, p.21). In addition, The National Centre for Excellence in the Teaching of Mathematics suggest numerical skills needed for life provides a useful conduit to perhaps introduce mathematical concepts to a greater audience, and even encourage more people to study mathematics post-16 years of age (NCETM, 2014).

Core Mathematics has been designed as a supportive post-16 subject, facilitating subjects that require a certain level of statistical skills. For example, the sciences, psychology, business studies, geography and increasingly sociology, require students to develop mathematical reasoning skills, statistical analysis techniques, as well as data analysis skills (Core Mathematics, 2015).

### **3.8 Overlaps with changes to mathematics and statistics education and the**

#### **Q-Step initiative**

This chapter has highlighted the shifting focus of pre-university mathematics and statistical education within the UK, away from procedural operations towards quantitative and mathematical reasoning (Nunez, 2006, pp.160-181; Schleppegrell, 2007; Walshaw and Anthony, 2008; Durrand-Guerrier, 2015, pp.453-457).

Mathematical context is gaining equitable standing to the procedural elements, forcing teachers to rethink pedagogical approaches.

Core Mathematics was designed as a supportive post-16 subject, facilitating subjects that require a certain level of mathematical skills. For example, the natural sciences, psychology, business studies, geography and increasingly sociology, require students to develop mathematical reasoning skills, statistical analysis techniques, as well as data analysis skills (Porkess, 2013). The ambitious Core Mathematics programme resonates strongly with several educational researchers who argue that mathematics should be used as a tool to facilitate other subject areas, and support the development of students reasoning and critical analysis skills (Forman, 1996; Dowling, 1998; Mercer and Sams, 2006). However, there is concern that students will be unable to make the conceptual links between the mathematics and statistical skills they acquire through Core Mathematics, and their other QCF level 3 qualifications (Smith, 2017).

The, Q-Step initiative, albeit a programme aimed at increasing the numbers of social science graduates trained in quantitative research methods and skills, has significant overlaps with the Core Mathematics programme. Many of the potential benefits highlighted in the Donaldson review (Donaldson, 2015), Porkess report – *A world full of data* (2013), Smith review (2017), and various other academics in this area at improving statistical education align to many of the Q-Step initiatives' objectives (Payne, *et al.*, 2004; Swan, 2005; Williams, *et al.*, 2008; MacInnes, 2009; Platt, 2012; Payne, 2014; Williams *et al.*, 2015). Both camps agree that a numerate society is essential for the prosperity of a nation. In addition, there is a consensus that more students need these basic skills to prepare them for jobs that currently don't exist, with a need for the UK to up its game in the world of quantitative methods (CBI, 2010).

There appears to be a common ground between both the mathematics deficit within the UK, particularly in Wales, and the quantitative deficit within the social sciences. Indeed, many of the negative attitudes towards mathematics reported by Swan (2005), and Noyes (2007) could explain the antipathy of students within the social sciences towards quantitative methods. Students on social science degree courses within the UK are likely to label quantitative methods courses as being too mathematical, not as useful or interesting as qualitative methods, and perhaps at odds with their view of social science as being more of an arts than a scientific subject (Williams *et al.*, 2008).

One of the central aims of the Q-Step initiative includes the following:

“The resulting expertise and resources developed are to be shared across the higher education sector through an accompanying support programme, forging links with schools and employers.”

(Nuffield Foundation, 2014, p.1)

Since the Q-Step initiative includes 15 UK based Q-Step centres, designing courses in politics, geography, social sciences, child-hood studies, criminology, economics, history, anthropology and population health, this rich mixture of statistical context could be utilised by the Core Mathematics programme (Table 2.1). Core Mathematics has been designed as a supportive post-16 subject, facilitating subjects that require a certain level of mathematics skills. For example, the sciences, psychology, business studies, geography and increasingly sociology, require students to develop mathematical reasoning skills, statistical analysis techniques, as well as data analysis skills (Porkess, 2013). Currently all major

examination boards in England offer a Core Mathematics qualification. The courses developed have a variety of names, with one exam boards qualification entitled: Mathematics for life. These qualifications are slightly biased towards mathematical procedural tasks, and should emphasise quantitative reasoning skills more prominently. In addition, the teacher resources are disappointingly mundane and lack interesting context (Core Mathematics, 2015).

There is a potential for both schemes to share and develop teacher resources, pedagogical approaches, and to develop curricula. It is hoped that the proposed activities and outputs from this thesis will outline the importance of both schemes working closer together, as well as measuring student attitudes towards mathematics and statistics. These findings could also have implications for current and future plans to adapt mathematics and statistics curricula content, as well as pedagogical approaches.

### **3.9 Conclusion**

The changing nature of mathematics as a discipline presents many challenges across the educational landscape. In particular post-16 mathematics education, and the increasing importance of statistics education needs greater attention by education ministers across the UK. Reasons to explain some of the antipathy towards quantitative methods within the social sciences are potentially rooted within the societal negative attitudes towards mathematics, mentioned throughout this chapter. The need for evidence to identify current attitudes towards post-16 mathematics and statistics, as well as exploring emerging transformative statistical curricula and associated pedagogies have also been explicitly stated by the RSS and ACME (RSS and ACME, 2015).

This thesis will now describe the development of a contextualised statistics course - the QCF level 3 course in Social Analytics (SA) (chapter four). This course was created to better prepare year 12 and 13 students for the quantitative methods contained within a number of courses (social science courses in particular) at university.





# Chapter 4 - Cardiff FE Q-Step initiative (Pilot Scheme in Social Analytics): 2014 –2016

## 4.1. Introduction

This chapter presents the FE and schools engagement initiative within the Cardiff Q Step Centre, focusing on the Pilot Scheme in Social Analytics (SA), created to aid the QCF level 3 course developments. The design and implementation of this initiative are the foci of this thesis, in response to the issues raised in chapters two and three. The Pilot Scheme aimed to better prepare students for the quantitative methods they are likely to encounter at university. This new course encompasses statistical thinking and analysis to explain various social phenomena such as: health inequalities, differential educational attainment and crime in society. The development of this qualification involved colleagues from St David's Sixth Form College (St David's), Cardiff and the Vale College (CAVC) and Agored Cymru (Access to HE diploma providers in Wales). Agored Cymru approved a series of units based on the Pilot Scheme in SA, which will be discussed in chapter eight.

As well as a description of the Pilot Scheme course, this chapter will discuss how the curriculum was developed, with several initial ideas generated via networking events with the Department of Statistics at the University of Auckland. A constructivist approach to learning theory was adopted to inform and drive the curriculum developments and pedagogic approaches associated with the Pilot Scheme in SA, which was delivered in 2014/15 and 2015/16. Descriptions of the scheme of work, learning outcomes and worksheets are also included in this chapter, to provide insights into the course content and delivery.

## **4.2 Curriculum development**

This section will introduce three areas involved with the curriculum development for the Pilot Scheme in SA:

- *A critique of what a curriculum should encompass, along with the difficulties of measuring and also operationalising curriculum objectives.*
- *Initiatives in New Zealand.*
- *The rationale and description of how the curriculum for the Pilot Scheme in Social Analytics (SA) was constructed, in conjunction with a group of FE lecturers and secondary school teachers.*

### *A critique of what a curriculum should encompass*

To describe the curriculum construction of the Pilot Scheme in SA, a critique of curriculum development literature is necessary. This will include a definition of a curriculum, along with an explanation of their purpose to facilitate the educational needs of students.

Stenhouse defines curriculum as a regular course of study at a university or school, having a structure that is characterised by harmony between the various parts or elements (1975). He goes on to state that they give suggestions to lecturers and teachers as to the pedagogical approaches that would be most effective for the various elements of the course; moreover, curricula are a set of guiding tools towards all of the experiences students gain, under the guidance of the lecturer or teacher (Caswell and Campbell, 1935).

Tyler suggests that in order to effectively design and successfully implement a course curriculum, the following points need to be addressed:

1. What educational purposes should the curriculum seek to attain?
2. How can learning experiences be selected which are likely to be useful in attaining these objectives?
3. How can learning experiences be organised for effective instruction?
4. How can the effectiveness of learning experiences be evaluated?
5. How can the academic staff work on improving the curriculum?

(Adapted from Tyler, 1949).

Prideaux (2015) has contested the definition of curriculum design, along with its purpose with reference to course delivery and pedagogical strategies. He argues that Tyler's points suggest curriculum design should proceed from defined statements of learner behaviour that can be easily measured (Prideaux, 2015). Moreover, when added together these learner behaviours should match the curriculum outcomes (Prideaux, 2015). This suggests the students' behaviours, or perhaps changes in behaviour to demonstrate certain learning targets have been met, should be identifiable within the curriculum. However, this description does not lend itself well to certain types of courses, where educational outcomes are much harder to measure, for example in medical education assessing a student doctor's clinical judgment and reasoning skills. These learner outcomes are much harder to align to a predefined curriculum, since individual experiences in relation to clinical judgment for example, are likely to be extremely variable and perhaps not even identifiable until they occur (Prideaux, 2015). A potential solution to this could include being mindful of unexpected or unanticipated learner behaviours that should help inform curriculum developments, being flexible for such occurrences if and when they occur.

Interestingly and not in relation to Prideaux's comments, Curry contests the use of students' behaviours in curriculum design, suggesting the underlying theory has questionable supporting evidence (Curry, 1990). This inability of a curriculum to accurately capture the desired and measurable learner outcomes resonates strongly with the current state of mathematics A' Level. As it stands, A' Level mathematics forces students to identify mathematics as a right or wrong subject that involves students carrying out mostly procedural tasks, i.e. calculations (Swan, 2005; Donaldson, 2015). And as already described in chapter three, there are distinct differences between mathematics and statistics, even though the two disciplines are mutually supportive (Franklin, 2013). Critical thinking and relational understanding of mathematics, of which statistics fosters as a discipline investigating uncertainty and variability (Gibbison, 2017), should be core transferrable skills embedded within A' Level mathematics (Skemp, 1976; Donaldson, 2015; Smith, 2017).

Prideaux has also written more generally on the subject of curriculum design, stating it is a result of human agency, underpinned by a set of values and beliefs about what students should know and how they come to know it (Prideaux, 2003). Curricula are often contested and problematic (Prideaux, 2003). For example, teachers or lecturers may support a set of underlying values that are no longer relevant, of which Prideaux refers to as saber-toothed curriculum: based on the fable of cave dwellers who continue to teach about hunting saber-toothed tigers long after they were extinct (Prideaux, 2003). This last point is extremely relevant as an underpinning rationale behind the QCF level 3 course that was developed within the Cardiff Q-step centre. As mentioned in chapter three (sub sections 3.4 to 3.7) A' Level mathematics clings too closely to the traditional content of

procedural mathematical and statistical techniques (Swan, 2005; Noyes, 2007, p.69; Porkess, 2013; Donaldson, 2015). The traditional content of mathematics A' Level could be viewed as a saber-toothed curriculum, that doesn't prepare students for higher education courses that utilise statistical principles and techniques; the social sciences, biology and psychology for example (Swan, 2005; Porkess, 2013; Donaldson, 2015). In addition, the unengaging nature of statistical modules within A' Level mathematics has been discussed (chapter three), reported by an increasing number of mathematics teachers across the UK (Kitchen *et al.*, 1997; Ward-Penny *et al.*, 2013; Cole, 2015).

#### *Initiatives in New Zealand*

The distinctive nature of the Pilot Scheme in SA course development process evolved from several networking ventures with the University of Auckland's Department of Statistics, which need to be discussed in more detail before the course content is presented. This will help explain why certain strategies were adopted in developing the Pilot Scheme in SA, identified as being successful in New Zealand (NZ).

The University of Auckland's Department of Statistics is a world leader in statistics education, being one of the largest in the world (Auckland, 2017). The Cardiff Q-Step Centre hosted representatives from the department in 2014, arranging a two day workshop facilitated by two of their academic staff (Dr Stephanie Budgett and Associate Professor Maxine Pfannkuch) to present workshops based on their schools engagement work and also undergraduate statistics modules.

Associate Professor Pfannkuch, Dr Budgett and Professor Chris Wild have also worked closely with the Ministry of Education in NZ to transform secondary school statistics education (Forbes, 2014), for example the introduction of visualisation and data handling techniques into secondary schools (Arnold *et al.*, 2011; Budgett *et al.*, 2013; Forbes, 2014). New Zealand has become a world leader in data handling and visualisation techniques in its secondary school statistics curriculum (Forbes, 2014).

The Teacher Placement Scheme, described in the next section, was an idea conceived with colleagues at Auckland University, to help build and sustain leadership capacity (Social Analytics champions) in statistics education across South Wales. The interdisciplinary nature of the Pilot Scheme in SA course emphasises its distinctiveness, encompassing both a skills and context focus.

*Rationale and description of how the curriculum for the Pilot Scheme in SA was constructed*

The lack of quantitative methods in A' Level sociology (discussed in chapter two) provides a rationale for developing the QCF level 3 course in SA to offer a suitable alternative (WJEC, 2016). In its current state, A' Level sociology does not truly reflect the discipline as it stands today, with no mention of the emergent interdisciplinary fields present (WJEC, 2016). For example, the Cardiff School of Social Sciences includes several research centres that carry out interdisciplinary research on health, crime, the environment, digital technologies, religion and medicine using large data sets and data linkage techniques with the aid of data software packages (SOCSI, 2016).

In addition, the course was created to address the issues connected with current (and proposed) mathematics and statistics courses at Key Stage 5 in England and Wales (chapter three). For example, it is unfortunate that ACME have made optional recommendations for the new A' Level in mathematics (first taught in September 2017) to include the analysis of large data sets, rather than making it a compulsory requirement (ACME, 2011). This would have enabled students to engage with more real world examples of large data sets, better preparing them for a range of higher education courses that include such analyses (Nuffield Foundation, 2016a).

Constructivism was the key learning theory in driving the Pilot Scheme in SA developments. This theory positions students at the centre of the learning process, whereby they construct their own knowledge (Duffy and Cunningham, 1996; Fosnot, 1996; Von Glasersfeld, 1996). This theory of learning resonates strongly with curriculum and pedagogical reform proposals made by Donaldson (2015) in his Successful Futures report (chapter three). Since the WG has accepted his recommendations, it seems prudent to develop a course using these principles, in line with the trajectory for other courses being modified and developed in Wales. In addition, constructivist approaches differ significantly to instructionist approaches, which usually place the teacher at the centre of the learning process, incorporating typically didactic methods of delivery, a technique traditionally favoured by mathematics and statistics teachers, that potentially contributes to the subjects negative societal image – discussed in chapter three (Swan, 2005; Scholnik *et al.*, 2006; Noyes, 2007, p.69; Harrison, 2014). Proponents of constructivist approaches state that concepts cannot simply be transferred from teacher to student, whereby learning is a process that involves active construction

and not passive acquisition (Duffy and Cunningham, 1996; Scholnik *et al.*, 2006). Constructivism can be subdivided into two forms: cognitive and social. Cognitive constructivism, developed by Piaget, concentrates on the importance of the mind in learning, whereas social constructivism developed by Vygotsky, focuses more on the importance of the environment and interactions between learners (Fosnot, 1996; Lui and Matthews, 2005). The two approaches are not mutually exclusive however, and both theories were used to inform and drive the curriculum development, learner experiences and pedagogic approaches for the Pilot Scheme in SA.

To aid in the QCF level 3 course developments, a Pilot Scheme in SA was created to act as a scaffold for the Agored Cymru approved units. The development of this qualification involved colleagues from St David's Sixth Form College (St David's), Cardiff and the Vale College (CAVC) and Agored Cymru (Access to HE diploma providers in Wales).

This Pilot Scheme in SA course was developed in collaboration with a group of FE lecturers and secondary school teachers from across South Wales, along with representatives from Agored Cymru. This group was specifically recruited for this purpose, referred to as the Teacher Placement Scheme (TPS).

The TPS encompassed a range of expertise from disciplinary backgrounds in the social sciences, politics, mathematics, political sciences, health sciences, biology and psychology. The group's expertise also included experience of teaching a variety of levels from school year 7 level through to master's and teacher training education levels. This enabled discussions to emerge and evolve around the core



themes of curriculum design and pedagogy, intersecting several disciplines and student age groups. This range of expertise enabled the group to decide on the core skills (critical thinking and statistical concepts/analysis in relation to the course aims of Social Analytics) students needed to effectively progress from year 10 onwards, with the end goal of accessing a variety of higher education courses.

The Pilot Scheme in SA course curriculum was generated by reflecting on all of Tyler's key themes for an effectively designed curriculum, aligned to a constructivist approach of placing the student at the centre of the learning experience. In reality, the input of the TPS takes Tyler's suggestions a step further by involving them in the curriculum development process. Below is a summary of how each of Tyler's key themes were utilised during the development and proposed evaluation phases of the Pilot Scheme:

1. What educational purposes should the curriculum seek to attain?

The TPS discussed the aims of the QCF level 3 SA course, to include preparation for students to access a range of HE courses with a significant statistical component. HE courses aligned to subjects in biology, psychology, business studies, geography and the social sciences.

2. How can learning experiences be selected which are likely to be useful in attaining these objectives?

The range of teaching experience within the group enabled us to troubleshoot and decide on the best teaching methods to use. The types of learning experiences selected were designed to achieve the educational purposes of the course – to increase students' data analytical and critical thinking skills as

preparation for certain HE courses.

3. How can learning experiences be organised for effective instruction?

The Scheme of Work (Appendix 4.2) was organised to ensure learners developed a range of complementary skills, using a variety of pedagogical techniques (discussed in more detail in section 4.5 of this chapter)

4. How can the effectiveness of learning experiences be evaluated?

Course evaluations were developed to be delivered at different time points throughout the course, to enable changes to be made (if necessary) in response to student feedback.

5. How can the academic staff work on improving the curriculum?

Evaluating student feedback from the course, and also evaluating the teaching methods selected and scheme of work arrangement (Appendix 4.2) could lead to changes being made with the curriculum (this did happen in practice, see section 4.5 – under delivery: removing the ANOVA content of the course)

(Adapted from Tyler, 1949).

The curriculum was purposely mapped to several A' Level subjects: mathematics, biology, psychology, geography and sociology. These are subjects that afford opportunities for quantitative data analysis and the incorporation of interesting contexts. This mapping was carried out to enable students engaging with the course to make explicit conceptual links between Social Analytics and the other subject areas. In addition, it would enable students to recognise the value of participating in such a course, supporting their A' Level subject areas.

The development of critical thinking skills was also central to the course development, and deemed to be good preparation for higher education in a variety of subjects (Landers, 1999; Gal, 2002; The Critical Thinking Community, 2016). The ability to objectively evaluate evidence and make judgments is of central importance to enable relational understanding of mathematics and statistics (Skemp, 1976; Landers, 1999; Gal, 2002). In a statistical context, critical thinking mutually supports relational understanding (Gal, 2002), as Skemp puts it, 'knowing what to do and why' (Skemp, 1976). The Critical Thinking Community, the largest foundation in the world that aims to foster critical thinking not only in higher education but also in society, emphasises the importance of developing critical thinking skills as an essential goal of higher education (The Critical Thinking Community, 2016). Developing students' judgment and critical thinking skills also align to constructivist principles, whereby students actively construct concepts and knowledge, as well as discuss and exchange ideas. This could then lead them to become aware of their own perspectives, understanding the world of the learner compared to the world of the expert (which could be the teacher in this context, or researchers) (Wood, 1995). For these reasons, opportunities for students to work in groups were encouraged by introducing games and worksheets throughout the course (section 4.5).

After the curriculum was constructed (Appendix 4.1), the TPS provided valuable evaluative advice from a curriculum development perspective. Advice included links being made to Bloom's Taxonomy, ensuring learning outcomes followed a hierarchical increase in skills development (Bloom *et al.*, 1956). This key consideration resonates strongly with Tyler's fifth point (Tyler, 1949).

FE lecturers and secondary school teachers' involvement with curriculum development disseminated information about the Pilot Scheme in SA to their respective education institutes. TPS members' colleagues in other educational institutes then also became accessible, and were more amenable to disseminating information about the programme to their students and other colleagues.

The course content and delivery will now be discussed in more detail to exemplify its unique interdisciplinary nature.

### **4.3 Course content**

The Pilot Scheme in SA was constructed to align with A' Level subject areas in mathematics, biology, psychology, politics, sociology, and geography (Appendix 4.1 and 4.2). These popular A' Levels lend themselves well to the aims of the Pilot Scheme in SA course. They also include facilitating A' Level subjects (biology, mathematics and geography), maximising student choice for higher education study, deemed to be valuable by many universities, including those in the Russell Group (Russell Group, 2016).

The course was developed to mirror an AS Level qualification, with two units forming the subsidiary 50% of the full A' Level. The subject areas chosen include; health and disease, science and technology, crime and deviance, which form the social science in practice unit, with the applied statistics unit covering the psychology of learning, mass media and journalism and becoming an effective researcher (Appendix 4.1 (Learning outcomes) and 4.2 (Scheme of Work)). As well as aligning to popular A' Level subject areas, they were also chosen to reflect interesting and engaging topics for year 12 and 13 students.

Elements of the course were also created using small segments of a Cardiff Q-Step module for second year undergraduates. The Cardiff Q-Step module: Lies Damned Lies and Statistics (Appendix 4.3), encourages students to think critically about data, delivered in a series of lectures, workshops and seminars. The module also aims to enable students to apply theoretical knowledge gained during lectures into practice via a series of data visualisation sessions. Again this was incorporated into the Pilot Scheme in SA scheme of work (Appendix 4.2) for the same reasons as above, to enable students to develop practical skills and data analysis techniques.

The course was designed to emphasise the importance of using statistical techniques in relation to the context, rather than performing traditionally isolated statistical calculations (as in A' Level mathematics for example). In addition, core statistical and scientific concepts were embedded throughout the module outline, to ensure students developed critical analysis skills. The course was also written to be flexible enough for teachers to use a variety of examples, without being too prescriptive. For example the Social Science in Practice unit requires students to explain the strengths and weaknesses of different methods used to measure health and disease and also to be able to discuss the nature of evidence and to include its reliability and validity (Appendix 4.1 and 4.2).

#### **4.4 Student recruitment strategies**

With the TPS in place, the Social Analytics champions were able to promote the Pilot Scheme course within their respective educational institutions, as well as providing opportunities for Cardiff Q-Step staff to deliver presentations to their students. Presentations usually included a description of the benefits of the course to their educational career, developing critical thinking skills and statistical

analysis skills. At TPS meetings it was agreed that TPS members described the course as a way of enhancing students' critical thinking and statistical skills, and not just to focus on more procedural statistical calculations. This was to ensure that students were not put off, especially if they had a mathematics phobia.

Students interested in applying were asked to fill in a short application form. A minimum of B grades in GCSE English and Mathematics were stated as a requirement for admission to the course, which was a recommendation made by the TPS. In the application form there was a section for students to explain why they wanted to participate in the course. This provided opportunities for the students to explain their reasons to join the course, which enabled an assessment to be made as to whether they understood its learning outcomes and if they had an idea what the course entailed. The form also required applicants to have one of their teachers explain their reasons for putting them forward for the course, along with an agreement that the course outline and time requirements had been fully explained to the applicant (i.e. attendance for two hours per week at Cardiff University). It was hoped that these measures would maximise the benefits that students would receive from the course, as well as ensuring the resources and effort put into the development and subsequent delivery could result in students developing core critical thinking and statistical skills to help them with their A' Level studies and to better prepare them for higher education. Filtering tools were also needed, for example GCSE grade entry requirements in Mathematics and English, since we were unaware of how many would apply, and needed a way to keep the student numbers on the course at a manageable level.

There was also a parental consent form distributed as part of the application process, since students participating in the course were mostly under 18 and still legally considered to be children. Students and parents were frequently made aware of the course demands, the need for good attendance and the expectation of good behaviour. Students were explicitly made aware that the course carried no academic credit at QCF level 3, but it could be used as part of their personal statement when applying for higher education courses through the Universities and Colleges Admissions Service (UCAS). Consent forms for students to participate in the quasi-experiment were gained in a separate form, and will be discussed in the next chapter (5.11).

#### **4.5 Delivery and development of the course**

Teacher observations and students evaluations were used to reflect on and develop the curriculum structure and pedagogic practices from 2014/15 to 2015/16, in participation with others such as the TPS group. These evaluative approaches incorporated useful strategies to enable educational theory, constructivism in this case, to be translated into praxis, in essence doing something (i.e. curriculum construction, development and utilisation of pedagogical practices) and then reflecting upon those actions, i.e. were they successful? Can they be improved upon?

The first run of the Pilot Scheme in SA lasted 21 weeks and was delivered by myself, starting on the 21/10/2014 and finishing on the 28/03/2015. Reflecting on Tyler's points (Tyler, 1949), the initial delivery enabled the TPS group to utilise primary evidence in the form of teacher observations (from myself) to discuss how the curriculum unfolded practically. For example, was there enough time allotted

through the scheme of work for students to assimilate the information delivered?

There was also an opportunity to collect evaluative data, mainly in the form of course evaluations from the students participating in the course (Appendix 5.5.1 and 5.5.2). Responses from the 2014/15 course evaluations indicated the majority of students could see the value of the course to their other studies (39/44 students agreeing or strongly agreeing). They also enjoyed the statistical elements of the course (39/44 students agreeing or strongly agreeing) and felt the statistics was linked well with relevant examples (41/44 students agreeing or strongly agreeing). These responses suggested the approaches taken in developing and delivering the course were successful with this group of students, in relation to the course aims and objectives.

Areas of improvement identified from the 2014/15 cohort were discussed with the TPS, and subsequently implemented for the 2015/16 cohort. Reflections from student responses recorded, as well as evidence from my own teaching observations, were discussed with the TPS group to help modify the curriculum for future delivery of the course. Several recommendations were made and implemented by the TPS group, which included: the Analysis of Variance content to be dropped from the scheme of work, with more time allotted to regression analysis. It was felt that covering fewer topics and going into others in more detail would enable the participants on the course to have a deeper learning experience. Another modification included reducing didactic methods to incorporate more hands-on activities. For example, in the 2015/16 cohort, more opportunities were created to enable students to handle data and engage with data visualisation techniques, a strategy demonstrated as being successful in secondary schools in



New Zealand (Arnold *et al.*, 2011; Budgett *et al.*, 2013; Forbes, 2014). It was hoped that this would enable participants to apply theoretical concepts in practice, providing a more varied learning experience. In addition, constructivist approaches to learning were pushed further by providing more hands on activities for students, increasingly placing them at the centre of the learning, encouraging them to actively construct their own knowledge and share it with their peers (Wood, 1995; Duffy and Cunningham, 1996; Fosnot, 1996; Von Glasersfeld, 1996).

Due to the positive feedback received from the students present on the 2014/15 Pilot Scheme in SA course, it was decided to run it again in 2015/16. The second run of the Pilot Scheme in SA course operated for 21 weeks (scheme of work - Appendix 4.2), starting on the 05/10/2015 and finishing on the 21/03/2016. The course was delivered in a series of lectures, workshops and seminars, with myself delivering the course up until Christmas 2015. A teaching associate, a joint appointment between Cardiff University and St David's Sixth Form Catholic College, delivered the remainder of the course. The introduction of another teacher to the second run of the Pilot Scheme course probably gave the students a different learning experience to the students who took the course in 2014/15. It also provided an opportunity to ascertain if there were potential differences in delivery when two different teachers followed the scheme of work. This change in delivery will be discussed in the methods and results chapters that follow.

Bodily-kinaesthetic learning opportunities were provided as often as possible, especially in the 2015/16 cohort, as a result of student feedback from the 2014/15 cohort, to enable students to take ownership of their own learning as well as fostering the development of practical skills in generating data (Gardner, 1983).

For example, one of the first activities students engaged with involved collecting measurements of body parts. This was then compared to categorical data, favourite types of food for example. Questions were then introduced to enable students to critically evaluate the usefulness of the different types of data collected, discussing the merits and disadvantages of both. Other Bodily-kinaesthetic learning opportunities were delivered at three points during the course, dedicated to data collection and analysis sessions. For example, students were asked to develop an IQ test, or a creativity test, and to include a definition of what they were measuring. Students were then guided to create a scale; a challenge to measure IQ or creativity (singing ability for example), then the participant's performance was measured against a grading criteria grid to help quantify the data – all designed by the students. Students were then asked to draw conclusions from their findings, along with a comment on the sampling methods they had used to collect the data. These carefully constructed learning experiences enabled them to see scientific research in action; they were part of the research process and were able to incorporate scientific and statistical concepts in practice. It also encouraged them to think critically about the data they had collected, how to draw conclusions and what impact the sampling methods they had chosen could have on the results and their interpretation of them. These latter goals resonate strongly with the aims of the Pilot Scheme in SA, and the constructivist approaches adopted to modify and enhance learner experiences in maximising interaction and exchange of ideas.

The scheme of work (Appendix 4.2) and learning outcomes (Appendix 4.1) also incorporated opportunities for students to develop a range of transferable skills. For example, during a two week period students worked in groups to develop a presentation based on a recent scientific breakthrough. In addition they were

asked to discuss if the breakthrough had made a positive or negative impact on society, along with evidence to support their views. There were also other opportunities for students to develop their reading and writing skills, via a series of comprehension exercises which evaluated the validity of a series of knowledge claims made about using guns in the USA. Providing a range of learning experiences ensured there was a pedagogically balanced delivery. Adopting a variety of pedagogic styles has been shown to develop students' analytic skills, especially in adult learners (Mainemelis *et al.*, 2002). In addition, improvements in student learning have also been reported by several researchers who advocate the use of different learning styles, and a variety of pedagogic approaches to facilitate the needs of learners (Lui, 1994; Boyle *et al.*, 2003; Hey *et al.*, 2016).

The majority of students on the Pilot Scheme also had plans to study at university. Exposing these students to university styles of learning, incorporating methods and contexts used from the Cardiff Q-Step module, helped to give these students an insight into university life. For example, working in groups to deliver presentations utilising different forms of data, typical of a seminar session (Appendix 4.3), exposed the students to a variety of learning experience typically found in HE courses, as well as developing higher level analytical skills.

The aim of the Pilot Scheme in SA is to develop a variety of skills which include: presentation, data visualisation and statistical and mathematical skills. These areas also align with other multiple intelligences proposed by Gardner (1983). These include: Visual-spatial (data visualisation), Verbal-linguistic (presentation skills) and Logical-mathematical (statistical and critical thinking skills) (Gardner, 1983).

Learning styles and Multiple Intelligence theories have received extensive academic scrutiny, with doubt being cast on the overuse of learning style questionnaires, with associated theories being supported by weak empirical evidence (Curry, 1990; Reynolds, 1997; Waterhouse, 2006). Gardner's Multiple Intelligences theories are continuously being adapted as a result of new empirical evidence (Gardner and Hatch, 1989; Gardner and Moran, 2006). His theories focus more on cognitive styles that have been utilised and perhaps misunderstood by proponents (and critiques) of learning styles (Sadler-Smith, 2001; Rayner and Riding, 2010). The cognitive development of learners includes many extraneous variables that can impact on the learning processes. Discussing these issues with the TPS, along with evaluating the successes of carefully constructed learning experiences enabled us as a group to decide what worked well in practice.

#### *Worksheets and games*

During the course delivery (2014/15 and 2015/16), students were tasked with completing a variety of worksheets to help achieve the learning outcomes of the course. In addition, core statistical and scientific concepts were embedded throughout the course to encourage the development of critical thinking skills. Figure 4.1 exemplifies these pedagogical practices, revealing the tasks students were asked to complete, in groups, in relation to the crime and deviance section in unit 1, Social Science in Practice. This worksheet guides students in using a simple geometric progression, based on growth rates for microbiological organisms. This is then supplemented with follow up questions, to encourage deeper learning, requiring students to think critically about the calculations performed in the first part. The final part requires students to choose a suitable statistical technique to

analyse the data presented, the Chi-squared test for example. The development of critical thinking skills lends itself well to discursive group work with this particular worksheet.

## La Cosa Nostra worksheet



You have recently been made the gang boss – and have been tasked with growing the size of your crime family.

You want to predict the number of potential gang members you can train – and are therefore required to use mathematical modelling equations.

$$N_1 = N_0 \times 2^t$$

Where  $t = g/mgtt$

$N_1$  = final gang numbers

$N_0$  = initial gang numbers

$g$  = amount of time given to train (days)

$mgtt$  = mean gang training time (days)



A. Calculate $N_1$ for the following regions, where $g = 108$ days:			
	$N_1$	$N_0$	mgtt
Sicilia		100	9
Veneto		100	11
Puglia		100	22
Lazio		100	18
Piemonte		100	15
Space for calculations –			
B. Answer the following questions related to your answers –			
<ol style="list-style-type: none"> <li>1. Which region resulted in the highest final gang numbers?</li> <li>2. What other factors could influence the amount of time needed to train gang members?</li> <li>3. Do you think it would be fair to pay gang members different rates- depending on the region they are located? Explain your answer.</li> </ol>			
C. The following crime rates were observed in Sicilia:			
Crime	Frequency (actual number)		
Murder	62		
Rape	55		
Theft	108		
Drug trafficking	79		
Arson	21		
Select an appropriate test to investigate whether these rates are expected values.			

**Figure 4. 1 Example of a worksheet delivered on the Pilot Scheme in SA.**

Games were also created throughout the course to help engage students, which linked context and data analysis techniques, encouraging students to interact and exchange ideas (Appendix 4.4) (Wood, 1995). An example of a game used during the course was introduced to the students during the crime and deviance section of the Social Science in Practice unit. The game reinforced a variety of statistical concepts, including: correlation, weighting of data and also other valuable skills linked to quantitative methods – reasoning and problem solving for example

(Appendix 4.4). Educational literature surrounding the use of gaming, especially in a digital context, is extensive. McCartly *et al.*, (2012), conducted a literature review of gaming in education, specifically addressing its uses in a digital format (becoming increasingly more popular than board games (McCartly *et al.*, 2012)). Their results suggest digital games should be created using sound learning principles, provide engagement for the learner, teach 21<sup>st</sup> century digital skills and provide a personalised learning experience (McCartly, 2012). There are however barriers in creating such resources, including; availability of relevant expertise, time, cost implications and the availability of suitable devices to access the games (Egenfeldt-Nielsen, 2004).

Reflecting on these barriers resulted in the games being created as physical copies (Appendix 4.4). Using games that are not digital do run the risk of being perhaps less engaging and not as visually stimulating (McCartly *et al.*, 2012), although successes have been reported by others who have used games that are not digital. For example, Coli *et al.*, (2017), discuss the benefits of creating a challenging and engaging board game that evaluated well with teenagers and young adults. Their development of a microbiology game included careful consideration to several pedagogic principles, as well as ensuring it was fun to play, without the need for digital enhancement (Coli *et al.*, 2017).

The teaching associate also developed and adapted several games for students to complete during sessions, where an example has been included in Appendix 4.5. The zin obelisk game encourages students to work in groups to select useful pieces of information that contain unfamiliar terms and phrases, to complete the puzzle (Appendix 4.5). This game in particular encouraged students' critical thinking



skills.

#### **4.6 Conclusion**

This chapter has discussed traditional views on curriculum design, along with issues that can make these definitions problematic. Curricula construction requires careful consideration to ensure the learning outcomes are appropriate, relevant and measurable. A constructivist approach to learning has been adopted to drive the curriculum development and pedagogical practices associated with the Pilot Scheme in SA (2014/15 and 2015/16). In this chapter, the development and delivery of the course has been described in detail. In addition, the case has been made that this course could better prepare students for the quantitative methods they are likely to encounter at university. While the development of the course formed an important feature of this thesis, the research study focuses primarily on an evaluation of the second year of the programme (2015/16). In particular, since a quasi-experiment was used to evaluate the Pilot Scheme in SA (2015/16), chapter five will draw upon elements of this chapter, exemplifying why certain methods were selected.

After examining the literature in chapters two and three, and creating a distinct course outlined in this chapter, the following research questions were generated to evaluate the courses' impact on year 12 and 13 students:

1. What are the attitudes of year 12 and 13 students to mathematics and statistics, before participating in a contextualised statistics course (Pilot Scheme in SA)?

2. What are the attitudes of year 12 and 13 students to critical thinking, before participating in a contextualised statistics course (Pilot Scheme in SA)?
3. What are the impacts of a contextualised statistics course (Pilot Scheme in SA) on year 12 and 13 student attitudes towards mathematics/statistics and critical thinking?
4. What are the student outcomes of participating in a contextualised statistics course (Pilot Scheme in SA course), in relation to mathematical and statistical abilities, in years 12 and 13?



## Chapter 5 Research Methods

### **5.1 Introduction**

This chapter will begin by providing a description of my own ontological and epistemological position, followed by the research strategy adopted and the data gathering processes that took place at multiple sites. A discussion of insider research will follow, culminating with a detailed overview of the research design and methods. The latter included the use of: questionnaires, interviews, formative test scores, course evaluations and secondary data analysis. Issues relating to the validity and reliability of the methods selected will also be discussed. The chapter concludes with a discussion of ethical considerations.

#### **5.1.1 Ontological and epistemological position**

The philosophical position adopted in this research is that of neo, or modern day logical positivism (Porpora, 2008). The research is concerned with mathematics and statistics attitudes and abilities in year 12 and 13 students, and whether a contextualised statistics course can have an impact on these parameters.

Therefore, with the aim of measuring these changes over time to generate an evidence base and subsequently explain potential causal patterns, the theoretical framework is grounded ontologically and epistemologically on the basis of neo-positivism.

Traditional positivist approaches include three main versions: Comte, Durkheim and Logical Positivism (Williams, 2016, p.160). As stated in chapter two, positivism was heavily criticised on several philosophical levels in the 1960s and 70s (Eisner, 1981; Fonow and Cook, 1991; Lincoln and Denzin, 2003; Tashakkori

and Teddlie, 2003, p.5). Modern day logical positivism is more moderate, in the form of quantitative social science and causal analysis (Porpora, 2008). The key features of positivism in the social sciences include:

- **Observation:** Observational evidence is paramount. This evidence can come in many forms, which can include; actual observations and survey questionnaire data for example.
- **Epistemology:** Positivists emphasise epistemology over ontology. Knowledge must always be grounded in observables, whereas unobservables are not scientific.
- **Theory:** Positivists do not reject theory, however hypotheses must be deduced from theory. In this context, theories should predict and explain particular things. This leads to the hypothetico-deductive (HD) model which includes: theory – hypothesis – observation – new theory, however the process may begin at any point.
- **Causality and probability:** Positivist causality states that when observable event B follows A, it doesn't mean that A caused B. We can however, state that when A occurs, B follows. This leads to probabilistic association of measured variables. For example, we can calculate probabilities for certain events following others. Three or more variables are crucially required to enable accurate probabilistic causal inferences to be made.
- **Laws:** A belief that the main aim of science (and social science) is to produce factual and generalisable statements of the world.
- **Value freedom:** Values and facts are incongruent, whereby the former are deemed to be unscientific, i.e. we cannot deduce facts from values.

(Adapted from Williams, 2016, pp.160-165)

The neo-positivist approach adopted during this study involved the generation of evidence to enable inferences to be made. These were then used to enact inferences to the best explanation. These approaches are also falsifiable, as well as replicable, enabling further research to be conducted to support, refute or perhaps modify any causal inferences made, with reference to any patterns identified.

The next section will explore the validity and reliability of experimental methods, aligned to a positivist paradigm.

## **5.2 Methodology**

This section will introduce the rationale behind the methods selected, including a theoretical and operational critique of experimental methods, in relation to sociologically situated research. Data were collected via the adoption of a quasi-experiment, including students who had self-selected onto the Pilot Scheme in SA (referred to as experimental group 1). Two control groups were used to compare against the experimental group, referred to as control groups 2 and 3. The case will be made that a quasi-experimental approach is a suitable and methodologically robust strategy to explore the research questions (end of chapter four).

The logic of experimental methods is linked to causal reasoning, which has evolved into a test of observations predicted by theory. Experiments aim to build up a picture, and if successful they can help to explain if A was the cause of B for example. For science (and social science research), causal explanations for why these events occurred is essential, within the context of a theory or law (Williams,

2016). In particular, Hempel (1962) describes the deductive nomological (DN) or covering law that states the event or occurrence that needs to be explained (the *explanandum*) involves the *explanans* (a statement or set of statements).

In relation to laboratory experiments, they begin with a hypothesis formed from a theory or law (Williams, 2016). In the context of a laboratory or closed system, this aims to control extraneous variables to enable measurements to be made on the impact of an intervention (independent variable) on an outcome variable of interest (dependent variable) (Clegg, 2005). For example, Le Chantelier's principle is a law that describes the effect of external physical parameters (temperature, pressure and concentration for example) on that of a chemical reaction in equilibrium (or balance). By adjusting one physical parameter (temperature for example) and controlling all known others, the impacts on the chemical reaction can be observed and measured. These experiments can be repeated over and over to achieve similar results, which involve the scientist being able to easily control extraneous variables in the laboratory (pressure and concentration for example) (Slavin, 2008).

Controlling for extraneous variables in the social world is extremely difficult to achieve (and often in the laboratory setting). This has led to the use of the term 'open system' which refers to experiments outside of the laboratory where extraneous variables are at times unaccounted for or perhaps even unknown (Williams, 2016). An alternative approach to the physical controls of the laboratory involves the use of randomisation methods. These methods usually involve the random selection and assignment of participants to an intervention (or experimental) group and a control group, called a randomised control trial (RCT).

These will now be discussed in more detail with specific reference to RCTs used in the social sciences.

Experimental methods in both education and sociology have a long history, particularly in the USA. Donald Campbell's research was essential in establishing the experiment as a legitimate research strategy in the evaluation of social and education programmes in the USA (Cook and Campbell, 1979). An example of their work includes the evaluation of the US Headstart programme (a programme of early childhood education, health and nutrition and parent involvement services offered to low income families), which involved the randomisation of participants into control and experimental groups, over a period of time. Their methods often included advanced modelling techniques, often with small sample sizes. Their results were useful in informing policy, though rarely unequivocal and led to the formation of more complex questions (Cook and Campbell, 1979).

The use of RCTs within education attempts to adopt a natural science approach of experimentation, where potential changes to a dependent variable of interest (educational attainment for example) are measured in relation to an independent variable (an educational intervention for example) (Clegg, 2005). External variables that could impact on the dependent variable of interest are controlled or accounted for; ensuring the ages of participants are the same or similar, selecting students with similar prior educational qualifications and grades for example (Slavin, 2008). These measures are taken to ensure there is robust internal validity, and enable any correlations identified, between the dependent and independent variable, to provide a causal explanation (Maxwell, 2004). From Slavin's example above, by controlling for external variables the educational



intervention could then explain the changes observed in the students' educational attainment (Cartwright, 2007; Slavin, 2008).

Experimental approaches usually include the use of a control (Cartwright, 2007). In the example used above, an experimental and control group would be created, one being exposed to the intervention, the other having no exposure to the intervention (the control group). If increases in educational attainment were observed in the experimental group and not in the control group, this would strengthen the claim that the intervention (independent variable) has had a positive impact on the students' educational attainment (dependent variable) (Clegg, 2005).

Experimental methods, such as RCTs, have been described as a methodological 'gold standard' in behavioural research used to ascertain causality (Malone *et al.*, 2004; Cartwright, 2007; Bonell *et al.*, 2011). RCTs enable the generation of quantifiable data, to support or reject pre-existing hypothesis or theories (Clegg, 2005). However, the validity of using RCTs is brought into contention by several other researchers, questioning the appropriateness of using such techniques for all types of research (Clegg, 2005; Kemm, 2006; Cartwright, 2007). In particular, RCTs can be problematic because they have the propensity to lead to a violation of assumptions. In this context, a violation of assumptions refers to the possibility of interactional effects between independent variables. This then has a knock-on effect, potentially undermining an association or correlation between an independent and dependent variable that has been made.

Other methodological problems linked to the nature of educational research include the adoption of an experimental approach to measure changes in an open system (see above under logic of experimental methods). In this context, an open system relates to the many extraneous variables that can impact upon the dependent variable being measured. In addition, measuring the uptake of an educational intervention on an experimental group can be difficult to ascertain, how do we know for example that the experimental group are receiving the educational intervention at the same rate, developing or changing in the same way (Slavin, 2008)? Is this something we want to measure? Again these issues relate directly to the sociological nature of the research, being an open system, and will be revisited towards the end of this chapter.

Ideally random assignment of participants, versus being placed into experimental and control groups, would enable the incorporation of randomised control trial experimentation (Clegg, 2005; Cartwright, 2007; Slavin, 2008). This would have the added benefit of strengthening the validity of the experimental approach, in terms of identifying causal explanations to changes in student attitudes to and abilities in statistics. If the students were not self-selecting onto the Pilot Scheme in SA course, this would reduce potential experimental bias. For example; the students would be randomly selected potentially having a mixture of pro and anti-statistics attitudes. Therefore any positive changes in attitude are less likely to be due to the students being pro statistics in the first place. Random assignment of participants into experimental and control groups was not possible in this study. This will be examined in more detail below and also in the limitations section of the discussion (7.5).

There are several methodological parameters that can be difficult to achieve, for example randomisation of the control and experimental group participants (Cartwright, 2007). Consequently, quasi-experiments have been used for many years in a variety of settings such as public health (Petticrew *et al.*, 2005) and community safety (Bennet, 1988). Quasi-experiments have a very similar structure and methodological rationale to RCT's, the main difference being that the groups are not randomly allocated. There are many cases where randomisation is difficult if not impossible to achieve, especially in educational research (Gersten *et al.*, 2000). For example; the use of specific types of students where the population size is very small (learners with additional or special needs), or students who self-select onto educational interventions for example (Gersten *et al.*, 2000). In the context of the research conducted in this investigation, an RCT was not used due to students self-selecting onto the Pilot Scheme; therefore randomisation could not be achieved. A quasi-experiment was deemed to be a suitable alternative, in the given time-frame for the research. In addition, external validity could be achieved by repeating the quasi-experiment in the future with different groups of 16-18 year old students (Gersten *et al.*, 2000). Thus, in the case of the current research, the replicable nature of quasi-experiments has the potential to culminate the evidence base, through further experiments, to support or falsify the theory that a contextualised statistics course can have overarching benefits for students over a range of curriculum areas.

Examples where others have used quasi-experiments include an educational intervention in the Cardiff Q-Step centre. Williams *et al.*, published the results of a study exploring student attitudes towards embedded quantitative modules within a substantive sociological degree scheme (Williams *et al.*, 2015). Their results

yielded interesting conclusions, which encompassed a methodological awareness of the limitations of their study. These processes are essential, to ensure robust levels of validity and reliability. Since another research group has adopted the methods proposed by myself, it provides them with an opportunity to conduct further research to indicate whether or not the embedded quantitative modules are effective.

Several potential issues in relation to using quasi-experiments are summarised and linked to this study below:

- Non-randomisation of participants into experimental groups: if the experimental group is self-selecting (as is the case in this study) this can introduce selection bias, which undermines the strength of an association between correlates with the independent and dependent variable (Slavin, 2008). Selection bias can also arise from differential attrition, even with random selection of participants into experimental groups. Attrition (i.e. participation drop out) may be selective or differential. This phenomenon occurs when the characteristics of the group participants who drop out of the group because of attrition differ systematically from the characteristics of group members who are retained in the group. Differential attrition may introduce bias in survey estimates, potentially impacting on the dependent variable data (Slavin, 2008). These potential sources of bias will be reflected upon in the discussion chapter (chapter seven).
- Equal experimental and control groups: for example – age of participants, level of education and educational achievement. In the context of this

research project, this would mean the experimental and control groups should have the same level of statistical ability. The use of pretesting can ascertain this, where several researchers suggest the standard deviation of pretest results should be no higher than 0.5 between groups (Gersten *et al.*, 2000; Maxwell, 2004). These experimental parameters will be gathered and presented later on in this chapter, under section 5.7.

- Achieving a large enough sample size is also essential; to enable potential observed differences between experimental and control groups to be achieved (Cartwright, 2007). Group sample sizes also need to be large enough to account for participation drop out (Gersten *et al.*, 2000). If there was a significant level of dropout from the participants, this could impact on the characteristics of the group, i.e. participants who dropped out of the group could have differed systematically from the characteristics of group members who were retained in the group (Slavin, 2008). And the perceived differences in attitude and ability could just be a product of the students left on the course being perhaps more pro-mathematics and better at statistics. However, recruiting a large enough sample size can be difficult to achieve for a variety of reasons, for example; working with unique populations that are difficult to recruit (special needs students for example) (Gersten *et al.*, 2000).
- Generalisability when using experimental approaches (Maxwell, 2004). For example, the research was carried out on a relatively small group of students, from two educational institutions within Cardiff. Consideration should be given to whether results are generalisable within (internal) or

beyond (external) the setting of a quasi-experiment (Gersten *et al.*, 2000). Within a single experiment, as carried out here, it is important to recognise the potential limitations of results recorded, within the setting of and confines attributed to the experimental approach adopted as the descriptive, interpretative and theoretical validity of conclusions depend on this (Maxwell, 2004). One could argue that controlling for extraneous variables that have the potential to have an impact on the dependant variable is methodologically flawed, and shouldn't be discarded or ignored (Maxwell, 2004; Saba, 2000). These considerations are valid and will be reflected upon in the discussion chapter.

- Moral and ethical implications, i.e. withholding a potentially useful and beneficial treatment or intervention to the control group could result in detrimental outcomes for that group (Slavin, 2008). Coupled with this, the impacts these moral and ethical implications can have on the researchers themselves could have some bearing on the way they interpret results, or the recommendations they make for future research (Slavin, 2008).
- Causal explanations between independent and dependent variables, in an open system, are close to impossible to achieve with certainty. Accounting for extraneous variables and violations of assumptions (interactional effects of independent variables) make causal explanations especially difficult (Slavin, 2008; Clegg, 2005; Williams, 2016). This has led social science researchers to make inferences to the best explanation (IBE). The principle of IBE aims to produce hypotheses or theories that explain observable phenomena, to cohere with accepted scientific knowledge (Mackonis,

2013). The research proposed will aim to use these principles, in generating theories to explain the data generated in line with existing knowledge on the topic (mathematics and statistics education).

The use of a quasi-experiment, which included taking data at different time points (baseline (pre) and end-point (post)) from the same groups of participants, also constitutes a longitudinal design. Longitudinal studies have a long history of being used across a range of research settings, especially in psychological investigations (Zapf *et al.*, 1996; Gibbons *et al.*, 1993; Ellis *et al.*, 2009). Educational research also utilises longitudinal methods across a range of age groups and settings (Vermetten *et al.*, 1999; Carlone *et al.*, 2014). Gibbons *et al.*, (1993) produced an extremely useful paper outlining the uses and misuses of longitudinal research in psychiatric research. Specifically, they make reference to the methodological strengths of comparing experimental and control groups over a period of time, to include end-point analysis (at the end of an intervention for example). They also make reference to the benefits of being able to assess patterns of correlation over time as well as acknowledging the problem of missing data and proposing how to deal with such occurrences. In particular, they suggest using Bayesian models to estimate missing observations (Gibbons *et al.*, 1993). The appropriateness of applying such techniques will be included later on in this chapter (section 5.10) and also in the discussion chapter (section 7.5).

Whilst experimental approaches to research suggest that a researcher should be objective if results are to be considered reliable and valid (Rosenberg, 2012; Bryman, 2001), a number of authors state that no researcher can ever be fully objective (Brannick and Coghlan, 2007; Drake, 2010; Mercer, 2007). These

sources also discuss how insider research can be of benefit while being aware of the issues it raises. Researchers draw on their own social, cultural and historical background and it is important to be mindful of this and work towards minimising bias (Brannick and Coghlan, 2007). Williams argues that objectivity is situated in specific social contexts (Williams, 2005). He argues that researchers should not perceive objectivity as being opposite to subjectivity, but rather as a socially situated practice. In addition, the search for truth, which can often clash with perceptions of reality, should be used as a methodological guiding tool that takes into consideration time and place, communities and people (Williams, 2005).

Being part of the research process raises a number of issues, particularly with respect to internal validity, and the next section examines these issues, including a consideration of how they were dealt with.

### **5.2.1 Insider research**

A variety of research methods are frequently used in conjunction with an experimental approach, such as focus groups and interviews (Stephenson *et al.*, 2003; 2004). The potential use of interviews with fellow colleagues to supplement the quasi-experiments findings requires an examination of the issues surrounding insider research.

Insider researchers may have a shared knowledge of the research environment that can enhance the research, in terms of the identification of the research sample and in analysing the data with the respect to the institutions being studied (Drake, 2010). However, interviewing fellow colleagues can be considered a 'social minefield' (Drake, 2010). This is due to the researcher's status within the



organisation; how they are perceived by colleagues and how this can affect the data gathered. In addition, the insider researcher will potentially continue to work in the institution after the results are published and this requirement to, 'live with the consequences,' may affect how the results are reported and disseminated (Drake, 2010). Insider research may have advantages including easier access to the research setting and participants and that the insider's role within the organisation can allow them to blend in, therefore reducing their effect of altering the research setting (Mercer, 2007). These issues relating to insider research, and my responses to them are described below in Table 5.1.

Issue	Explanation
Subjectivity	<p>Researchers may make assumptions based on an individual's own knowledge and experience and may struggle to make the familiar strange. A review of the methods literature on this topic (Delamont, 2002; Greene, 2014; Van Heugten, 2004), was used to introduce a teaching associate to deliver the second half of the Pilot Scheme in SA. The interview that took place involved asking obvious questions, to enable a search for the truth as opposed to perhaps reaffirming my own opinions and beliefs about the SA course. Within interviews it was important to make my position as researcher clear and ensure that interviewees clarified any 'deferring responses' (Chavez, 2008).</p>
Power	<p>In terms of my role as both a teacher and researcher, it is important to consider how my status as being involved with the Pilot Scheme in SA may affect the research process. It was important to ensure that confidentiality was maintained. In addition, a reciprocal peer interview was conducted in my office. Issues relating to power and investigating the practice of peers is discussed further in sections 5.2.1 and 5.12.</p>
Bias in data collection and also data analysis	<p>As is described by Greene (2014) and Van Heugten (2004), it is important to identify and mitigate bias. Therefore I was careful to avoid discussing my own opinions with colleagues and teachers throughout the research in order not to influence their responses. Since a reciprocal peer interviewing technique was adopted, refraining from discussing my own opinions was difficult at times, although I ensured that the teaching associate mostly steered the interview, since I was more interested in her opinions and observations than in voicing my own. A self-reflection of my own beliefs, and opinions about the Pilot Scheme in SA is an activity that was undertaken at a later date.</p>

**Table 5. 1 Key issues with insider research, and how they were dealt with in this research study.**

Insider researchers are more likely to take things for granted, fail to ask obvious questions, fail to challenge assumptions and may struggle to make the familiar strange (Delamont, 2002; Delamont and Atkinson, 1995; Mercer, 2007). Being aware of these issues enabled me to deal with them as they became apparent. This included questioning the content of the Pilot Scheme in SA, in which I was involved in preparing and delivering, and also interviewing the teaching associate about her views and perspectives on the impacts of the Pilot Scheme in SA course on the participating students. In being conscious of the need to not take things for granted, the teaching associate interview included obvious questions and care was taken to question even the most obvious of answers. This included asking questions about the content and aims of the Pilot Scheme course in SA, where the answers (or perhaps preferred potential answers) were obvious to myself, being involved with creating them in the first place.

### **5.3 Research design**

This section will outline the different research phases of the quasi-experiment and the methods used within these stages. Mostly quantitative methods were used, with the inclusion of a reciprocal interview with the teaching associate who took over the teaching of the experimental group half way through the Pilot Scheme in SA course. The use of a teaching associate partially removed a potential source of experimental bias that will be expanded upon in this chapter, section 5.8.

Quantitative data were collected to identify attitudes to mathematics, attitudes to critical thinking, student performance in a series of formative tests, secondary data on students' predicted and final A/AS Level grades and a series of module evaluations from the experimental group.

Data collection took place over a period of 54 weeks, including a series of critical time-points, outlined in Table 5.2 below:

<b>Approximate date</b>	<b>Description</b>	<b>Relevant Appendix</b>
March - August 2015	<ul style="list-style-type: none"> <li>• Collection of background information, development of project plan and research design, development of research tools</li> <li>• Experimental group 1 (intervention group – taking the Pilot Scheme in SA) and control groups 2 and 3 identified and created</li> <li>• Formative tests created</li> <li>• Questionnaires selected (to explore attitudes to mathematics and attitudes to critical thinking)</li> <li>• Pilot Scheme in SA course evaluations adapted from previous course (2014/15)</li> </ul>	<ul style="list-style-type: none"> <li>• Attitudes to Mathematics Inventory (ATMI) - 5.1</li> <li>• Critical Thinking – 5.2</li> <li>• Pilot Scheme in SA mid-course evaluation – 5.5.1</li> <li>• Pilot Scheme in SA end of course evaluations – 5.5.2</li> </ul>
September 2015 – April 2016	Pilot Scheme in Social Analytics (SA) course delivered (21 weeks)	4.1-4.5
September 2015	<ul style="list-style-type: none"> <li>• Questionnaires given out to experimental and control groups – attitudes to mathematics and attitudes to critical thinking</li> <li>• Formative test 1 given out to experimental and control groups</li> </ul>	<ul style="list-style-type: none"> <li>• ATMI - 5.1</li> <li>• Critical Thinking – 5.2</li> </ul>
October 2016	Analysis of initial questionnaires and formative test 1	
December 2015	Pilot Scheme in SA mid-course evaluation forms given out	Pilot Scheme in SA mid-course evaluation – 5.5.1
January 2016	<ul style="list-style-type: none"> <li>• Teaching associate</li> </ul>	

	<p>takes over teaching the Pilot Scheme in SA course</p> <ul style="list-style-type: none"> <li>• Analysis of mid-course evaluation forms for the Pilot Scheme in SA</li> </ul>	
February 2016	Formative test 2 given out to all experimental and control groups	
March 2016	Analysis of formative test 2	
March 2016	<ul style="list-style-type: none"> <li>• Questionnaires given out to experimental and control groups – attitudes to mathematics and attitudes to critical thinking</li> <li>• Formative test 3 given out to experimental and control groups</li> <li>• Pilot Scheme in SA end of course evaluation forms given out</li> </ul>	<ul style="list-style-type: none"> <li>• ATMI - 5.1</li> <li>• Critical Thinking - 5.2</li> <li>• Pilot Scheme in SA end of course evaluations - 5.5.2</li> </ul>
April 2016	<ul style="list-style-type: none"> <li>• Analysis of final questionnaires and formative test 3</li> <li>• Analysis of end of course evaluation forms for the Pilot Scheme in SA</li> </ul>	
April 2016	Interview with teaching associate conducted	Teaching associate interview - 5.8
May 2016	Analysis of interview with teaching associate	
September 2016	Student A/AS Level predicted grades and actual grades collected from teachers	

**Table 5. 2 Timeline for the quasi-experiment, including important events relevant to the research process and the relevant appendix linked to the data being collected.**

As described in Table 5.2, data were collected using a series of questionnaires, evaluation forms from the Pilot Scheme in SA, results from a series of formative

tests, collection of student A/AS Level predicted grades and actual grades and from an interview with the teaching associative. None of the results were presented to any of the participants of the quasi-experiment. Each of these methods will now be described in more detail in the following sections, as well as an overview of the educational institutes the participants originated from.

### **5.3.1 FE College and Sixth Form Schools' profiles and experimental and control groups**

The two educational establishments selected for the quasi-experiment are located in the city of Cardiff. Senior managers from both institutes gave permission for the FE College and Sixth Form Colleges' names to be mentioned in this thesis. These include Cardiff and the Vale College and St David's Sixth Form College. It was felt the inclusion and description of both institutions names was essential in bringing to life the research conducted, ensuring these institutions received public recognition for their participation and cooperation in the study. An ESRC National Centre for Research Methods report exemplifies this stance, warning against the forced anonymity of communities or institutions within a sociological study (Crow and Wiles, 2008). Crow and Wiles (2008) state that certain groups and communities of participants being studied as part of research project actually prefer to be named, rather than being just another statistic. There is also an acknowledgement of the dangers of not anonymising the institutes, for example if the findings present them in a negative light this could hamper relations for future research collaborations and the participants on the study could be identified and have unwanted details revealed publicly (Morrow and Richards, 1996; Haggerty, 2004). After careful consideration, naming the institutions recognises our partnership working on this project, which may potentially open the door for other

researchers to link with them. Therefore it was felt important to name these institutions in this thesis

Cardiff and Vale College (CAVC) is one of the largest colleges in the Wales, predominately located in Cardiff city. The college has over 20,000 students in each year and a large staff team of industry experts, sector specialists and knowledgeable and experienced support teams. Students can choose from a selection of academic or vocational courses, from entry-level qualifications through to masters' level. For entry onto their A' Level courses, prospective students need to have a minimum of five GCSE's at grade C or higher, including mathematics and English Language (CAVC, 2017). The college has a high student success rate, with 89% achieving their main qualification.

Recent inspections (2015) from Her Majesty's Inspectorate for Education and Training (Estyn) include an award of, "double good," for the quality of their teaching and learning across all courses (CAVC, 2017).

St David's Sixth Form College (St David's) describes itself as the only Catholic sixth form college in Wales, based in Cardiff city (St David's, 2017). St David's has over 1600 A' Level students, with A' Levels being the main course on offer. There is also provision for GCSE resits, and opportunities for other vocational courses such as Access course units (St David's, 2017). For entry onto their A' Level courses, requirements include six GCSEs graded at A\*- C, including mathematics and English Language (St David's, 2017). Certain courses, such as science A' Level's, have additional entry requirements, which include a grade BB at Double Award GCSE Science (higher tier) (St David's, 2017).

St David's describe their student support as being a central pillar of the college, as confirmed in the 2010 ESTYN Report on the college, which praised St David's for the high standards of learning and the achievements of their students (St David's, 2017). St David's has also developed a national reputation for academic excellence, with 30% of students achieved grade 'A\*' or 'A' at A' Level and 432 students progressing to University, in 2016.

Experimental and control groups were created in August 2015, with students at both St David's and CAVC being given the opportunity to apply to take the Pilot Scheme in SA. The initial size of the Pilot Scheme was 44; 24 from St David's and 20 from CAVC. The Pilot Scheme in SA class finished with 29 students, 19 from St David's (number of year 12 students = 11 and number of year 13 students = 8) and 10 from CAVC (number of year 12 students = 5 and number of year 13 students = 5) (Table 5.3). Students in the Pilot Scheme in SA formed experimental group 1.

Control groups 2 and 3 consisted of a combination of students from CAVC (Control group 2, n=20, number of students in year 12 = 11 and number in year 13 = 9) and St David's (Control group 3, n=64, number of students in year 12 = 30 and number in year 13 = 34) (Table 5.3). Students in these groups were fellow classmates of students in experimental group 1. Students from CAVC in experimental group 1 and control group 2 shared the same A' Level psychology class, with classes comprising both year 12 and year 13 students. Students from St David's, in experimental group 1 and control group 3, shared the same A' Level government and politics, sociology or psychology classes, with classes comprising both year 12 and year 13 students. A/AS Level classes in psychology at CAVC (WJEC, 2017) and



government and politics (WJECb, 2017), sociology (WJEC, 2016), and psychology (WJEC, 2017) at St David's are WJEC approved specifications.

Experimental and control groups	Year 12 student numbers	Year 13 student numbers
1 (Pilot Scheme in SA)	16	13
2 (CAVC)	11	9
3 (St David's)	30	34

**Table 5. 3 Numbers of students in year 12 and 13, arranged into experimental and control groups**

### **5.3.2 Data collection time-points**

Data were collected at specific points throughout the 21 weeks of the delivery of the Pilot Scheme in SA (Table 5.2). Data were collected from those individuals present in class using paper-based copies of questionnaires and formative tests. For a variety of methodological and practical reasons, it was decided to take snapshots of the groups' attitudes and performance in formative tests, rather than tracking each individual student. Tracking individual students relies on the participant to be present for each data collection event, as well as ensuring they don't drop out, which can lead to an increased cumulative frequency of missing values (Schilling and Applegate, 2012; Trautwien *et al.*, 2006). In addition, changes in group and not individual attitudes, performances in formative tests, and overall potential changes in students predicted and final A/AS Level grades formed the core elements of the research aims and questions from the outset of this project, derived from existing educational experiments and research literature (Williams *et al.*, 2015; Slavin, 2008; Petty, 2006; Maxwell, 2004; Gersten *et al.*, 2000). The disadvantages of taking this approach relate to the treatment of missing data, which were effectively ignored during this study. Gibbons *et al.*, (1993) state that

mistreatment of missing values, or choosing to ignore them can lead to artificially inflated correlation patterns. These considerations will be examined in the limitations section of the discussion chapter (section 7.5).

Data from each group were collected no later than a week apart, depending on when the A' Level classes were scheduled in the respective experimental and control groups. Strict instructions were given to the teachers giving out formative tests and questionnaires to ensure that they were handed in no later than a week after receiving them. This was to ensure data being collected represented information on those groups at that specific time point, enabling comparisons to be made between groups.

Since students taking part in the Pilot Scheme in SA and control groups could have been present when questionnaires were being given out in the A' Level classes being taken in their respective educational institutes (i.e. control groups 2 and 3), teachers were asked to ensure these students were not given the same questionnaires (i.e. duplication of data) and were asked to come to class 30-45 minutes later.

#### **5.4 Data collection – Questionnaires**

Questionnaires were used to gather attitudinal data from the groups in this investigation. The use of questionnaires has been used widely by a variety of research groups as a legitimate research tool, to explore attitudes of groups of interest (Boynton and Greenhalgh, 2004; Mincemoyer and Perkins, 2005; Trautwein *et al.*, 2006; Croasmun and Ostrom, 2011; Majeed *et al.*, 2013; Yee and Chapman, 2013; Williams *et al.*, 2015).

All questionnaires used in this study involved the inclusion of a Likert scale. Likert scales are commonly used in the social sciences and with attitude scores. They can be a useful and reliable measure of self-efficacy (Croasmun and Ostrom, 2011). The selection and design of questionnaires used, along with issues linked to validity, will be described in more detail below.

Students' attitudes to mathematics and critical thinking were measured before (week 1) and after (week 21) the intervention was delivered, for all experimental and control groups.

#### **5.4.1 Student questionnaires (attitudes to mathematics and critical thinking - pre and post)**

Participants in all groups were asked to complete two different questionnaires (attitudes to mathematics and attitudes to critical thinking), before and after the intervention. These questionnaires were cross-checked by teachers from CAVC and St David's, to ensure they were appropriate for the target groups, with attention being paid to the type of language used and whether students had the potential to answer the questions. These questionnaires have been used on other populations of students of similar age in previous educational research studies (Tapia and Marsh, 2004; Mincemoyer and Perkins, 2005). The Attitudes to Mathematics Inventory (ATMI) questionnaire was used to measure student attitudes to mathematics (Tapia and Marsh, 2004) (Appendix 5.1). This questionnaire was selected for a variety of reasons, including; the completion time was set at a maximum of 20 minutes covering 40 questions, which is ideal with the control groups completing them during their scheduled A' Level classes (teachers involved with the research were conscious that student participation shouldn't be

time consuming in their scheduled lesson) or during the Pilot Scheme in SA session. In addition, the questions were arranged to have a reversed polarity to increase the likelihood that participants thoroughly read the questions and filled them in accurately, as opposed to just checking off the same response every time (Linacre, 2002). And since this questionnaire contained the highest numbers of questions, this strategy of reversed polarity was deemed to be even more important in this case. The questions also aligned closely to the research aims and questions for the project, in particular questions focusing on the usefulness of mathematics, questions 4-7 for example (Appendix 5.1). In addition, the 5-point Likert scale (a-e) enabled participants to produce answers that can include strongly agree, agree, strongly disagree, and disagree or neutral. The use of a neutral category for this questionnaire will be discussed in this chapter under section 5.10 – reliability and validity.

Several other researchers have also confirmed the validity of using the ATMI, reporting a high reliability of the scale with a high Cronbach alpha value = 0.963, and 0.97 for a shorter version of the ATMI (Majeed *et al.*, 2013; Yee and Chapman, 2013). These papers suggest the ATMI has a high internal consistency, which further added to the rationale to use it as an accurate measure of mathematics attitudes amongst older students (16-18 years old).

Numbers of participants who completed this questionnaire are outlined in Table 5.4

Experimental and control groups	Week 1	Week 21
1	25	18
2	20	12
3	64	51

#### **Table 5. 4 Numbers of participants who completed the ATMI**

The critical thinking questionnaire was used to measure students' attitudes to the usefulness of critical thinking in a variety of educational and everyday life contexts (Mincemoyer and Perkins, 2005) (Appendix 5.2). This questionnaire was selected for a variety of reasons, including; the completion time was set at a maximum of 15 minutes covering 20 questions, which was ideal with the control groups completing them during their scheduled A' Level classes or during the Pilot Scheme in SA sessions. Due to the lower number of questions in this questionnaire, it was felt reversing the polarity was unnecessary (Linacre, 2002). The questions aligned closely to the research aims and questions for the project, in particular questions focusing on the usefulness of critical thinking (a key component of the Pilot Scheme in SA), questions 1, 3 and 8 for example (Appendix 5.2). In addition, the 5-point Likert scale enabled participants to produce answers that can include never, rarely, sometimes, often and always. The use of a neutral category for this questionnaire will be discussed in this chapter under section 5.10 – reliability and validity.

A research group has also confirmed the validity of using the critical thinking questionnaire, reporting a relatively high reliability of the scale with a high Cronbach alpha value = 0.72 (Mincemoyer and Perkins, 2005). This report suggests the critical thinking questionnaire has a relatively high internal consistency, which further added to the rationale to use it as an accurate measure of critical thinking amongst older students (16-18 years old).

Numbers of participants who completed this questionnaire are outlined in Table 5.5.

Experimental and control groups	Week 1	Week 21
1	25	18
2	20	13
3	64	51

**Table 5. 5 Numbers of participants who completed the critical thinking questionnaire**

**5.4.2 Data analysis - Questionnaires (attitudes to mathematics and critical thinking - pre and post)**

Questionnaire results were analysed using SPSS to produce descriptive statistics (Miller *et al.*, 2002). The use of inferential statistics was ruled out due to the small sample sizes present in several of the groups (experimental group 1 and control group 2). Using inferential statistics on groups with small sample sizes often leads to inconclusive results, with differences between groups being close to impossible to find (Gersten *et al.*, 2000).

The ATMI questionnaire was used in conjunction with the end of course evaluation forms (Appendices 5.5.1 and 5.5.2). This triangulation of data was used to focus in on, and investigate students' attitudes towards statistics, from the broader area of mathematics attitudes. This will be presented in the results chapter.

## **5.5 Data collection and analysis - Student evaluation forms of the Pilot Scheme in SA (mid and end)**

Participants in experimental group 1 were asked to complete an evaluation form of the Pilot Scheme in SA course, at two points during the courses. The evaluation forms were handed out in December 2015 (mid-course evaluation, Appendix 5.5.1) and March 2016 (end of course evaluation, Appendix 5.5.2) (Table 5.2). For both evaluation forms handed out, 24 were completed. The end of course evaluation forms were given out a week after the formative test 3 and the ATMI and critical thinking questionnaires were given out.

The course evaluation forms were constructed and adapted using a standard course evaluation template used to evaluate FE courses, in a previous FE lecturing position I have held (Appendices 5.5.1 and 5.5.2). In addition, the course evaluation forms had been used in the previous cohort of students on the Pilot Scheme in SA in 2014/15. By trialing this evaluation form out with a previous group, the questions selected generated useful data that was deemed to be a worthwhile endeavor to repeat during this research project. Both evaluation forms posed identical questions, with the March evaluation form posing additional questions to explore student destinations after their A' Level studies. These questions asked whether they were considering applying to university, if yes which one and which courses they were thinking of studying. In addition, they were asked if they were thinking of applying to Cardiff University, and if yes which courses they were thinking of applying for. These questions were included to help explore the possibility of asking the participants follow up questions after the course, i.e. whether the Pilot Scheme in SA had any bearing on their decision to apply to Cardiff University.

Questions present on both evaluation forms were developed to explore students' judgment on whether the course aims were made clear, if the statistics was linked well with relevant examples, and also linked to their other studies. Enjoyment of the statistics elements delivered, and whether the course was enjoyable as a whole were also included in the evaluation forms. Questions present on both forms required students to tick a box on a Likert scale, which included the headings: strongly agree, agree, disagree and strongly disagree. Due to the lower number of questions in this questionnaire, it was felt reversing the polarity was unnecessary (Linacre, 2002).

Course evaluation results were analysed using SPSS to produce descriptive statistics (Miller *et al.*, 2002).

### **5.6 Data collection - Student predicted A/AS Level and final A/AS Level grades**

Access to student predicted and final grades required the input of FE lecturers present in St David's and CAVC. Since the teachers from CAVC and St David's formed such an integral part of the data collection process as well as being members of the TPS, access to student grades was relatively straightforward (chapter four, section 4.2).

Using predicted grades as a baseline to compare against is arguably unreliable, with a variety of many other factors that can influence the final A' Level grade (Kingdon and Cassen, 2010; Strand, 2014). Factors such as gender, ethnicity and socioeconomic class will have a bearing on student A' Level performance (Kingdon and Cassen, 2010; Strand, 2014). In addition, as the project progressed, it became apparent that student predicted grades could vary depending on the individual or



organisation that was looking at them. For example, predicted grades used on UCAS forms were at times inflated to ensure they met the entry requirements of the higher education courses being applied to. For these reasons, it was decided not to use this data as a source of evidence.

### **5.7 Data collection - Student formative tests**

In addition to comparing students' predicted and final grades, participants in all groups were asked to complete several formative tests. These tests assessed statistical ability and data analysis skills, i.e. interpreting tables and graphs.

Content was constructed by carefully ensuring students from all groups would have received the relevant teaching in their A' Level studies (in this case A' Levels in psychology, sociology and government and politics), to ensure that they would be able answer the questions. To counter concerns that experimental group 1 would have received training that is more aligned to the content of the formative tests, practice formative tests were presented to all groups, to ensure that everyone became familiar with the format.

All formative tests used elements of past GCSE statistics examination papers, of which no one from any of the groups had previously sat. This information was ascertained by reviewing the application forms of participants on the Pilot Scheme in SA – experimental group 1 (as part of the application process, applicants were asked to list their GCSE results). GCSE results were also collected from the control groups 2 and 3, to ensure no one had a GCSE in statistics. These checks were essential for questions to be included in the formative tests. Any students with prior experience of completing GCSE statistics papers might have conferred an unfair advantage, and thus weakened the internal validity of this form of data

collection. If students had completed a GCSE in statistics, they would have been allowed to participate on the Pilot Scheme course in SA, although their results would have been omitted from the quasi-experiment data, or if they were included, their results would have been flagged as having completed this qualification.

Questions used for the formative tests came from the examinations board Assessment and Qualifications Alliance (AQA), being the only education board to offer GCSE statistics in the UK (AQA, 2017).

For formative test 1, questions 2, 3 and 4 were used from the June 2012 exam. For formative test 2, question 1 was used from the June 2013 exam, and questions 2 and 3 were used from the June 2014 exam. And for formative test 3, questions 10, 11 and 12 were used from the June 2013 exam. All past examination papers, with the associated mark schemes that were used to mark them, were downloaded and used from the AQA website (AQA, 2017).

The formative tests were created, with a progressive increase in difficulty to measure student statistical abilities. Formative test 1 (maximum total mark = 16) was used to assess statistical and mathematical concepts that covered: percentages, scientific experimental terminology and data interpretation (using percentages). Formative test 2 (maximum total mark = 12) covered: scientific experimental terminology, data interpretation and estimation, levels of measurement and simple rate calculations. Formative test 3 (maximum total mark = 30) covered: standard deviation calculations as well as a discussion on its usefulness with the data presented, data interpretation and simple arithmetic calculations, a description of trends and the impacts of extraneous variables,

percentage decrease calculations, and the normal distribution (with students being asked to use the available data to sketch a distribution of ages).

These topics were selected and covered by all participants in experimental group 1 and control groups 2 and 3, since they represented compulsory areas of the A/AS Level curriculum set out in the psychology, sociology and government and politics classes being taken by participants in the groups (WJEC, 2016; WJEC, 2017; WJECb, 2017). This crosschecking was essential to ensure all participants in the quasi-experiment had the potential to be able to answer the questions in the formative tests. The formative tests increased in difficulty, to correspond to the topics being covered during their A/AS Level classes. As students in all groups progressed in their studies, the level of difficulty should concurrently be increasing. I felt this was an important element of the formative tests, to ensure participants in all groups were being challenged with an increase in academic expectations on their own courses at CAVC and St David's.

Teachers were persuaded to make time in their classes for students to sit the formative tests, by emphasising the relatively short time they took to complete (formative test 1 = 20 minutes, formative test 2, 15 minutes, and formative test 3 – 30 minutes). In addition, since these formative tests were exploring concepts and content that were being explored within their A' Level classes, teachers could see the overlap and were happy to allot time for these tests to being completed in class. Topics included in the formative tests were double checked with the teaching staff from CAVC and St David's, to ensure students had been taught the relevant content, to be able to answer the questions presented to them.

### **5.7.1 Data analysis - Student formative tests**

The use of formative test 1, as a pretest baseline measurement, revealed experimental group 1 and control group 2 had standard deviations that were less than 0.5 apart. However control group 3 had a considerably larger standard deviation compared to experimental group 1, which could indicate a greater spread of statistical ability amongst the participants in control group 3. The implications of this will be included in the results and also discussion and recommendation chapters (seven and eight).

The use of Cohen's *d* (1988), as a measure of effect size between groups, enabled direct comparisons to be made between groups, in terms of their statistical ability derived from the formative tests. To use Cohen's *d*, the data being compared should be normally distributed.

Cohen's *d* was also calculated, using the mean values and standard deviations from the formative test results, to give an indication of the effect size between groups. Effect sizes can also be interpreted in terms of the percent of non-overlap of the intervention group's scores (i.e. experimental group 1) with those of the untreated groups (control groups 2 and 3), (Cohen, 1988, pp.21-23). These results will enable us to directly compare the results from the formative tests between the groups, and measure the magnitude of differences in scores, if any exist.

Student formative test performance was analysed using SPSS to produce descriptive statistics (Miller *et al.*, 2002).

### **5.8 Data collection - Teaching associate interview**

The teaching associate took over teaching the Pilot Scheme in SA group, after the December 2015 Christmas break (see chapter four). Changing teachers half way through the course was deemed to be a useful addition to the research process, and for the students on the Pilot Scheme in SA. Removing myself from front line teaching removed some degree of bias, where resultant data from the quasi-experiment could not be completely attributed to my own teaching style and approach. For example, if experimental group 1 showed a marked improvement in A/AS Level grades and attitudes to mathematics and critical thinking, this could have been due to the pedagogical approaches I adopted as an individual teacher. Introducing another teacher to deliver the course also provided an opportunity to ascertain if there would be any differences as to how the course was practically implemented from the scheme of work.

The partial removal of myself from the quasi-experiment enabled a more objective analysis of the data, which could have changed my interpretation of the results. This could be a result of making the familiar strange, partially removing myself from the research setting (Delamont, 2002; Evans, 2002; Greene, 2014; Van Heugten, 2004). The teaching associate used different teaching styles, examples and contexts compared to those used in the first stage of the experiment (Appendices 4.4 and 4.5). Some could argue that this has changed the parameters of the experimental process (Cartwright, 2007; Slavin, 2008), although it was deemed to be a price worth paying to enable more of an objective analysis of the results to be made. In addition, it also reduces the likelihood that any differences in student attitudes and abilities were primarily down to teaching style and pedagogical practices. The teaching associate used the same curriculum that I

would have followed, which was developed with the Teacher Placement Scheme. There were however differences in pedagogical styles used during the course noted. Several of these issues relating to delivery of the Pilot Scheme in SA course, will be examined in more detail in chapters six and seven.

The teaching associate interview (Appendix 5.8) was added to the techniques used in this research project, to enable a two-way conversation to take place between the interviewee and myself. Specifically, a reciprocal peer interview technique was used, providing a significant opportunity for the interviewee to speak candidly and exercise control over the interview process (Porter *et al.*, 2009). This type of interview also enables the interviewer to participate in the conversation, and be included in the data being collected. It was felt that this format was appropriate under the circumstances, since the teaching associate and myself delivered the Pilot Scheme in SA. The interview lasted approximately an hour, and included questions exploring several themes linked to changes in student attitudes to mathematics and statistics during the second half of the course, student satisfaction with the course, and if it had made any observable difference to their A/AS Level studies (Appendix 5.8). Questions exploring pedagogical approaches adopted were also included, to note any potential differences used in comparison to my own teaching techniques. These questions were constructed to explore the impact of using different pedagogical techniques and approaches, in relation to student attitudes to mathematics (ATMI questionnaire) and also ability in statistics (formative tests). These themes (pedagogical techniques and approaches, student attitudes to mathematics and statistics and also abilities in statistics) could then be used to further explore the research questions for the study. Aronson (1994) supports the use of themes to investigate observable behavioural changes in

participants. Typically used in ethnographic interviews, the qualitative data gathered can be used to support other forms of data, for example the quantitative data generated in this study. These results will be presented in the results chapter.

Teacher's observations were also used to assess potential changes in student behaviours and attitudes during the Pilot Scheme in SA sessions. The observations were framed to investigate the themes identified as part of the reciprocal interview. These were then recorded in note form and stored with the course folder.

Teachers based at CAVC and St David's were not selected to be interviewed, since it was felt that they were too close to the Pilot Scheme development phase (being members of the Teacher Placement Scheme) and the research project. The potential experimental bias from the teacher's involved could lead to unreliable results.

#### **5.8.1 Data analysis - Teaching associate interview**

Qualitative data collected during the teaching associate interview were noted down and analysed using the themes constructed above. These were supplemented with teacher observations and analysed using the same themes.

#### **5.9 Triangulation**

Certain analytical steps, such as triangulation, can be taken to decrease post analysis results bias, potentially leading to increases in the validity and reliability of research findings (Lincoln and Guba, 1985; Bryman, 2001). This isn't always the case though, where epistemological category mistakes can be made (Williams,

2005). Below is an exemplification of how triangulation was used in this investigation.

The methods used during the quasi-experiment generated many different forms of evidence. These accumulations of data were used to explore themes to crosscheck findings, and also to aid in their interpretation. For example, the student attitudes towards mathematics and critical thinking were investigated using the ATMI and critical thinking questionnaires, course evaluations for the Pilot Scheme in SA and observations made and collected during the reciprocal peer interview. Impacts on student attainment and achievement in statistics (and in other subject areas that contain statistics), by participating in a contextualised statistics course, were explored using the formative tests and also by analysing their predicted and actual A/AS Level grades.

### **5.10 Reliability and Validity**

This section will describe the key concepts of reliability and validity in relation to quantitative research methods, moving onto specific references of issues linked to these concepts in this investigation. These will be discussed again (after reflecting on the results) in the limitations section (section 7.5).

Reliability explains the degree to which a research instrument measures a given variable consistently every time it is used under the same condition with the same subjects. Reliability usually refers to data and not necessarily to measurement instruments. From different perspectives or approaches, researchers can evaluate the extent to which their instruments provide reliable data (Yilmaz, 2013).



Validity refers to the accuracy of research data. A researcher's data can be said to be valid if the results of the study measurement process are accurate. That is, a measurement instrument is valid to the degree that it measures what it is supposed to measure. There are different types of validity. *Internal validity* refers to whether there is a causal relationship between the independent and dependant variables. *External validity* reflects the degree to which one can generalise research results or the effects of the independent variable beyond the present conditions of testing; that is, other settings, programmes, persons, places, times, cases, or approaches (Yilmaz, 2013).

Issues linked to validity and reliability relevant to this investigation include:

- The method used to collect data at various time points could potentially lead to small sample sizes, making comparison between groups problematic. In addition, the significance of the findings could be brought into question. Choosing to take data from individuals present during data collection points, discussed in section 5.3.2 of this chapter, could effectively lead to missing data points causing the sample size to drop even further. And how do we know that the data collected is accurately measuring the group's attitudes if there are missing data points? This brings into question the internal validity, i.e. is the method chosen accurately measuring what it is supposed to measure (Yilmaz, 2013)? Gibbons *et al.*, (1993) and Daniels *et al.*, (2011) suggest the use of baseline and end-point data to create Bayesian models to calculate an estimate of the missing observations. However, adopting this strategy could prove to be problematic, due to the

many extraneous variables that would need to be built into the model, as well as accounting for the interactional effects of the variables from the baseline and end-point data (i.e. pre and post intervention data) (Gibbons *et al.*, 1993; Daniels *et al.*, 2011). To elaborate further, the characteristics of the participants in this study included an insufficiency of data, due to the scope and time restraints. To create an accurate model that could predict responses from the questionnaires created and included in this study would potentially require the input of many additional factors that could influence their attitudes and ability to statistics, socioeconomic class and gender for example. In addition, a much larger sample size from multiple populations would be required to enable the input of more data to improve the accuracy of the Bayesian model (Gelman, 2007). However, creating such models can become very complicated and expensive, potentially requiring post stratification of the relevant data i.e. adjusting sampling weights (Gelman, 2007). In addition, violation of assumptions would also have to be explored to ascertain if any interactional effects of the independent variables and extraneous variables have occurred. These would undoubtedly have an impact on any Bayesian models created (Gibbons *et al.*, 1993; Daniels *et al.*, 2011).

- The questionnaires selected for this study – ATMI and critical thinking, included a series of questions measuring attitudes to mathematics and critical thinking. The main aims of the Pilot Scheme in SA are to enhance students’ statistical and critical thinking skills. As already discussed, public perception in relation to the differences between mathematics and statistics suggest they elide them together, imprinting negative mathematical

attitudes onto statistics (Gal and Ginsberg, 1994; National Numeracy, 2017). For these reasons, a questionnaire exploring mathematics attitudes was deemed to be a useful way to investigate if students changed their attitudes to mathematics after engaging with a contextualised statistics course. If a questionnaire was used to measure purely statistical attitudes, there was a concern that certain attitudes might not be captured, or confused with mathematical anxieties. Such difficulties were reported by Jordan *et al.*, (2014) who investigated mathematical and statistical anxieties as separate entities with dyslexic university students. Some elements of their findings suggested that the participants saw little or no difference between mathematics and statistics, resulting in similar levels of recorded anxiety (Jordan *et al.*, 2014). Other studies that have investigated statistics anxieties in university students have also reported similar difficulties (e.g. Musch and Broder, 1999; Vigil-Colet and Condon, 2008). The difficulty in accurately measuring these types of attitudes could have an impact on the internal validity, i.e. are the research instruments measuring what they are supposed to measure.

- The ATMI and critical thinking questionnaires also included neutral category, a strategy encouraged by Linacre (2002). There are disadvantages to using a neutral category, with the propensity for participants to gravitate towards selecting this option (Linacre, 2002). This could result in a dilution of the results, eroding the potential for patterns to emerge. An advantage of including a neutral option, especially in larger questionnaires, does give the participant the choice to sit on the fence

(Linacre, 2002). This is especially useful, if the participants don't particularly agree or disagree with a statement or question (Linacre, 2002).

- Patterns of correlation identified in the experimental and control groups will need to be carefully examined, with sources of experimental biases thoroughly investigated. For example, the Hawthorne effect has the potential to skew the results, in relation to the participants being aware that they are part of an educational experiment. This could lead to modifications in their behaviour potentially impacting on the internal validity of the results, for example completing questionnaires differently, due to having awareness that they are being observed (McCambridge *et al.*, 2014). McCambridge *et al.*, (2014) conducted a review of 19 health science evaluative studies, which include 13 experimental designs, investigating the presence of the Hawthorne effect. Most of the studies reported some evidence of the Hawthorne effect, although there was a consensus that measuring this impact on the results of these evaluative studies was extremely difficult due to the complexity of the evaluation object (McCambridge *et al.*, 2014).

### **5.11 Consent forms and data storage**

This section will discuss the processes involved with gaining consent from the research participants, and how the resultant data was stored.

Students from all groups were invited to participate in the research. I presented an identical explanation of the research process involved, including a discussion based on the rationale behind the quasi-experiment. This was to ensure equal

treatment of all groups was taking place, with experimental manipulations being limited to the independent variable (Pilot Scheme in SA as the educational intervention). Students were then asked to complete a consent form if they were happy to participate in the research (Appendix 5.10.1). All students from all groups agreed to participate in the quasi-experiment, being reminded that they could opt out at any time over the course of the experiment. The ethics committee at the Cardiff School of Social Sciences did not classify the participants as vulnerable, warranting no special ethical measures or procedures.

Teachers from St David's and CAVC involved with handing out questionnaire forms and formative tests were also asked to meet with senior managers from their respective institutes, to ensure we had institutional support for the project (Appendix 5.10.2). Reassurances about what the student data were going to be used for, as well as how they were going to be stored, ensured senior managers from CAVC and St David's were supportive and satisfied that appropriate measures were in place to protect student data.

Participation consent is an essential part of the research process, especially in educational research (Johnson and Christensen, 2008, pp.110-112). It enables the researcher to explain the rationale behind the research, be upfront and describe how the data will be used, as well as the potential research outputs (Johnson and Christensen, 2008, pp.110-112). In addition, student data were anonymised.

## **5.12 Ethics**

Many ethical considerations were reflected upon during the research project. For example, withholding a potentially supportive intervention that could enhance students' attainment in their A' Level studies was an unfavourable outcome. In

addition, if there was a significant improvement in students A' Level results for individuals involved on the Pilot Scheme and not for the control group, this could have had unforeseen moral implications for the researchers involved (Slavin, 2008). Reassurances were given to the ethics committee at Cardiff School of Social Sciences, which included stopping the quasi-experiment if significant differences or potentially harmful outcomes were observed (i.e. students on the Pilot Scheme were beginning to fail in their A' Level studies).

Cartwright's and Slavin's perspectives on quasi-experiments were reflected upon, which state that there are potentially unfavourable moral and ethical implications endemic to this form of experimental research (Cartwright, 2007; Slavin, 2008). Nevertheless the robust evidence that can be generated was deemed to be an equitable trade-off (Cartwright, 2007; Slavin, 2008). In addition, the replicable nature of quasi-experiments means this experiment can be repeated several times – with the aim of increasing the evidence base to support the theory that a contextualised statistics course can have overarching benefits for students over a range of curriculum areas.

In considering the issue of the relationship between the students and the teacher-as-researcher, which is particularly relevant to this piece of research because the teacher can be considered to be in a position of power, it was important that students did not feel pressured into participating in the research (Masson, 2000).

A number of other ethical issues may have arisen due to the dual role of researcher and teacher, including students feeling obliged to take part. There was potential for possible favouritism towards those who co-operated, in my capacity as an

admissions tutor to the Cardiff School of Social Sciences. Students taking part might have presumed that it would have offered an advantage in the admissions process, if they were considering making an application to Cardiff University, for example. These issues were considered and strategies to avoid or deal with these occurrences were identified:

- Participants were informed that they were not obliged to take part and if they agree to take part in the research, the students were reminded that they were able to withdraw with no obligation to continue to take part.
- The introduction of a teaching associate to deliver the second half of the Pilot Scheme in SA course. This could have reduced the likelihood that students were just attending the course to carry favouritism with an admissions tutor (by being able to interact with me as a teacher of the course if I had delivered all of it) if they were to make an application to study a HE course at Cardiff University.
- Throughout the process, the teachers based in CAVC and St David's acted as an extra line of advice to enable the participants from the experimental and control groups to highlight any potential concerns about the research, thereby allowing students to deal with a third party.
- Participants in the quasi-experiment were made aware of the exciting nature of being involved in educational research of this nature, and were also told that it would not confer any positive benefit in terms of applying to Cardiff University.

Ethical approval was granted from the Cardiff School of Social Sciences ethics committee in September 2015. If there were signs that the quasi-experiment was

having a detrimental effect, I explicitly noted in the ethics application that the Pilot Scheme would be quickly re-evaluated and potentially stopped, ensuring the best interests of the students were at the forefront of the projects aims and objectives.

### **5.13 Conclusion**

This chapter has outlined the research methods and methodology of the study. As stated throughout, an experimental approach was undertaken, making use of predominantly quantitative methods including: questionnaires, formative tests, analysis of students predicted and actual A/AS Level grades, course evaluations for the Pilot Scheme in SA and the teaching associate reciprocal interview. This chapter has also considered a range of relevant concepts, including generalisability, reliability and validity. In addition, this chapter also explored the ethical issues arising from conducting educational experiments on year 12 and 13 students. While the research design is further evaluated in chapter seven, the strengths and limitations of the research design with respect to my dual role as teacher and researcher have been considered. Chapter six follows, presenting the results section.





# Chapter 6 Results

## 6.1 Introduction

This chapter will present the results collected, in relation to the methods highlighted in chapter five. The sub-sections presented will directly address the research questions:

1. What are the attitudes of year 12 and 13 students to mathematics and statistics, before participating in a contextualised statistics course (Pilot Scheme in SA)?
2. What are the attitudes of year 12 and 13 students to critical thinking, before participating in a contextualised statistics course (Pilot Scheme in SA)?
3. What are the impacts of a contextualised statistics course (Pilot Scheme in SA) on year 12 and 13 student attitudes towards mathematics/statistics and critical thinking?
4. What are the student outcomes of participating in a contextualised statistics course (Pilot Scheme in SA course), in relation to mathematical and statistical abilities, in years 12 and 13?

It will be shown, that by engaging year 12 and 13 students in a contextualised statistics course (Pilot Scheme in SA), their attitudes and abilities with respect to mathematics, statistics and critical thinking led to a series of measurable changes. The course has potentially contributed to increases in their mathematical and statistical confidence, and also increases in ability. Their views on the importance of the subject both in an academic context, and also in everyday life also became more positive. In comparison, students from both control groups showed mostly

decreases in their mathematical and statistical confidence, and ability. However, their views on the importance of mathematics and statistics, both in an academic context and also in everyday life, became more positive in both control groups.

As a reminder here is an overview of the different time points at which data were collected as part of the quasi-experiment (Table 5.2).

<b>Approximate date</b>	<b>Description</b>	<b>Relevant Appendix</b>
March - August 2015	<ul style="list-style-type: none"> <li>• Collection of background information, development of project plan and research design, development of research tools</li> <li>• Experimental group 1 (intervention group – taking the Pilot Scheme in SA) and control groups 2 and 3 identified and created</li> <li>• Formative tests created</li> <li>• Questionnaires selected (to explore attitudes to mathematics and attitudes to critical thinking)</li> <li>• Pilot Scheme in SA course evaluations adapted from previous course (2014/15)</li> </ul>	<ul style="list-style-type: none"> <li>• ATMI - 5.1</li> <li>• Critical Thinking – 5.2</li> <li>• Pilot Scheme in SA mid-course evaluation – 5.5.1</li> <li>• Pilot Scheme in SA end of course evaluations – 5.5.2</li> </ul>
September 2015 – April 2016	Pilot Scheme in Social Analytics (SA) course delivered (21 weeks)	4.1-4.5
September 2015	<ul style="list-style-type: none"> <li>• Questionnaires given out to experimental and control groups – attitudes to</li> </ul>	<ul style="list-style-type: none"> <li>• ATMI - 5.1</li> <li>• Critical Thinking – 5.2</li> </ul>

	<p>mathematics and attitudes to critical thinking</p> <ul style="list-style-type: none"> <li>• Formative test 1 given out to experimental and control groups</li> </ul>	
October 2016	Analysis of initial questionnaires and formative test 1	
December 2015	Pilot Scheme in SA mid-course evaluation forms given out	Pilot Scheme in SA mid-course evaluation – 5.5.1
January 2016	<ul style="list-style-type: none"> <li>• Teaching associate takes over teaching the Pilot Scheme in SA course</li> <li>• Analysis of mid-course evaluation forms for the Pilot Scheme in SA</li> </ul>	
February 2016	Formative test 2 given out to all experimental and control groups	
March 2016	Analysis of formative test 2	
March 2016	<ul style="list-style-type: none"> <li>• Questionnaires given out to experimental and control groups – attitudes to mathematics and attitudes to critical thinking</li> <li>• Formative test 3 given out to experimental and control groups</li> <li>• Pilot Scheme in SA end of course evaluation forms given out</li> </ul>	<ul style="list-style-type: none"> <li>• ATMI - 5.1</li> <li>• Critical Thinking – 5.2</li> <li>• Pilot Scheme in SA end of course evaluations – 5.5.2</li> </ul>
April 2016	<ul style="list-style-type: none"> <li>• Analysis of final questionnaires and formative test 3</li> <li>• Analysis of end of course evaluation forms for the Pilot Scheme in SA</li> </ul>	
April 2016	Interview with teaching associate conducted	Teaching associate interview - 5.8

May 2016	Analysis of interview with teaching associate	
September 2016	Student A/AS Level predicted grades and actual grades collected from teachers	

**Table 5.2. Timeline for the quasi-experiment, including important events relevant to the research process.**

**6.2 The impacts of a contextualised statistics course (Pilot Scheme in SA) on year 12 and 13 student attitudes towards mathematics/statistics and critical thinking.**

The current attitude of mathematics and statistics, amongst year 12 and 13 students, was a key research theme derived from the research literature in chapter three. The use of the ATMI and critical thinking questionnaires pre and post intervention produced illuminating data, representing differences between the groups. Student course evaluations from experimental group 1 (Pilot Scheme in SA) were also used to collect additional information about the course, including aspects of what the students enjoyed and didn't enjoy. In addition, the teaching associate reciprocal interview provided additional qualitative information.

The raw data is available upon request to the author. This is to ensure the results presented in this chapter are not seen as a favourable story selected by the researcher, with all results being made available to demonstrate transparency and openness.

**6.2.1 Student questionnaires (attitudes to mathematics, statistics and critical thinking - pre and post)**

Results from the ATMI and critical thinking questionnaires revealed slight decreases in responses, due to either student drop out or illness, from all groups. Results presented were selected from questions, in the questionnaires, that addressed the research questions directly.

The number of responses, both pre and post intervention for the ATMI questionnaire are highlighted in Table 6.1:

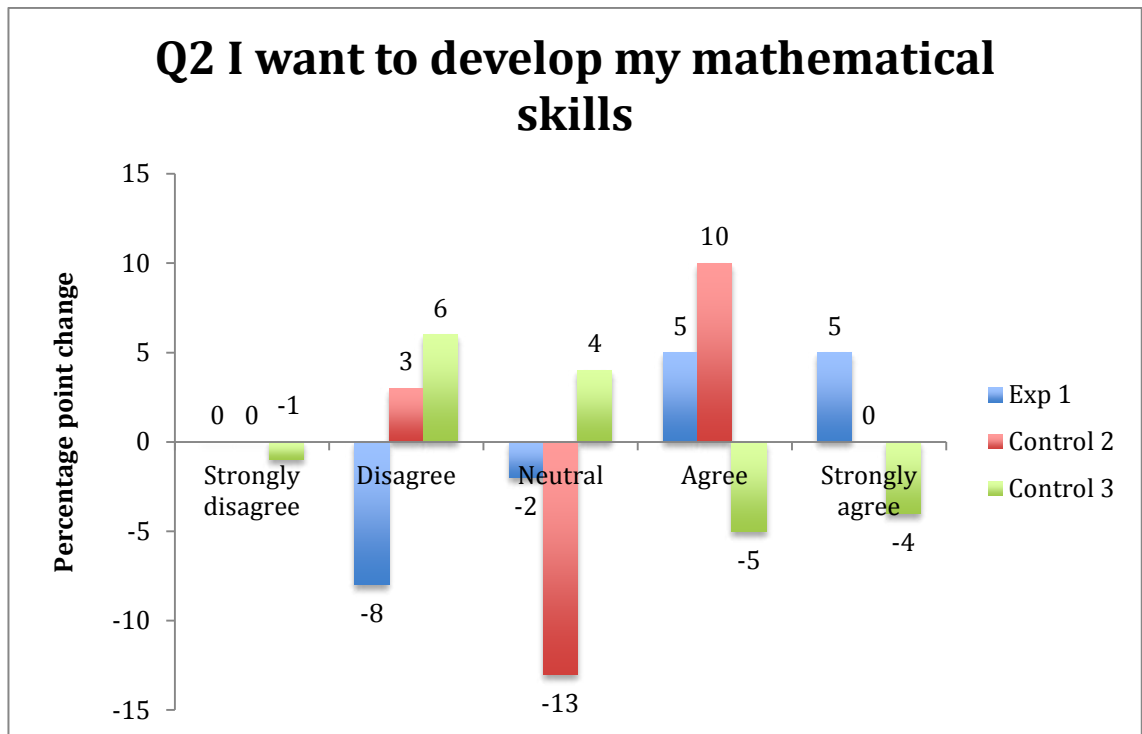
Group	Pre	Post
Experimental group 1 (Pilot)	25	18
Control group 2 (CAVC)	20	12
Control group 3 (St David's)	64	51

**Table 6. 1 Sample sizes for ATMI questionnaire, pre and post intervention**

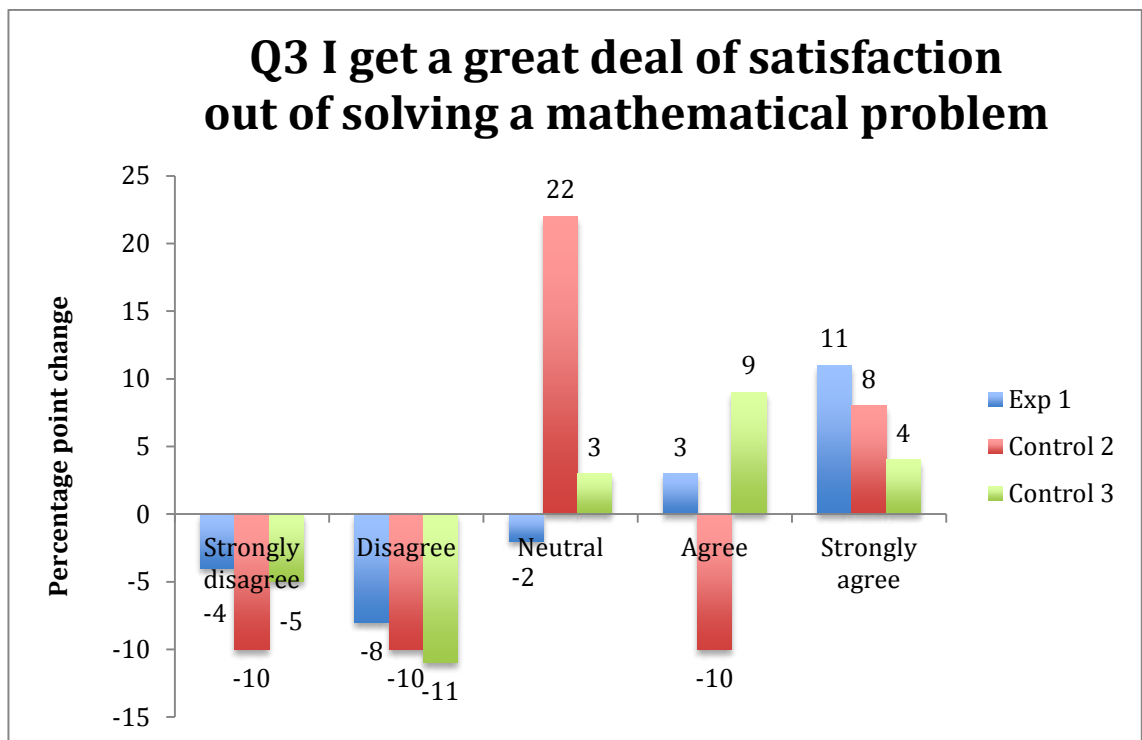
Changes in attitude results for the ATMI and critical thinking questionnaires are presented by each question, displayed by each individual group, in Appendix 6.

The following section will present a series of figures and tables, illustrating the changes in year 12 and 13 student attitudes (for the ATMI questionnaire) from all groups, pre and post intervention. All percentage point changes are expressed to the nearest whole number. The graphs are presented in percentages to enable comparisons to be made, due to the differences in sample size pre and post intervention.

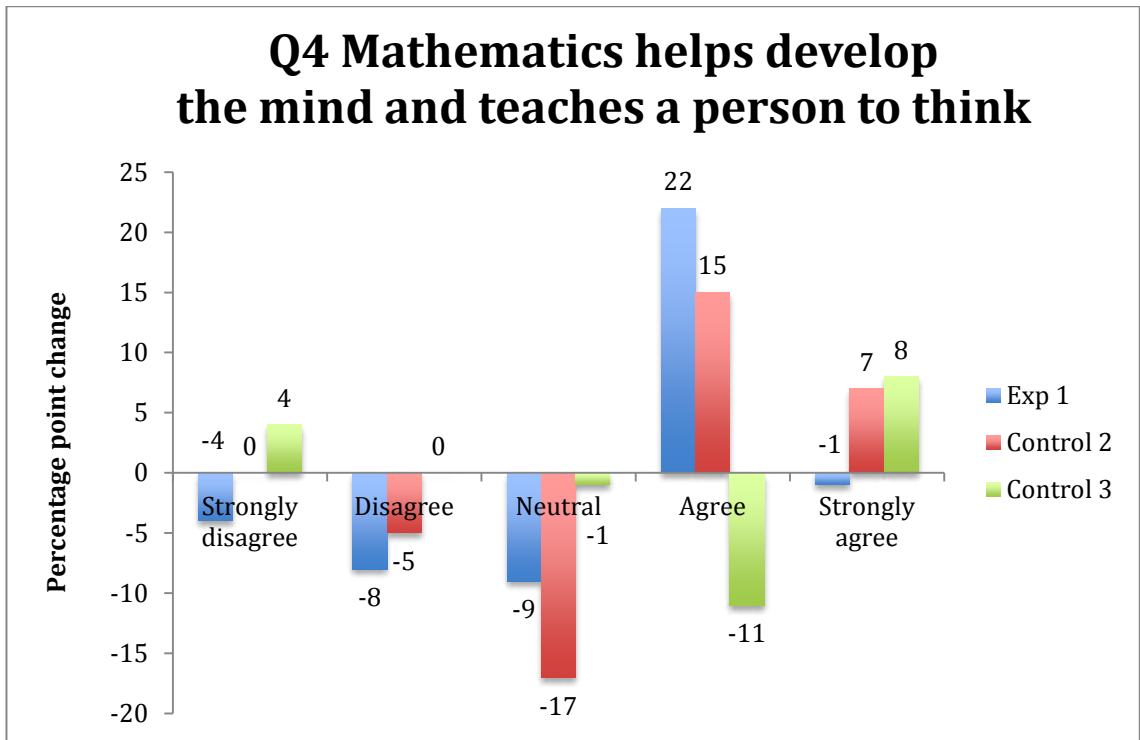
**6.2.2 ATMI results**



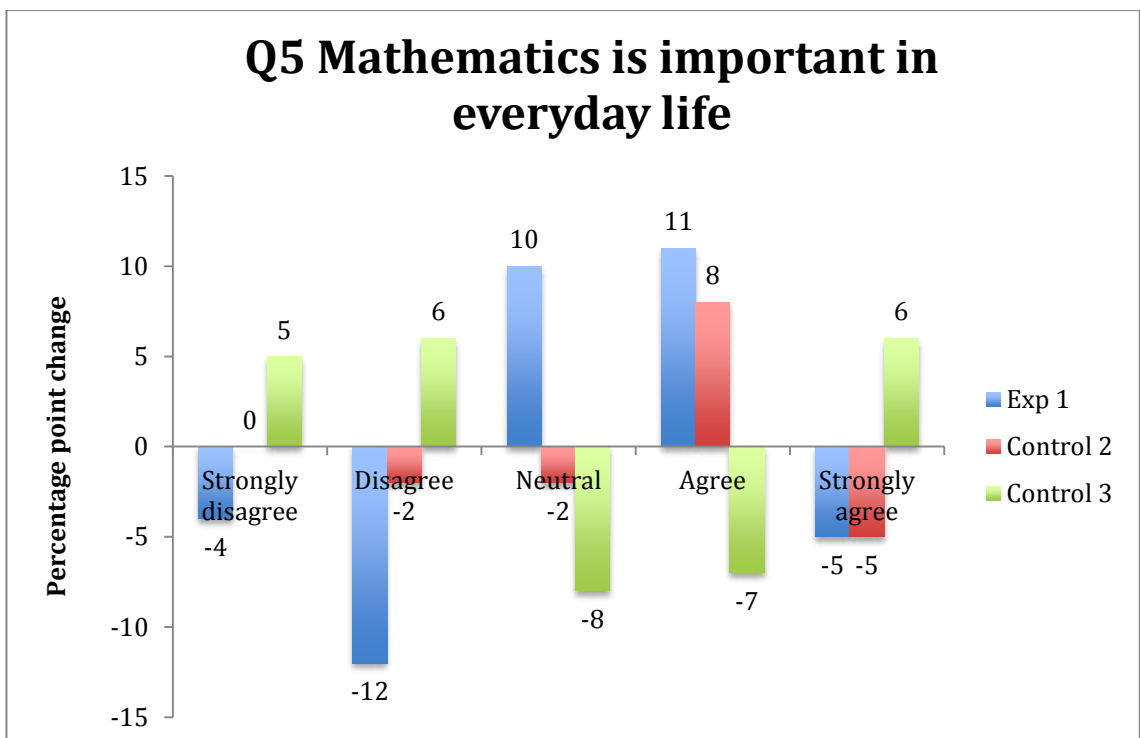
**Figure 6. 1 ATMI questionnaire responses for Q2: I want to develop my mathematical skills.**



**Figure 6. 2 ATMI questionnaire responses for Q3: I get a great deal of satisfaction out of solving a mathematical problem.**

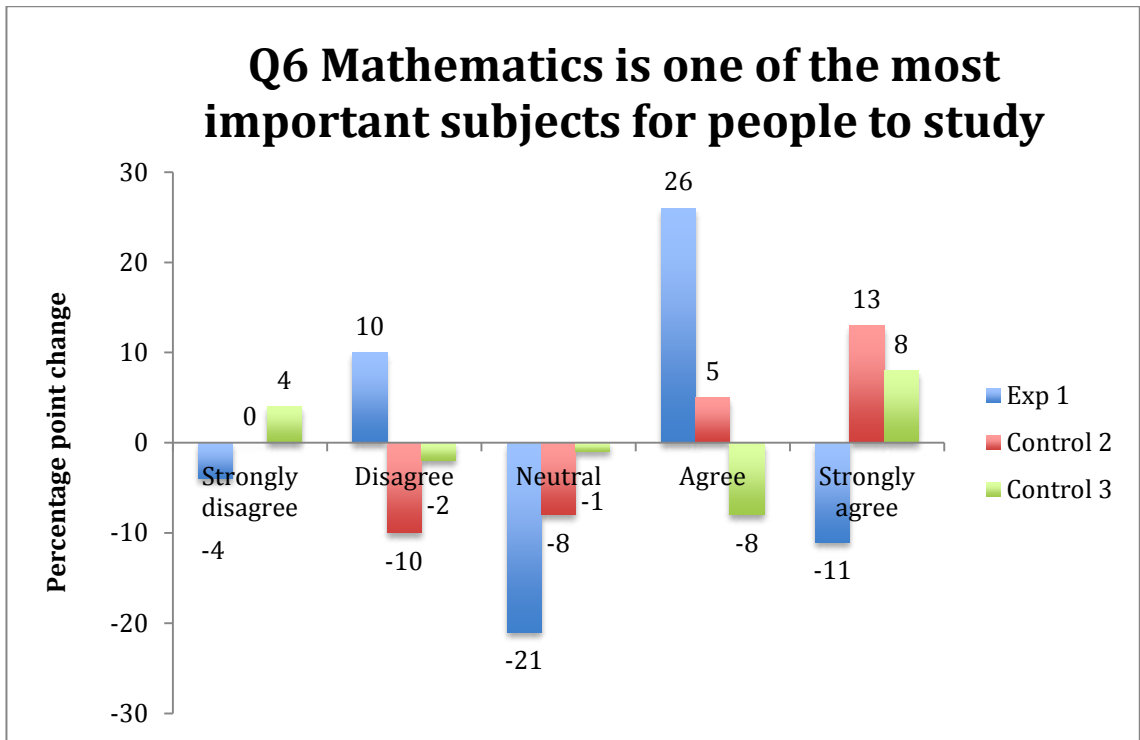


**Figure 6. 3 ATMI questionnaire responses for Q4: Mathematics helps develop the mind and teaches a person to think.**

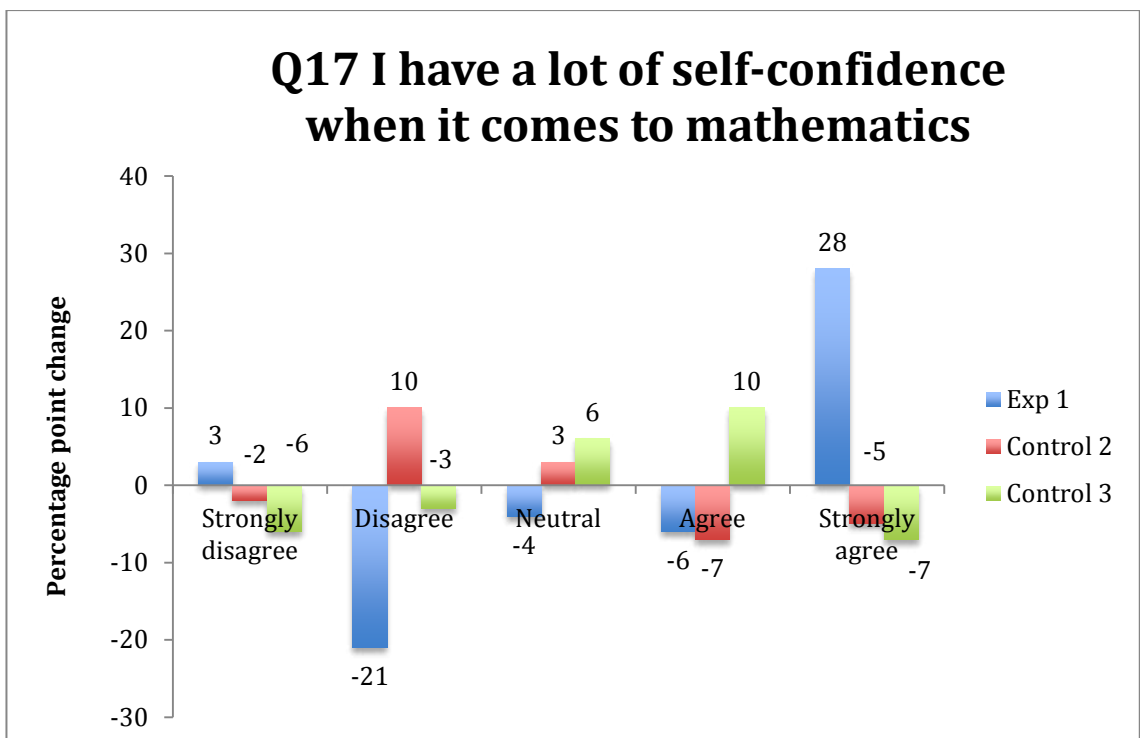


**Figure 6. 4 ATMI questionnaire responses for Q5: Mathematics is important in everyday life.**

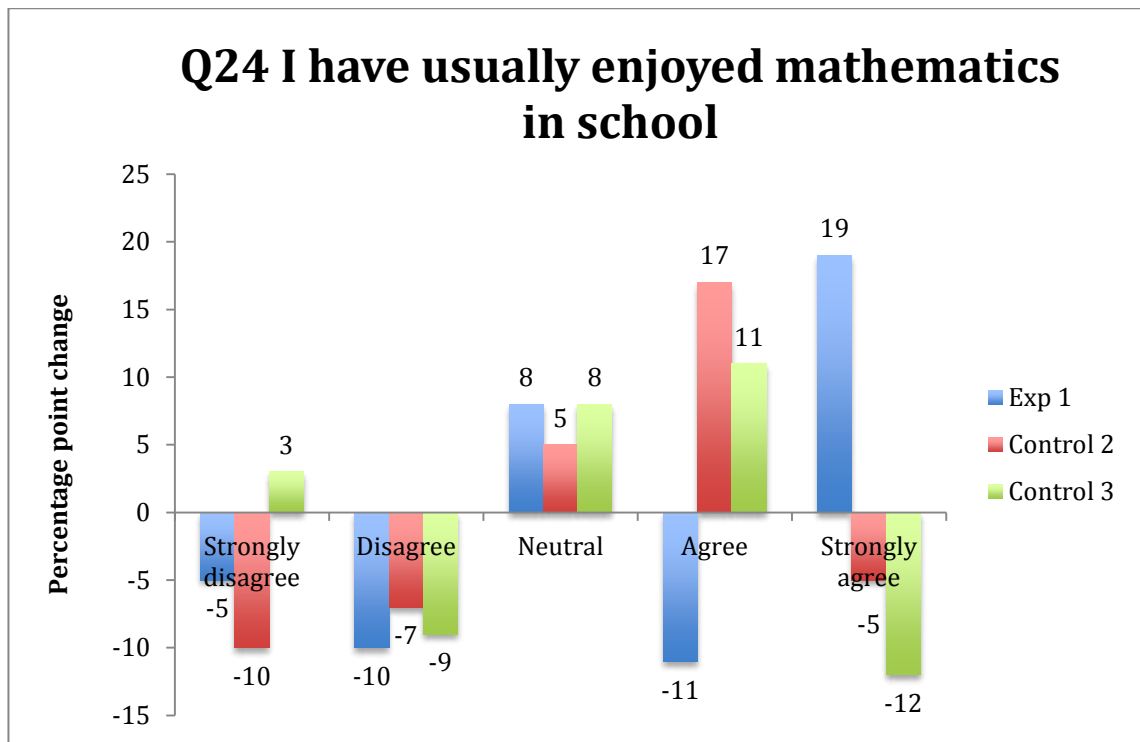




**Figure 6. 5 ATMI questionnaire responses for Q6: Mathematics is one of the most important subjects for people to study.**



**Figure 6. 6 ATMI questionnaire responses for Q17: I have a lot of self-confidence when it comes to mathematics.**



**Figure 6. 7 ATMI questionnaire responses for Q24: I have usually enjoyed mathematics in school.**

Noticeable changes, as a proportional percentage of experimental group 1 responses to the ATMI questionnaire, pre and post intervention include answers to question 2 (I want to develop my mathematical skills) which saw increases of 5% for the agree category, and 5% for the strongly agree category, while for question 3 (I get a great deal of satisfaction out of solving a mathematical problem), an increase of 11% in the strongly agree category, and a slight increase of 3% in the agree category was observed (Figures 6.1-6.2 and Table 6.2). In addition, answers to question 4 (Mathematics helps develop the mind and teaches a person to think) saw an increase of 22% for the agree category, and for question 5 (Mathematics is important in everyday life), an increase of 11% for the agree category was observed (Figures 6.3-6.4 and Table 6.2). For question 6 (Mathematics is one of the most important subjects for people to study), an increase of 26% was observed

for the agree category, and for question 17 (I have a lot of self-confidence when it comes to mathematics) an increase of 28% was observed for the strongly agree category, while for question 24 (I have usually enjoyed mathematics in school) there was an increase of 19% for the strongly agree category (Figures 6.5-6.7 and Table 6.2).

		a	b	c	d	e	
Question number		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N
2a	pre	0	8	8	28	56	25
2b	post	0	0	6	33	61	18
	% change	0	-8	-2	5	5	
3a	pre	4	8	24	36	28	25
3b	post	0	0	22	39	39	18
	% change	-4	-8	-2	3	11	
4a	pre	4	8	20	28	40	25
4b	post	0	0	11	50	39	18
	% change	-4	-8	-9	22	-1	
5a	pre	4	12	12	28	44	25
5b	post	0	0	22	39	39	18
	% change	-4	-12	10	11	-5	
6a	pre	4	12	32	24	28	25
6b	post	0	22	11	50	17	18
	% change	-4	10	-21	26	-11	
17a	pre	8	32	32	28	0	25
17b	post	11	11	28	22	28	18
	% change	3	-21	-4	-6	28	
24a	pre	16	16	20	28	20	25
24b	post	11	6	28	17	39	18
	% change	-5	-10	8	-11	19	

**Table 6. 2 Proportional percentage point change of experimental group 1 participant pre and post responses to questions, from ATMI questionnaire**

Noticeable changes, as a proportional percentage of control group 2 responses to the ATMI questionnaire, pre and post intervention include answers to question 2 (I want to develop my mathematical skills) which saw increases of 10% for the agree category, and no change for the strongly agree category, while for question 3 (I get a great deal of satisfaction out of solving a mathematical problem), an increase of 8% in the strongly agree category was observed (Figures 6.1-6.2 and Table 6.3). In addition, answers to question 4 (Mathematics helps develop the mind and teaches a person to think) saw increases of 15% for the agree category, and 7% for the strongly agree category, and for question 5 (Mathematics is important in everyday life), an increase of 8% for the agree category was observed, (Figures 6.3-6.4 and Table 6.3). Results for question 6 (Mathematics is one of the most important subjects for people to study) revealed increases of 5% for the agree category, and 13% for the strongly agree category, while for question 17 (I have a lot of self-confidence when it comes to mathematics) a decrease of 5% was observed for the strongly agree category and a decrease of 7% for the agree category, and for question 24 (I have usually enjoyed mathematics in school) there was a decrease of 5% for the strongly agree category, while the agree category increased by 17% (Figures 6.5-6.7 and Table 6.3).

		a	b	c	d	e	
Question number		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N
2a	pre	0	5	30	40	25	20
2b	post	0	8	17	50	25	12
	% change	0	3	-13	10	0	
3a	pre	10	10	20	35	25	20
3b	post	0	0	42	25	33	12
	% change	-10	-10	22	-10	8	
4a	pre	0	5	25	35	35	20
4b	post	0	0	8	50	42	12
	% change	0	-5	-17	15	7	
5a	pre	0	10	10	50	30	20
5b	post	0	8	8	58	25	12
	% change	0	-2	-2	8	-5	
6a	pre	0	10	25	45	20	20
6b	post	0	0	17	50	33	12
	% change	0	-10	-8	5	13	
17a	pre	10	15	55	15	5	20
17b	post	8	25	58	8	0	12
	% change	-2	10	3	-7	-5	
24a	pre	10	15	20	25	30	20
24b	post	0	8	25	42	25	12
	% change	-10	-7	5	17	-5	

**Table 6. 3 Proportional percentage point change of control group 2 participant pre and post responses to questions, from ATMI questionnaire**

Noticeable changes, as a proportional percentage of control group 3 responses to the ATMI questionnaire, pre and post intervention include answers to question 2 (I want to develop my mathematical skills) which saw small decreases of 5% for the agree category, and 4% for the strongly agree category, while for question 3 (I get a great deal of satisfaction out of solving a mathematical problem), an increase of 4% in the strongly agree category was observed (Figures 6.1-6.2 and Table 6.4). In addition, answers to question 4 (Mathematics helps develop the mind and teaches a person to think) saw a decrease of 11% for the agree category, and an increase of 8% for the strongly agree category, while for question 5 (Mathematics is important in everyday life), a decrease of 7% for the agree category was observed (Figures 6.3-6.4 and Table 6.4). Results for question 6 (Mathematics is one of the most important subjects for people to study) revealed a decrease of 8% for the agree category, and an increase of 8% for the strongly agree category, while for question 17 (I have a lot of self-confidence when it comes to mathematics) a decrease of 7% was observed for the strongly agree category and an increase of 10 % for the agree category (Figures 6.1-6.7 and Table 6.4). Question 24 (I have usually enjoyed mathematics in school) revealed a decrease of 12% for the strongly agree category, while the agree category increased by 11% (Figures 6.5-6.7 and Table 6.4).

		a	b	c	d	e	
Question number		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N
2a	pre	19	14	25	34	8	64
2b	post	18	20	29	29	4	51
	% change	-1	6	4	-5	-4	
3a	pre	33	25	20	13	9	64
3b	post	27	14	24	22	14	51
	% change	-5	-11	3	9	4	
4a	pre	8	9	27	48	8	64
4b	post	12	10	25	37	16	51
	% change	4	0	-1	-11	8	
5a	pre	11	6	36	41	6	64
5b	post	16	12	27	33	12	51
	% change	5	6	-8	-7	6	
6a	pre	8	14	41	30	8	64
6b	post	12	12	39	22	16	51
	% change	4	-2	-1	-8	8	
17a	pre	39	34	14	2	11	64
17b	post	33	31	20	12	4	51
	% change	-6	-3	6	10	-7	
24a	pre	28	33	16	3	20	64
24b	post	31	24	24	14	8	51
	% change	3	-9	8	11	-12	

**Table 6. 4 Proportional percentage point change of control group 3 participant pre and post responses to questions, from ATMI questionnaire**

### **6.2.3 Critical thinking results**

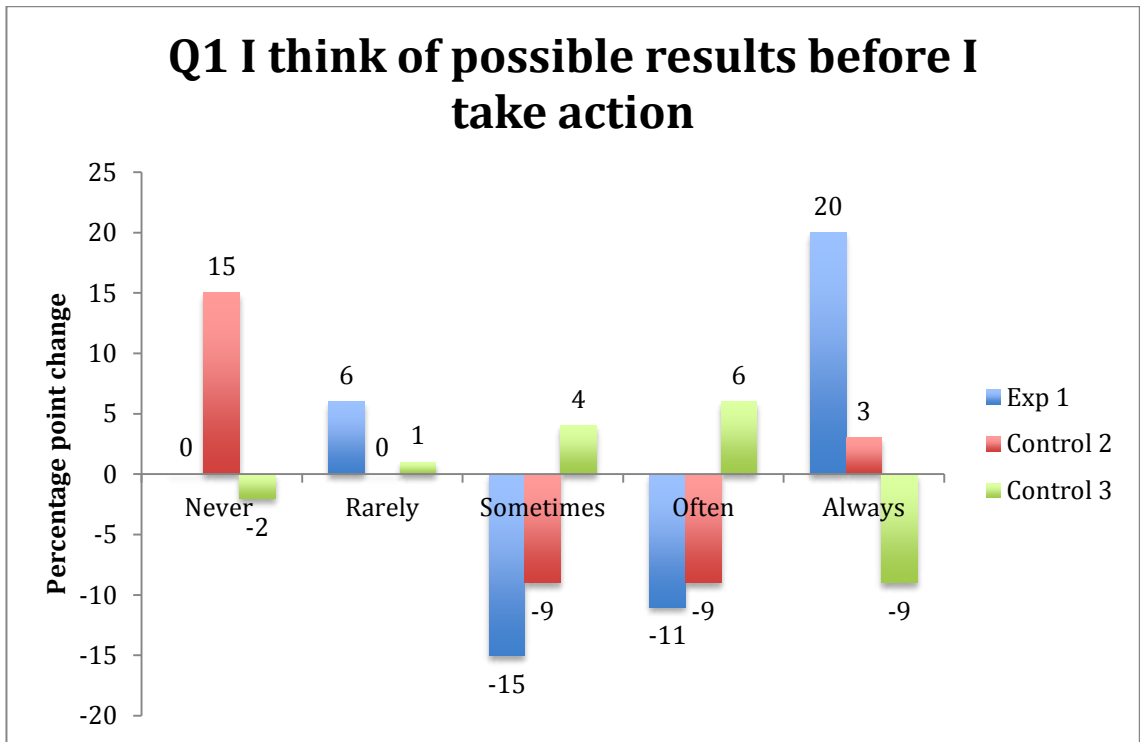
The number of responses, both pre and post intervention for the critical thinking questionnaire are highlighted in Table 6.5:

Group	Pre	Post
Experimental group 1 (Pilot)	25	18
Control group 2 (CAVC)	20	13
Control group 3 (St David's)	64	51

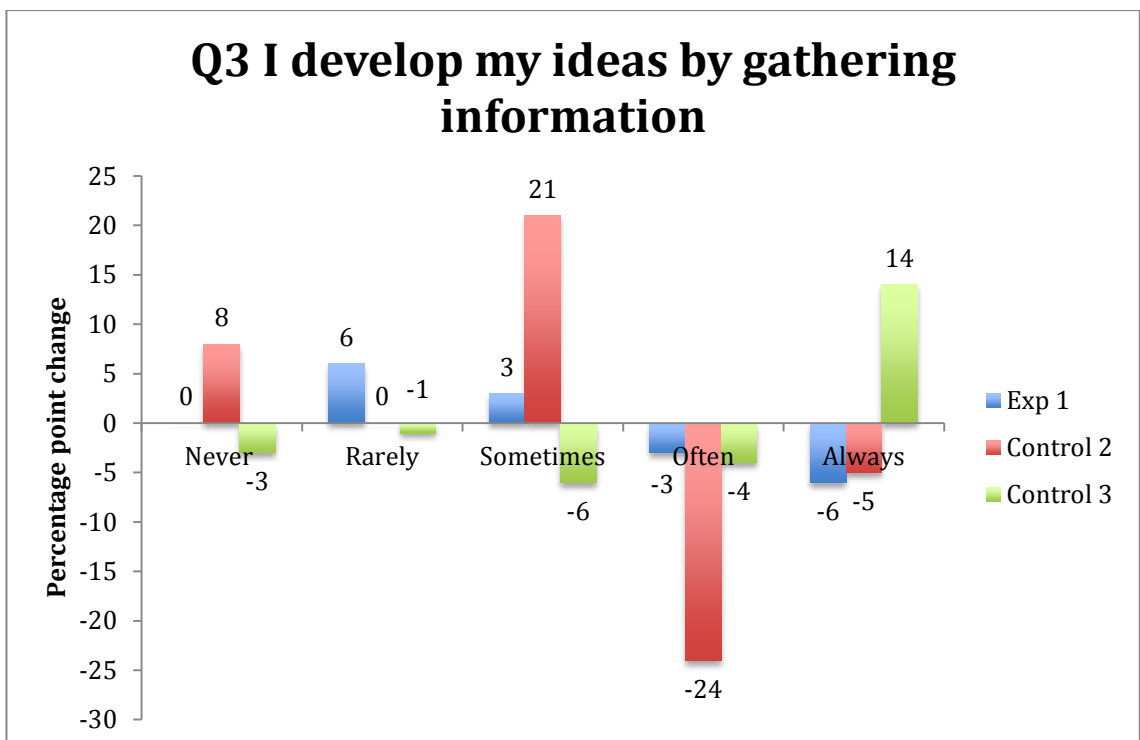
**Table 6. 5 Sample sizes for critical thinking questionnaire, pre and post intervention**

The following section will present a series of figures and tables, illustrating the changes in year 12 and 13 student attitudes (for the critical thinking questionnaire) from all groups, pre and post intervention. All percentage point changes are expressed to the nearest whole number. The graphs are presented in percentages to enable comparisons to be made, due to the differences in sample size pre and post intervention.

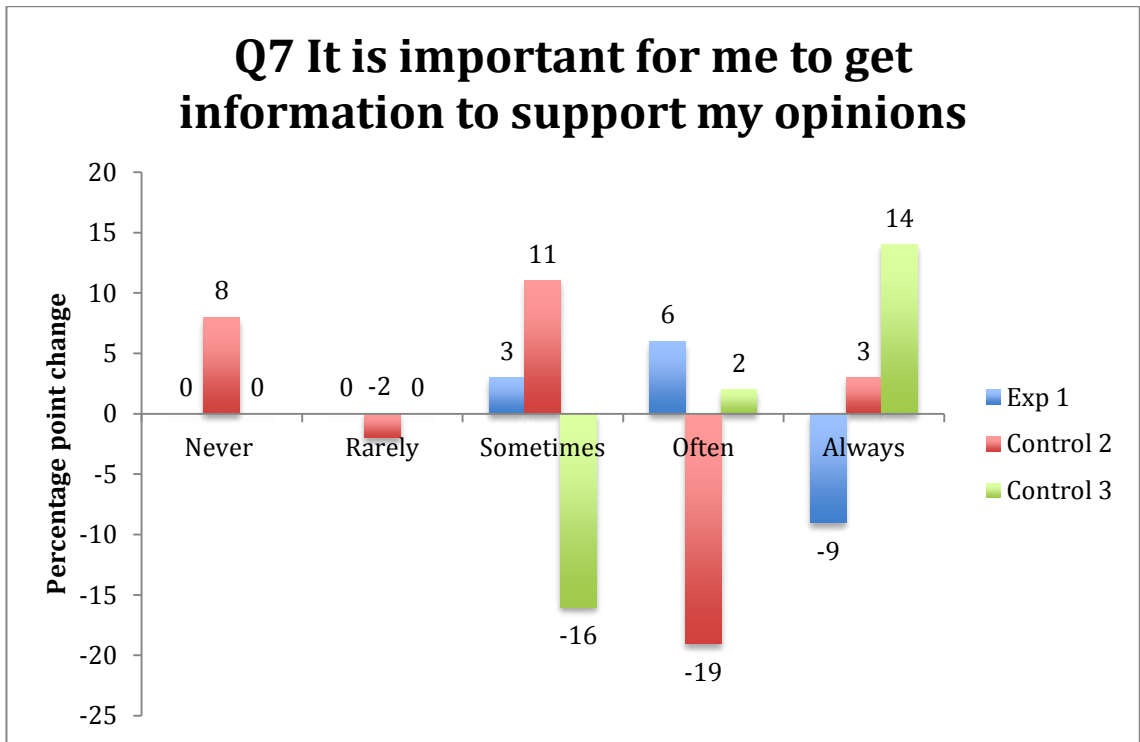




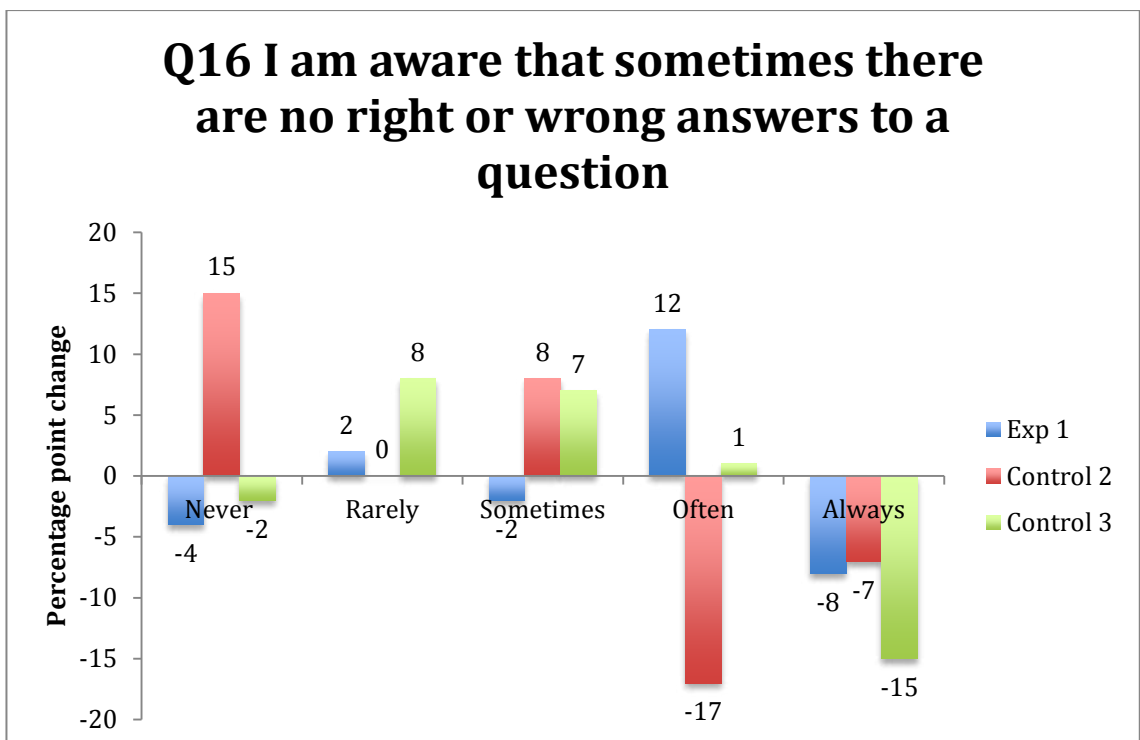
**Figure 6. 8 Critical thinking questionnaire responses for Q1: I think of possible results before I take action.**



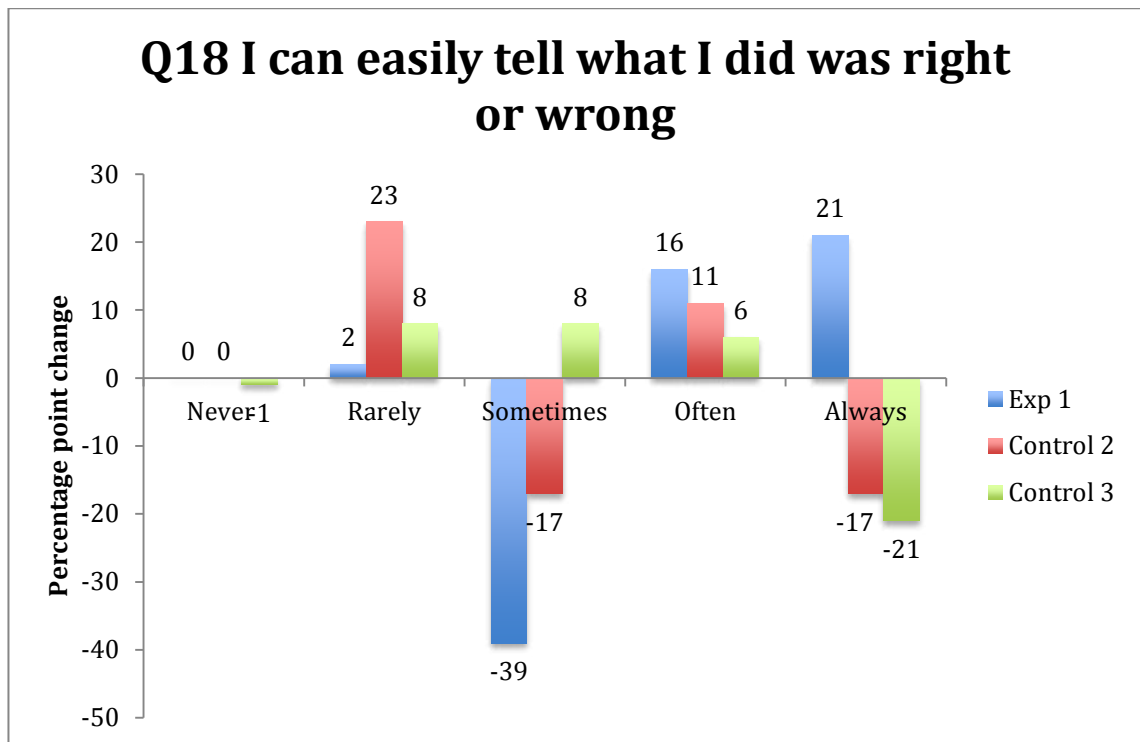
**Figure 6. 9 Critical thinking questionnaire responses for Q3: I develop my ideas by gathering information.**



**Figure 6. 10 Critical thinking questionnaire responses for Q7: It is important for me to get information to support my opinions.**



**Figure 6. 11 Critical thinking questionnaire responses for Q16: I am aware that sometimes there are no right or wrong answers to a question.**



**Figure 6. 12 Critical thinking questionnaire responses for Q18: I can easily tell what I did was right or wrong.**

Noticeable changes, as a proportional percentage of experimental group 1 responses to the critical thinking questionnaire, pre and post intervention include answers to question 1 (I think of possible results before I take action), which saw an increase of 20% in the always category, and a decrease of 11% in the often category, while question 3 (I develop my ideas by gathering information) revealed decreases of 3% for the often category, and 6% for the always category (Figures 6.8-6.9 and Table 6.6). In addition, answers to question 7 (It is important for me to get information to support my opinions) revealed an increase of 6% for the often response, and a decrease of 9% for the always category, while for question 16 (I am aware that sometimes there are no right or wrong answers to a question), an increase of 12% for the often category and a decrease of 8% for the always category was observed (Figures 6.10-6.11 and Table 6.6.). Question 18 responses

(I can easily tell what I did was right or wrong) revealed an increase of 21% for the always category, and an increase of 16% for the often category (Figure 6.12 and Table 6.6).

		1.00	2.00	3.00	4.00	5.00	
Question number		Never	Rarely	Sometimes	Often	Always	N
1a	pre	0	0	32	44	24	25
1b	post	0	6	17	33	44	18
	% change	0	6	-15	-11	20	
3a	pre	0	0	8	64	28	25
3b	post	0	6	11	61	22	18
	% change	0	6	3	-3	-6	
7a	pre	0	0	8	44	48	25
7b	post	0	0	11	50	39	18
	% change	0	0	3	6	-9	
16a	pre	4	4	24	32	36	25
16b	post	0	6	22	44	28	18
	% change	-4	2	-2	12	-8	
18a	pre	0	4	56	28	12	25
18b	post	0	6	17	44	33	18
	% change	0	2	-39	16	21	

**Table 6. 6 Proportional percentage point change of experimental group 1 participant pre and post responses to questions, from critical thinking questionnaire**

Noticeable changes, as a proportional percentage of control group 2 responses to the critical thinking questionnaire, pre and post intervention include answers to question 1 (I think of possible results before I take action), which saw an increase of only 3% in the always category, and a decrease of 9% in the often category, while question 3 (I develop my ideas by gathering information) revealed decreases of 24% for the often category, and 5% for the always category (Figures 6.8-6.9 and Table 6.7). In addition, answers to question 7 (It is important for me to get

information to support my opinions) revealed a decrease of 19% for the often response, and an increase of 3% for the always category, while for question 16 (I am aware that sometimes there are no right or wrong answers to a question), a decrease of 17% for the often category and a decrease of 7% for the always category was observed (Figures 6.10-6.11 and Table 6.7). Question 18 responses (I can easily tell what I did was right or wrong) revealed a decrease of 17% for the always category, and an increase of 11% for the often category (Figure 6.12 and Table 6.7).

		1.00	2.00	3.00	4.00	5.00	
Question number		Never	Rarely	Sometimes	Often	Always	N
1a	pre	0	0	40	40	20	20
1b	post	15	0	31	31	23	13
	% change	15	0	-9	-9	3	
3a	pre	0	0	25	55	20	20
3b	post	8	0	46	31	15	13
	% change	8	0	21	-24	-5	
7a	pre	0	10	20	50	20	20
7b	post	8	8	31	31	23	13
	% change	8	-2	11	-19	3	
16a	pre	0	15	15	40	30	20
16b	post	15	15	23	23	23	13
	% change	15	0	8	-17	-7	
18a	pre	0	0	40	20	40	20
18b	post	0	23	23	31	23	13
	% change	0	23	-17	11	-17	

**Table 6. 7 Proportional percentage point change of control group 2 participant pre and post responses to questions, from critical thinking questionnaire**

Noticeable changes, as a proportional percentage of control group 3 responses to the critical thinking questionnaire, pre and post intervention include answers to question 1 (I think of possible results before I take action), which saw an increase of only 6% in the always category, and a decrease of 9% in the often category, while question 3 (I develop my ideas by gathering information) revealed a decrease of 4% for the often category, and an increase of 14% for the always category (Figures 6.8-6.9 and Table 6.8). In addition, answers to question 7 (It is important for me to get information to support my opinions) revealed an increase of 2% for the often response, and an increase of 14% for the always category, while for question 16 (I am aware that sometimes there are no right or wrong answers to a question), a small increase of 1% for the often category and a decrease of 15% for the always category was observed (Figures 6.10-6.11 and Table 6.8). Question 18 responses (I can easily tell what I did was right or wrong) revealed a decrease of 21% for the always category, and an increase of 6% for the often category (Figure 6.12 and Table 6.8).

		1.00	2.00	3.00	4.00	5.00	
Question number		Never	Rarely	Sometimes	Often	Always	N
1a	pre	2	3	23	47	25	64
1b	post	0	4	27	53	16	51
	% change	-2	1	4	6	-9	
3a	pre	3	13	31	53	0	64
3b	post	0	12	25	49	14	51
	% change	-3	-1	-6	-4	14	
7a	pre	0	6	47	31	16	64
7b	post	0	6	31	33	29	51
	% change	0	0	-16	2	14	
16a	pre	2	9	20	34	34	64
16b	post	0	18	27	35	20	51
	% change	-2	8	7	1	-15	
18a	pre	3	8	33	31	25	64
18b	post	2	16	41	37	4	51
	% change	-1	8	8	6	-21	

**Table 6. 8 Proportional percentage point change of control group 3 participant pre and post responses to questions, from critical thinking questionnaire**

**6.2.4 Summary of student questionnaires (attitudes to mathematics, statistics and critical thinking - pre and post)**

Results presented in this section have revealed differences between groups, in relation to their attitudes to mathematics (ATMI questionnaire) and critical thinking questionnaire.

Participants in experimental group 1 (Pilot group) presented with the largest percentage increases for the strongly agreeing options, from pre to post intervention attitudes, with respect to questions that focused on exploring whether students wanted to develop their mathematical abilities (Q2), the level of satisfaction they derived from solving mathematical problems (Q3) and self-

confidence with mathematics (Q17), from the ATMI questionnaire (Tables 6.2, 6.3 and 6.4). There were also percentage increases for the agree options with respect to the importance of mathematics in everyday life (Q5) and as a subject being one of the most important for people to study (Q6).

In comparison, students in both control groups who didn't receive the treatment, showed negative differences in their attitudes to mathematics. These included decreases in their mathematical confidence. The control groups 2 and 3 mostly saw percentage decreases, from pre to post intervention attitudes, with respect to Q2, Q3 and Q17, from the ATMI questionnaire (Tables 6.3 and 6.4). However, their views on the importance of mathematics, both in an academic context (Q6) and also in everyday life (Q5), revealed an increase in both control groups (Tables 6.3 and 6.4).

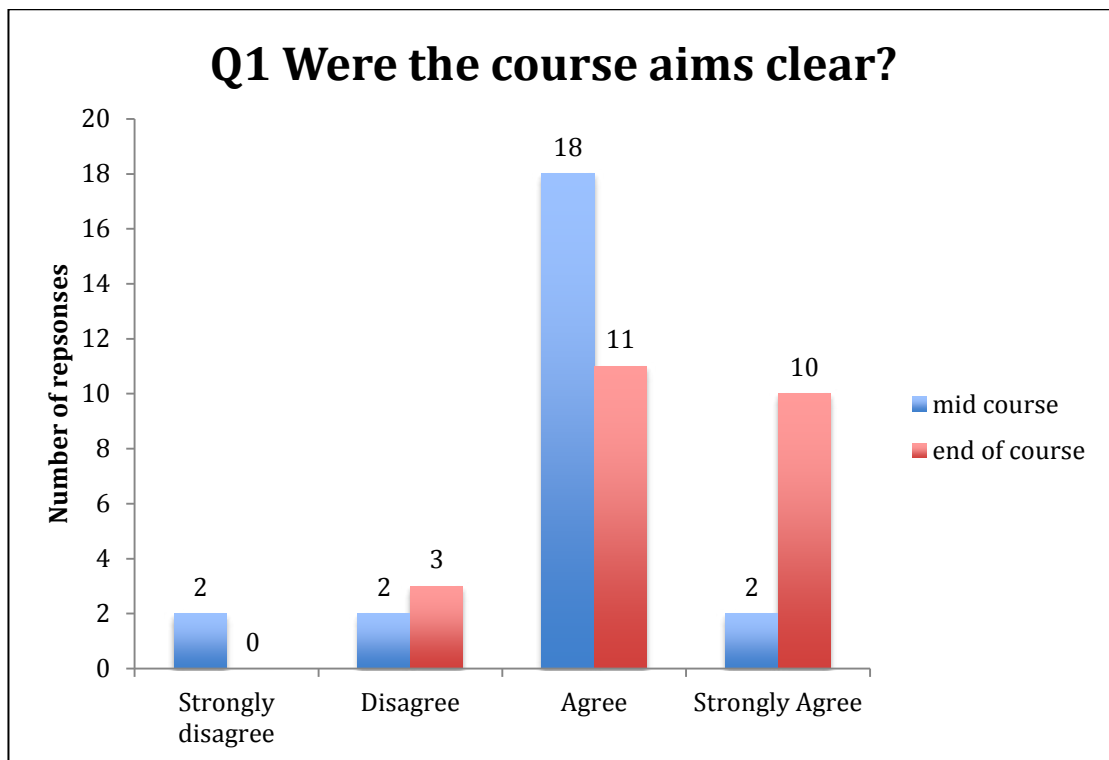
Participants in experimental group 1 (Pilot group) presented with the largest percentage increases for the always options, from pre to post intervention attitudes, with respect to questions exploring the students' ability to think of possible results before they take action (Q1) and whether they can tell what they did was right or wrong (Q18), from the critical thinking questionnaire (Tables 6.6, 6.7 and 6.8).

In comparison, students in both control groups who didn't receive the treatment, showed negative differences with respect to critical thinking. These included, in most cases, decreases for the always option, with respect to Q1 and Q18, from the critical thinking questionnaire (Tables 6.7 and 6.8).



### **6.3 Student evaluation forms of the Pilot Scheme in SA (mid and end)**

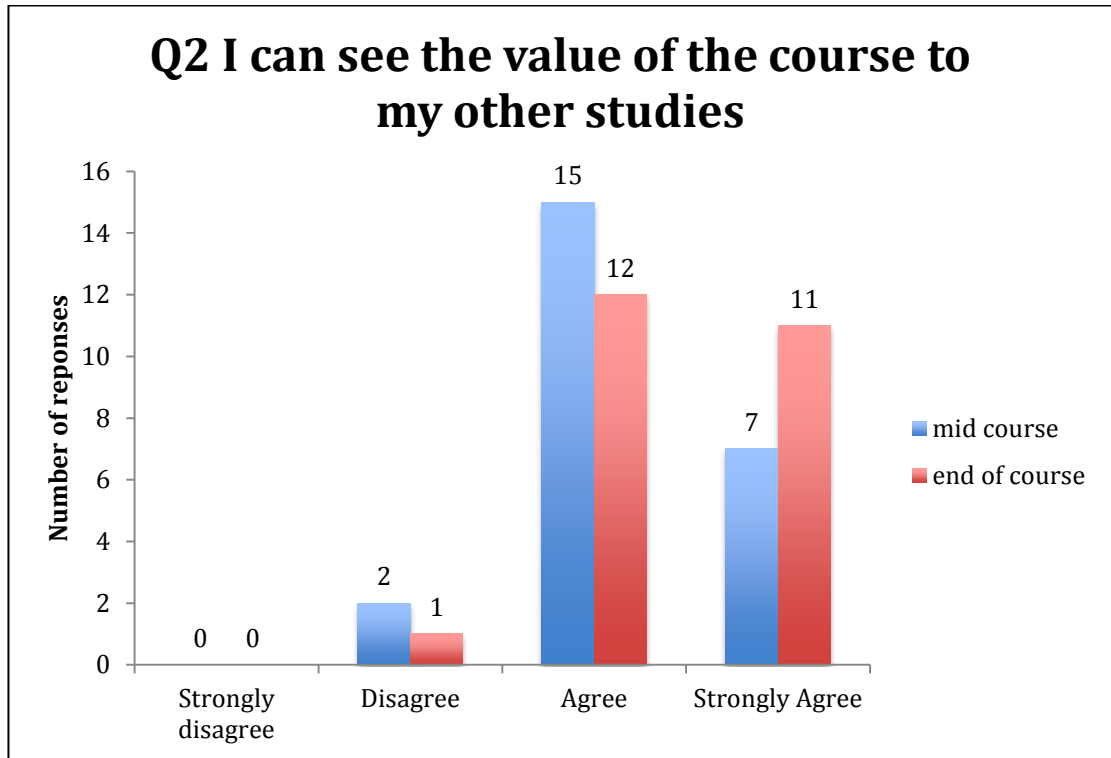
Participants in experimental group 1 were asked to complete a course evaluation in the middle and at the end of the course. The numbers of individuals who completed these evaluations were 24, at both time points of data collection. This section will present a series of figures and a table to reveal changes in student attitude towards the course. The figures will be presented as numbers of responses on the y axis, since the sample sizes both pre and post are the same.



**Figure 6. 13 Course evaluation responses from experimental group 1: Were the course aims clear?**

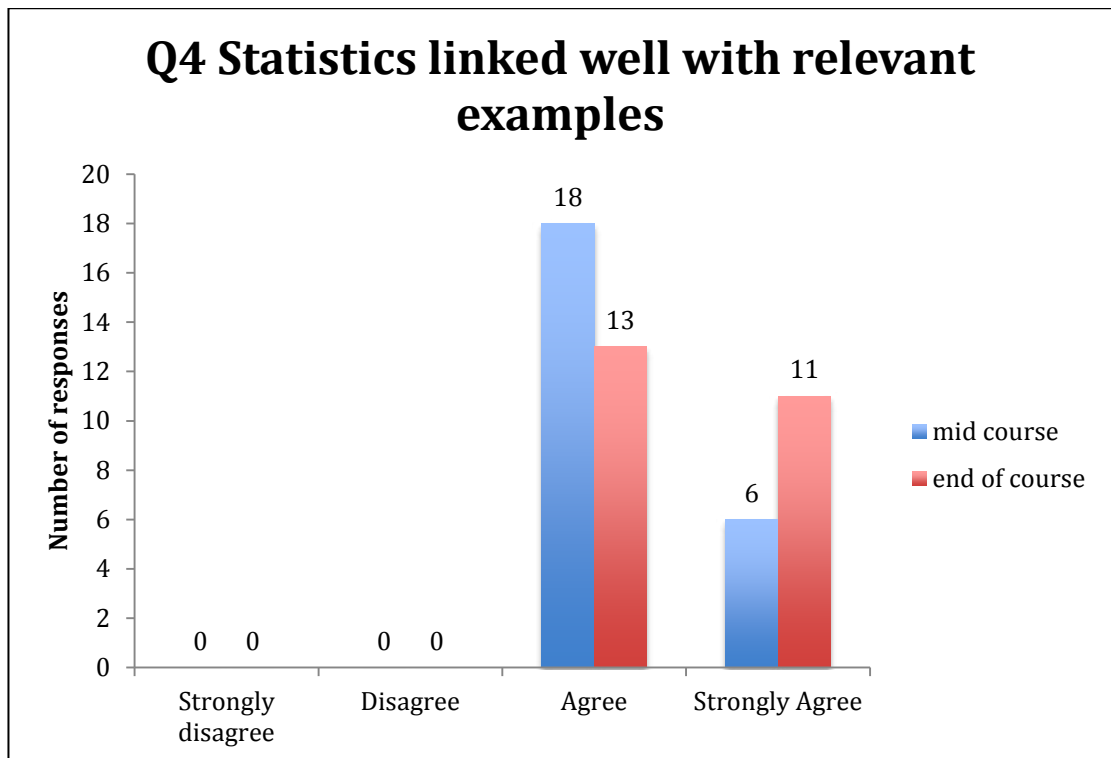
Student responses to Q1, were the course aims clear, from the Pilot group, revealed an increase in the strongly agree option, changing from 2 at the mid-course evaluation, to 10 at the end of course evaluation, whereas the agree option decreased from 18 mid-course, to 11 at the end of course evaluation (Figure 6.13).

Numbers for the strongly disagree and disagree options stayed relatively low, being 2 and 2 mid-course, changing to 0 and 3 at the end of course evaluation (Figure 6.13).



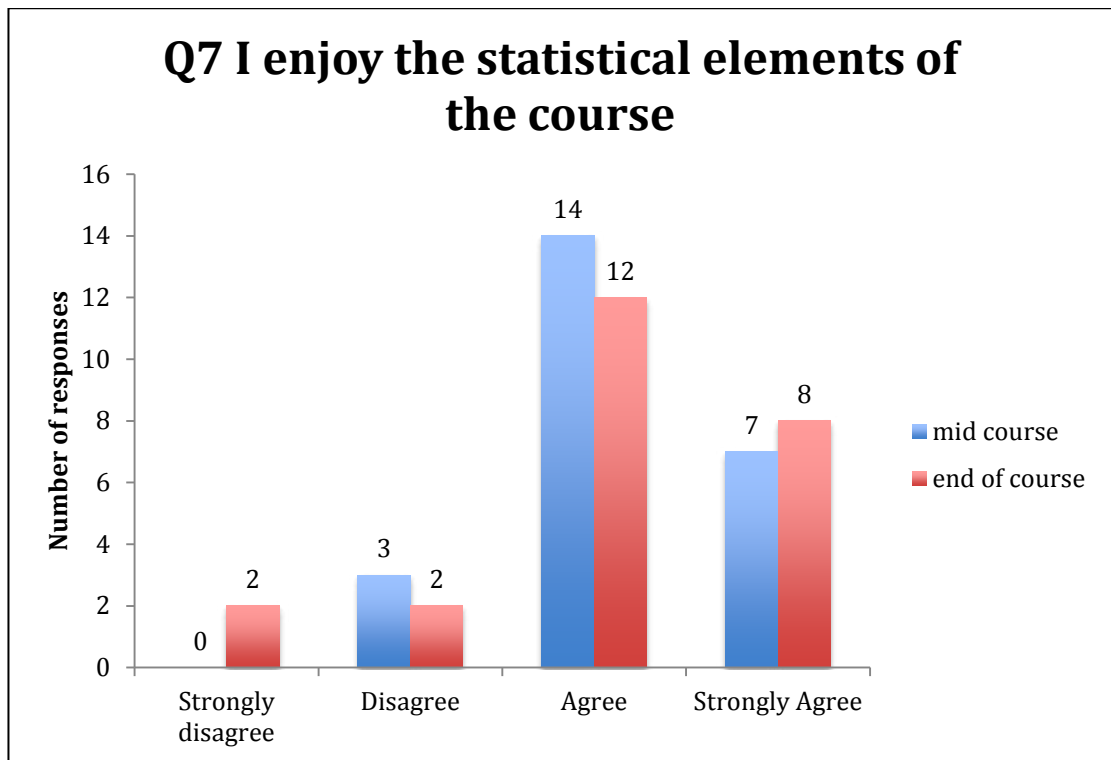
**Figure 6. 14 Course evaluation responses from experimental group 1: I can see the value of the course to my other studies.**

Student responses to Q2, I can see the value of the course to my other studies, from the Pilot group, revealed increases in the strongly agree option, changing from 7 at the mid-course evaluation, to 11 at the end of course evaluation, whereas the agree option decreased from 15 mid-course, to 12 at the end of course evaluation (Figure 6.14). Numbers for the strongly agree and disagree options stayed relatively low, being 0 and 2 mid-course, staying the same at 0 (strongly disagree) and slightly decreasing to 1 (disagree) at the end of course evaluation (Figure 6.14).



**Figure 6. 15 Course evaluation responses from experimental group 1: Statistics linked well with relevant examples.**

Student responses to Q4, the statistics was linked well with relevant examples, from the Pilot group, revealed increases in the strongly agree option, changing from 6 at the mid-course evaluation, to 11 at the end of course evaluation, whereas the agree option decreased from 18 mid-course, to 13 at the end of course evaluation (Figure 6.15). Numbers for the strongly agree and disagree options stayed at 0 for the strongly disagree and disagree options, at both mid-course and end of course evaluation points (Figure 6.15).



**Figure 6. 16 Course evaluation responses from experimental group 1: I enjoy the statistical elements of the course.**

Student responses to Q7, I enjoy the statistical elements of the course, from the Pilot group, revealed small increases in the strongly agree option, changing from 7 at the mid-course evaluation, to 8 at the end of course evaluation, whereas the agree option decreased from 14 mid-course, to 12 at the end of course evaluation (Figure 6.16). Numbers for the strongly agree and disagree options stayed relatively low, being 0 and 3 mid-course, increasing to 2 (strongly disagree) and decreasing to 2 (disagree) at the end of course evaluation (Figure 6.16).

Q1	Strongly disagree	Disagree	Agree	Strongly Agree	N
pre	8	8	75	8	24
post	0	13	46	42	24
% change	-8	4	-29	33	
Q2	Strongly disagree	Disagree	Agree	Strongly Agree	
pre	0	8	63	29	24
post	0	4	50	46	24
% change	0	-4	-13	17	
Q4	Strongly disagree	Disagree	Agree	Strongly Agree	
pre	0	0	75	25	24
post	0	0	54	46	24
% change	0	0	-21	21	
Q7	Strongly disagree	Disagree	Agree	Strongly Agree	
pre	0	13	58	29	24
post	8	8	50	33	24
% change	8	-4	-8	4	

**Table 6. 9 Proportional percentage point change of the Pilot group participant pre and post responses to questions, from the course evaluation**

Noticeable changes, as a proportional percentage of the Pilot groups responses to the mid-course and end of course evaluations, include answers to question 1 (were the course aims clear) which saw a decrease of 29% for the agree category, however the strongly agree category increased by 33%, while for question 2 (I can see the value of the course to my other studies), an increase of 17% in the strongly agree category, and a decrease of 13% in the agree category was observed (Table 6.9). In addition, answers to question 4 (the statistics was linked well with relevant examples) saw a decrease of 21% for the agree category, whereas the strongly agree option increased by 21% (Table 6.9). For question 7 (I enjoy the statistical elements of the course), a decrease of 8 % was observed for the agree category, whereas the strongly agree option increased by 4%, and the strongly disagree option increased by 8% (Table 6.9).

### **6.3.1 Summary of student evaluation forms of the Pilot Scheme in SA (mid and end)**

Participants from experimental group 1 (Pilot group), revealed percentage increases for the strongly agree option, from the mid to the end of course evaluation reports, with respect to the course aims being clear (Q1), seeing the value of the course to their other studies (Q2), the statistics being linked well with good examples (Q4). Responses to the question ascertaining if the participants enjoyed the statistical elements of the course stayed relatively the same (Q7).

### **6.4 Student outcomes of participating in a contextualised statistics course (Pilot Scheme in SA course), in relation to mathematical and statistical abilities, in year 12 and 13.**

The use of the formative tests, pre and post the intervention produced insightful data, representing clear differences between the groups.

#### **6.4.1 Student formative tests**

Formative test results were marked, collated and transformed into percentages, to help create a series of descriptive statistics, for all 3 formative tests. Sample sizes for each formative test are presented in Table 6.10.

	F1	F2	F3
Experimental group 1 (Pilot)	21	16	12
Control group 2 (CAVC)	20		14
Control group 3 (St David's)	61	56	49

**Table 6. 10 Sample sizes for each formative test**

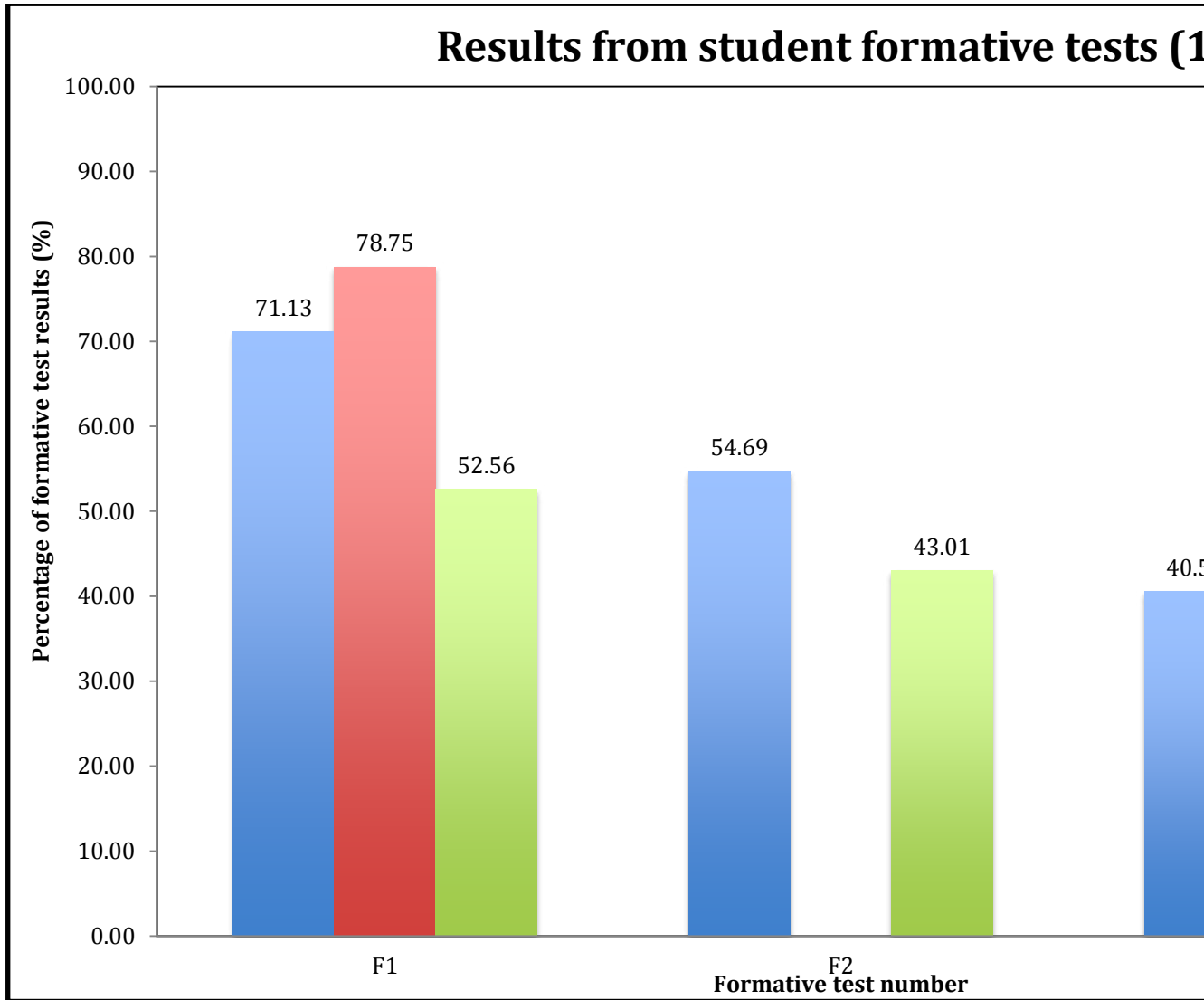
Table 6.11 Presents the experimental and control groups mean scores for each set of formative test results. For F1, experimental group 1 achieved a mean score of 71.13%, while control group 2 scored slightly higher with a mean percentage of 78.75% (Table 6.11). Control group 3 group scored a considerably lower mean percentage, at 52.56% (Table 6.11). For F2, experimental group 1 achieved 54.69%, while control group 3 scored 43.01% (Table 6.11). Control group 2 was unable to sit the F2 test, and therefore have no score for this set of results. For F3, experimental group 1 achieved 40.55%, control group 2 achieved 22.14% and control group 3 finished with a mean percentage mark of 17.01% (Table 6.11).

Descriptive Statistics					
Percentages from Formative Tests	N	Range	Minimum	Maximum	Mean
Experimental group 1 F1	21	56.25	37.50	93.75	71.13
Experimental group 1 F2	16	75.00	25.00	100.00	54.69
Experimental group 1 F3	12	83.34	13.33	96.67	40.55
Control group 2 F1	20	56.25	37.50	93.75	78.75
Control group 2 F2	0				
Control group 2 F3	14	46.67	.00	46.67	22.14
Control group 3 F1	61	93.75	.00	93.75	52.56
Control group 3 F2	56	83.33	.00	83.33	43.01
Control group 3 F3	49	40.00	.00	40.00	17.01

**Table 6. 11 Descriptive statistics from the formative test results (percentages) (2 d.p.).**

The range, maximum and minimum percentage marks across the groups can be observed in Table 6.11. For experimental group 1, there is a wide range of marks, being 56.25%, 75% and 83.34% for the formative test result percentages from F1, F2 and F3 (Table 6.11). For control group 2, the range of marks is moderately high, being 56.25% and 46.67% for the formative test result percentages from F1 and F3 (Table 6.11). For control group 3, the range of marks is high, being 93.75%, 83.33% and 40% for the formative test result percentages from F1, F2 and F3 (Table 6.11). These formative mean score differences are also displayed in Figure 6.17, to draw attention to changes in scores over time, omitting the: range, maximum and minimum values.





**Figure 6. 17\_Results from student formative tests (1, 2, 3), expressed as percentages (2 d. p.). Experimental group 2 (CAVC), Control group 3 (St David's).**

The standard deviation scores for the formative tests: pre, mid and at the end of the intervention, acted as crucial indicators of the data spread from each of the experimental and control groups, in relation to their statistical ability (Gersten *et al.*, 2000; Maxwell, 2004). The calculation of this indicator of data spread involved the use of mean scores from the formative test results, presented in Table 6.12. The use of F1, as a pretest baseline measurement, revealed experimental group 1 and control group 2 had standard deviations that were less than 0.5 apart (Table 6.13). However control group 3 had a considerably larger spread of data (standard deviation = 9.11) compared to experimental group 1 and control group 2 (Table 6.13). For F2, the standard deviations of experimental group 1 and control group 3 were equal, being 3.59 (Table 6.13). For F3, the standard deviations of the experimental group 1 and control group 3 were again equal (3.38), whereas control group 2 was slightly lower, being 2.33 (Table 6.13).

	mean	median	mode
Experimental group 1 F1	11.40	12.00	13.00
Experimental group 1 F2	6.56	6.50	4.00
Experimental group 1 F3	12.20	7.00	7.00
Control group 2 F1	12.60	14.00	14.00
Control group 2 F2			
Control group 2 F3	6.64	7.00	8.00
Control group 3 F1	8.41	9.00	10.00
Control group 3 F2	5.16	4.50	4.00
Control group 3 F3	5.10	5.00	6.00

**Table 6. 12 Mean, median and modal values for the formative test results (2 d.p.). Maximum total marks for each test: F1 = 16, F2 = 12, F3 = 30.**

	F1	F2	F3
Experimental group 1 (Pilot)	2.64	3.59	3.38
Control group 2 (CAVC)	2.68		2.33
Control group 3 (St David's)	9.11	3.59	3.38

**Table 6. 13 Standard deviations for formative test results (2 d.p.).**

The use of Cohen's d, as a measure of effect size between groups, enabled the direct comparison to be made between groups, in terms of their statistical ability derived from the formative tests. To use Cohen's d, the data being compared should be normally distributed. Using Table 6.12, we can see that the mean, median and modal values are similar which suggests normality. Experimental

group 1 F3 does show a higher level of variability however, which could suggest this set of data is not normally distributed (Ghasemi and Zahediasl, 2012). This issue will be revisited in the discussion chapter. Using statistical methods to check for normality would require larger sample sizes, therefore visual inspection of the values presented in Table 6.12 was deemed to be sufficient (Ghasemi and Zahediasl, 2012). Cohen's d values between groups were calculated using the means and standard deviations of each group (UCCS, 2017). The results of the Cohen d value between control group 2 and experimental group 1, from F1, show that control group 2 performed slightly better than experimental group 1, displaying some level of overlap, denoted by the negative score (Table 6.14). However, the Cohen d value between control group 3 and experimental group 1 show a medium effect size, suggesting some overlap in ability (Table 6.14). This difference decreased slightly between control group 3 and experimental group 1 for F2, revealing a Cohen d value of 0.39 (Table 6.14). For the final formative test, F3, the Cohen d value between control group 2 and experimental group 1 increases to 1.92, and also between control group 3 and experimental group 1 increasing to 2.10 (Table 6.14).

	Experimental group 1 (Pilot)	Control group 2 (CAVC)	Control group 3 (St David's)
Experimental group 1 (Pilot) – F1		-0.46	0.45
Experimental group 1 (Pilot) - F2			0.39
Experimental group 1 (Pilot) - F3		1.92	2.10

**Table 6. 14 Cohen's d comparisons between experimental and control groups (2 d.p.).**

Cohen's Standard	Effect Size	Percentile Standing	Percent of Non - overlap
	2.0	97.7	81.1%
	1.9	97.1	79.4%
	1.8	96.4	77.4%
	1.7	95.5	75.4%
	1.6	94.5	73.1%
	1.5	93.3	70.7%
	1.4	91.9	68.1%
	1.3	90	65.3%
	1.2	88	62.2%
	1.1	86	58.9%
	1.0	84	55.4%
	0.9	82	51.6%
LARGE	0.8	79	47.4%
	0.7	76	43.0%
	0.6	73	38.2%
MEDIUM	0.5	69	33.0%
	0.4	66	27.4%
	0.3	62	21.3%
SMALL	0.2	58	14.7%
	0.1	54	7.7%
	0.0	50	0%

**Table 6. 15 Interpretation of Cohen's d**

A more detailed description of the significance of Cohen d values is presented above (Table 6.15).

Cohen (1988, pp.8-14) defined effect sizes as "small,  $d = .02$ ," "medium,  $d = 0.5$ ," and "large,  $d = 0.8$ ", stating that "there is a certain risk inherent in offering conventional operational definitions for those terms for use in power analysis in as diverse a field of inquiry as behavioural science" (Table 6.15).

Effect sizes (ES) can also be thought of as the average percentile standing of the average intervention (or experimental) group relative to the control group. An ES of 0.0 indicates that the mean of the intervention group is at the 50th percentile of the control group. An ES of 0.8 indicates that the mean of the intervention group is at the 79th percentile of the control group. An effect size of 1.7 indicates that the mean of the intervention group is at the 95.5 percentile of the control group UCCS (2017).

Effect sizes can also be interpreted in terms of the percent of non-overlap of the intervention group's scores with those of the control group, see Cohen (1988, pp.21-23). An ES of 0.0 indicates that the distribution of scores for the intervention group overlaps completely with the distribution of scores for the control group, there is 0% of non-overlap. An ES of 0.8 indicates a non-overlap of 47.4% in the two group's scores. An ES of 1.7 indicates a non-overlap of 75.4% in the two group's scores.

#### **6.4.2 Summary of student formative tests**

The formative test results revealed a plethora of data, as a result of several different analyses. An examination of the standard deviations from experimental group 1 (Pilot group) and control group 2 (CAVC) show values that are close to each other, suggesting the data spread within these groups are similar (Table 6.13). In addition, the Cohen d values between these groups suggest control group 2 start off with a slightly higher statistical ability. By the third formative test, experimental group 1 performed better than control group 2 (Table 6.14). The mean percentage marks across the formative tests, between experimental group 1 and control group 2 reveal similar marks for F1, and then a much larger difference

in F3, with experimental group 1 scoring 18.42% higher than control group 2 (Figure 6.17).

Control group 3 (St David's) revealed a much higher standard deviation in F1, which suggest a greater spread of statistical ability, in comparison with the other groups (Table 6.13). The effect size differences between experimental group 1 and control group 3 begin as medium for F1, and then end up being a considerable large effect size difference by F3 (Table 6.14). The mean percentage marks across the formative tests, between experimental group 1 and the control group 3 reveal large differences across all the formative tests, with control group 3 consistently scoring lower marks than experimental group 1 (Figure 6.17).

### **6.5 Teaching associate reciprocal interview**

Teacher observations of the Pilot Scheme in SA were considered to be a key source of data in relation to the research questions. The reciprocal interview with the teaching associate produced interesting data, which support several results collated from the ATMI and critical thinking questionnaires, as well as the end of the Pilot Scheme SA course evaluation. This section will present the results from the reciprocal interview, exploring several themes identified in the methods section (pedagogical techniques and approaches, student attitudes to mathematics and statistics and also abilities in statistics) related to the questions that were asked during the hour-long conversation. Teacher observations will also be incorporated where appropriate.

### Describe the Pilot Scheme course. What were the aims?

The teaching associate (TA) described the Pilot Scheme in SA as a context rich statistics course, with a focus on critical thinking and mathematical skills. The TA outlined her aims for the course, indicating that she tailored the course towards the specific needs of the class, in relation to the A' Level subjects they were studying. The TA also changed some of the resources, compared to the previous years' resources, when I taught the second part of the course. Modifications to the resources and handouts were in response to the student voice, i.e. areas they felt they needed more help with. Where possible, worksheets were modified to help support students existing A' Level and Welsh Baccalaureate studies.

In comparison, I followed the scheme of work more closely (Appendix 4.2), and focused resource and handout content on statistical concepts as opposed to the TA's strategy of focusing on developing students' mathematical skills to support the statistical elements and critical thinking. For example compare the games created in Appendix 4.4 (created by myself) and 4.5 (created and adapted by the TA).

### Teaching strategies used – what worked? What didn't work?

The TA started the second half of the course by giving the course participants few handouts and some guidance. This strategy proved to be ineffective, which led to her increasing the number of handouts given and the amount of guidance provided to complete in class tasks. Students' quotes at the beginning of her teaching period include:



“Why am I here?”

“How are these sessions useful?”

“The maths is hard”

These comments enabled the teaching associate to adapt her teaching to make the relevance of the course more explicit and also directly link topics and skills being developed in the sessions to their A' Level studies. These comments also led her to change her expectations of the class, realising that the class needed more instructions than she first realised. The TA also noted kinaesthetic tasks were received well by the class, leading to very good class participation.

The teaching associate, having a background in philosophy, also made the following comments on her own mathematical ability:

“I like a challenge and enjoy mathematics, which edged me on to learn more about statistics.”

These comments suggest the teaching associate perceived statistics as being underpinned by mathematics, which encouraged her to learn more about statistics. These considerations could explain the differences in pedagogical approaches adopted between the teaching associate and myself.

In comparison, I provided the Pilot Scheme in SA class with regular handouts from the start of the course, and continued to do so up to the point where the TA took over in January 2016. I also found the class responded well to hands on tasks. I

have no recollection of students questioning the usefulness of the course for the first half of delivery. This could be due to several reasons, perhaps they were giving the course time to assess its usefulness, or they could have just kept these comments to themselves. Of course, these conclusions are just speculation from my own observations.

Student attitudes and confidence to mathematics/statistics – did it change during the course?

The TA noted several participants in the Pilot Scheme in SA group liked mathematics, while others enjoyed the challenge of the course. She also noted that many participants gained confidence in their abilities in statistics and critical thinking, displayed by greater engagement with discursive activities, and asking more insightful questions on questioning the validity of data for example, during the time she had with them.

Since I taught the class for the first half of the course, identifying changes in student confidence would be less likely, potentially due to an insufficient amount for the intervention to have an effect. As a result, I noted no change in student attitudes towards mathematics and statistics.

Comment on student ability

The TA noted no change in student ability, from her own observations of student participation in class activities, completing worksheets etc. She did however reiterate the largest difference she noticed was that of an increase in confidence with handling data and engaging with mathematics and statistics.

As with the TA, I noted no change in students' ability in mathematics and statistics, for the relatively short period of time I taught the group.

Did the students enjoy the course?

The TA noted students participating in the group indicated that the Pilot Scheme in SA was the most enjoyable course of all their A' Level studies. She also noted that within the Pilot Scheme SA group, students from CAVC were more actively engaged with debate and critical thinking activities, while the students from St David's were happy to listen to her talk for longer periods.

My experiences with the Pilot Scheme group were similar to the TA's, especially with regards to the preferences of class activities and teaching strategies of the students from CAVC and St David's.

Notice any difference in the students - linked to their A' Level subject choice? Did this impact on their learning? Could you tell what they were studying?

The teaching associate noted that it was difficult to ascertain what the students were studying just from teacher observations. The students did however tell the TA what they were studying, which enabled her to modify her handouts to help support their subjects. In addition, she noted the students enjoyed looking at real world examples, drawn from different disciplines. The students noted that it enabled them to perceive their own A' Level subjects from different perspectives, helping to consolidate their learning.

### Are there any other comments you would like to make?

The teaching associate noted variation in attendance for participants on the course, for example some students only attended when their friends were present. And since the course was in the evening, several students commented on the difficulties in committing to an extra curricula activity. These important sources of feedback will be used to modify future runs of the course (expanded in the discussion chapter).

#### **6.5.1 Summary of teaching associate reciprocal interview**

Results from the reciprocal interview support findings from the questionnaires and course evaluation for the Pilot Scheme in SA. Teacher observations (recorded in note form) from the Pilot Scheme in SA noted an increase in student confidence with mathematics and statistics. These observations were collected as separate forms of data, due to there being no occurrences of team teaching on the course. Differences in teaching style and approaches were identified, specifically in relation to the main aims of the course. The TA focused on supporting student mathematical skills to support the statistical techniques being delivered, while I concentrated more on statistical principles and critical thinking. The differences in our perceptions as to what statistics is could explain these slightly divergent approaches. Differences in pedagogical styles adopted could have had an effect on the identity of the course being delivered, as well as how it is perceived by the participants on the course. These considerations will have implications for the pedagogical guidance created for the course, in relation to expanding it out to other students and teachers. In addition, the differences in focus for the course could have also had an impact on how the students on the Pilot Scheme completed

all of the questionnaires as part of this study. These issues will be examined in more detail in the discussion.

## **6.6 Conclusion**

This chapter has shown, that by engaging year 12 and 13 students with a contextualised statistics course (Pilot Scheme in SA), their attitudes and abilities with respect to mathematics, statistics and critical thinking led to a series of measurable changes. The course has potentially contributed to increases in their mathematical and statistical confidence, ability and views on the importance of the subject both in an academic context, and also in everyday life as becoming more positive.

Although the positive impacts of the course are somewhat tentative, and in places difficult to make unequivocal inferences, there is no evidence to suggest the course had a negative impact on the experimental group.

In comparison, students who didn't receive the treatment from both control groups showed differences in their attitudes and abilities with respect to mathematics, statistics and critical thinking. These included decreases in their mathematical and statistical confidence, and ability. However, their views on the importance of mathematics and statistics, both in an academic context and also in everyday life, revealed an increase in both control groups.

The results presented in this chapter have revealed a number of potential differences between the intervention and control groups. These differences identified will now be explored in more detail in chapter seven.



## Chapter 7 Discussion

### 7.1 Introduction

The research conducted during this project has provided data to help explain the impacts of a contextualised statistics course, on a group of year 12 and 13 students from two educational establishments in Cardiff. This chapter will answer the research questions identified as part of this research study. In addition existing literature (chapters two and three) will be drawn upon to elucidate explanations for the resultant findings presented. The chapter will conclude with an overview of the limitations of the study, with reflections embedded throughout.

As a reminder, the research questions were:

1. What are the attitudes of year 12 and 13 students to mathematics and statistics, before participating in a contextualised statistics course (Pilot Scheme in SA)?
2. What are the attitudes of year 12 and 13 students to critical thinking, before participating in a contextualised statistics course (Pilot Scheme in SA)?
3. What are the impacts of a contextualised statistics course (Pilot Scheme in SA) on year 12 and 13 student attitudes towards mathematics/statistics and critical thinking?
4. What are the student outcomes of participating in a contextualised statistics course (Pilot Scheme in SA course), in relation to mathematical and statistical abilities, in years 12 and 13?

With reference to research question 1, the attitudes of year 12 and 13 students to mathematics and statistics before participating in a contextualised statistics course (Pilot Scheme in SA) showed some evidence of being negative.

For research question 2, the attitudes of year 12 and 13 students to critical thinking before participating in a contextualised statistics course (Pilot Scheme in SA) were generally more positive, in comparison to the mathematics and statistics attitude scores.

With reference to research question 3, engaging year 12 and 13 students in a contextualised statistics course (experimental group 1) appears to have contributed to the observed increases in their mathematical, statistical and critical thinking skills confidence. In addition, their attitudes changed, revealing an increase in their views on the importance of mathematics in an academic context and also in everyday life. In comparison, the control groups revealed decreases in their mathematical and critical thinking skills confidence. However, they did feel more strongly at the end of the quasi-experiment, with respect to the importance of mathematics in an academic context and also in everyday life.

With respect to research question 4, evidence from the formative tests suggests experimental group 1 improved their statistical abilities. This improvement was higher than both control groups.

Reasons for these differences could point to the impact of the Pilot Scheme in SA course, constructed and delivered in a novel and engaging format, dissimilar to traditional curricula and styles of delivery of statistics within post-16 mathematics



courses. Student engagement with the course could have contributed to the increased level of confidence in mathematics and also increased level of ability in statistics, observed in the Pilot Scheme in SA group. However, the positive impacts of the course are somewhat tentative, and in places difficult to make unequivocal inferences. However, there is no evidence to suggest the course had a negative impact on the experimental group.

The results will now be discussed in detail, arranged into two overarching themes at the heart of the research project:

- The impacts of a contextualised statistics course (Pilot Scheme in SA) on year 12 and 13 student attitudes towards mathematics/statistics and critical thinking.
- Student outcomes of participating in a contextualised statistics course (Pilot Scheme in SA course), in relation to mathematical and statistical abilities, in year 12 and 13.

## **7.2 The impacts of a contextualised statistics course on year 12 and 13 student attitudes towards mathematics/statistics and critical thinking.**

This section draws on relevant literature to explain the findings related to the year 12 and 13 student attitudes towards mathematics/statistics and critical thinking. Relevant findings from the results section (chapter six) will involve the ATMI and critical thinking questionnaires, student evaluation forms of the Pilot Scheme in SA (mid and end) and the teaching associate reciprocal interview. This section will specifically address research questions 1, 2 and 3.

### **7.2.1 Attitudes towards mathematics/statistics and critical thinking**

Participants in experimental group 1 (Pilot group) presented with the largest percentage increases for the strongly agreeing options, from pre to post intervention attitudes, with respect to questions that focused on exploring whether students wanted to develop their mathematical abilities (Q2), the level of satisfaction they derived from solving mathematical problems (Q3) and self-confidence with mathematics (Q17), from the ATMI questionnaire (Tables 6.2, 6.3 and 6.4). There were also percentage increases for the agree options with respect to the importance of mathematics in everyday life (Q5) and as a subject being one of the most important for people to study (Q6).

In comparison, students in both control groups who didn't receive the treatment, showed negative differences in their attitudes to mathematics. These included decreases in their mathematical confidence. Control groups 2 and 3 mostly showed percentage decreases, from pre to post intervention attitudes, with respect to (Q2), (Q3) and (Q17), from the ATMI questionnaire (Tables 6.3 and 6.4). However, their views on the importance of mathematics, both in an academic context (Q6) and also in everyday life (Q5), revealed an increase in both control groups (Tables 6.3 and 6.4).

Participants in experimental group 1 presented with the largest percentage increases for the always options, from pre to post intervention attitudes, with respect to questions exploring the students' ability to think of possible results before they take action (Q1) and whether they can tell what they did was right or wrong (Q18), from the critical thinking questionnaire (Tables 6.6, 6.7 and 6.8).

In comparison, students who didn't receive the treatment from both control groups showed differences with respect to critical thinking. These included, in most cases, decreases for the always option, with respect to Q1 and Q18, from the critical thinking questionnaire (Tables 6.7 and 6.8).

These results are interesting, especially considering that the control group's confidence in their mathematical abilities decreased after the experiment, yet their views on the importance of mathematics increased. As stated in chapter four, students from CAVC and St David's were exposed to various forms of data and analytical techniques during their A' Level classes in sociology, psychology and government and politics. Perhaps their encounters with mathematics in these non-traditional forms (compared to GCSE mathematics) enabled them to realise the importance of developing these skills, although this is only speculation. Other explanations could be linked to the Hawthorne effect (discussed in chapter five), whereby the participants in all groups were aware that they were being observed, and that they were part of an educational study. This could have had a bearing on their behaviours, leading them to answer the questionnaires in a different way (McCambridge *et al.*, 2014).

Experimental group 1 experienced a contextualised statistical course (underpinned by mathematics), anchored to engaging content identified and created by the TPS. Since these students encountered statistics in a variety of interesting and useful forms (as reported in the student evaluation questionnaires), results from the attitudes to mathematics and the course evaluation suggest it could have enabled them to build their confidence and also desire to develop these skills further. In contrast, traditional methods of teaching

mathematics are characterised by a didactic approach, which lacks debate, giving mathematics an uninteresting identity (described in chapter three) (Noyes, 2007, p.69; Porkess, 2013; Donaldson, 2015). Coupled with this, mathematics has a socially accepted negative identity; it's okay to be bad at maths (Harrison, 2014; National Numeracy, 2017). These confounding factors, and widespread concern with poor mathematics teaching that students encounter during their compulsory education act as reinforcing agents to the negative stereotypes highlighted above (Smith, 2004 and 2017). These factors could also explain the control group's decreases in mathematical confidence, with reference to the mathematical encounters they have received in secondary school education.

The critical thinking attitudes of participants in experimental group 1 revealed increases in their perceived ability to think of possible results before they take action and also whether they can tell what they did was right or wrong. In contrast, students from both control groups revealed mostly decreases with respect to these questions. Participants in experimental group 1 encountered statistical content with a heavy focus on scientific method, as well as approaching the data they encountered with a critical eye. These concepts and skills developments resonate strongly with Skemp (1976), stating students should develop a relational understanding (knowing what to do and why) (described in chapter three and four). In addition, the curriculum was underpinned by a set of values and beliefs aligned to a constructivist approach to learning (identified and constructed by the TPS) about what students should know and how they come to know it, a strategy recommended by Prideaux (2003) (described in chapter four). Intentionally constructing a curriculum that embeds statistical concepts and critical thinking has had the intended effect of increasing (albeit) perceived

abilities in critical thinking. These approaches could explain the increases in critical thinking skills observed in experimental group 1.

### **7.2.2 Student evaluation forms of the Pilot Scheme in SA (mid and end)**

Participants from experimental group 1 revealed percentage increases for the strongly agree option, from the mid to the end of course evaluation reports, with respect to the course aims being clear (Q1), seeing the value of the course to their other studies (Q2), and the statistics being linked well with good examples (Q4). Responses to the question ascertaining if the participants enjoyed the statistical elements of the course stayed relatively the same (Q7).

Responses from the course evaluation appear to support some of the findings from the mathematical and critical thinking attitudes results. For example, experimental group 1 revealed increases in agreeing with the statement that the statistics delivered during the course was linked well with good examples. These results also correlate with the previous year's evaluative results, from 2014/15. The 2015/16 group also revealed increases in agreeing that the course was valuable to their other studies, as well as the course aims being clear. In the mathematics and critical thinking attitudes results, participants in this group revealed increases in their mathematical confidence as well as critical thinking skills. These results could be attributed to the over-arching rationale behind the development of the course, with the TPS group identifying what students should know and how they come to know it (Prideaux, 2003). The contextualised nature of the statistics and fostering of critical thinking skills throughout the course also support Skemp's relational understanding skills which he suggests are key concepts that students need to develop – 'knowing what to do and why' (Skemp,

1976). In addition, the direct mapping of course content and skills to current A' Levels many of the students were studying has led them to report that they felt the course supported them in their other studies (described in chapter four).

The final result in this section, relating to enjoyment of the statistics, revealed similar responses pre and post. However, the initial responses to this section were positively skewed, which suggest the majority of the students enjoyed mathematics and statistics before they engaged with the course. These results could suggest that experimental group 1 were pro mathematics even before they started the course, which could explain the increases in positive attitudes to mathematics and statistics, as well as giving favourable responses in the course evaluation in general.

Research conducted on current statistical modules within A' Level mathematics (Lee *et al.*, 2017; Minards, 2013; Cole, 2015) reported students and teachers describing these modules as boring, laborious and unimaginative (described in chapter three). These findings are worrying, especially with the growing importance of pre-university students needing to be statistically literate in an increasing range of HE courses, social sciences and geography for example (covered in chapter three). The mathematical, statistical and critical thinking skills identified as being important for HE study, and consequently incorporated into the Pilot Scheme in SA by the TPS gave the course a unique identity. Skills highlighted as being essential preparation for HE study across a range of subjects (Gal, 2002; Nunez, 2006, pp.160-181; Schleppegrell, 2007; Walshaw and Anthony, 2008; Durrand-Guerrier, 2015, pp.453-457). These skills incorporated into the Pilot

Scheme in SA could have contributed to the increases in enjoyment of the statistics, observed in the course evaluations from experimental group 1.

### **7.3 Student outcomes of participating in a contextualised statistics course in relation to mathematical and statistical abilities, in year 12 and 13.**

This section will draw on relevant literature to explain the results that explored the student outcomes of experimental group 1, in relation to their mathematical and statistical abilities in year 12 and 13. This section will specifically address research questions 3 and 4.

#### **7.3.1 Student formative tests**

As expected, the experimental group 1 scored higher marks than the control group 3, across all formative test results. This suggests that the intervention could have had a positive impact on the statistical abilities of experimental group 1, when completing the formative tests. As stated in the methods chapter (section 5.7), all participants would have covered the formative test content in their A' Level classes and were therefore prepared to answer all of the questions they encountered. Since experimental group 1 participated in the Pilot Scheme in SA course, they were trained to develop their critical thinking and data analysis skills. This unique training has potentially contributed to improving their statistical abilities, demonstrated in their higher formative test results in F3.

In addition, Cohen *d* effect size results support the above findings, revealing similar levels of statistical ability overlap between the experimental group 1 and control group 2 at F1. This changes at F3, with experimental group 1

outperforming control group 2. Again the Cohen d effect size results for experimental group 1 reveal their statistical abilities were higher than control group 3 at all formative test points. The use of Cohen's d provided useful data for comparison between groups, however the variability in experimental group 1 F3 results (Table 6.12) does bring into question the normality of this set of data, which would violate a key underlying assumption (Ghasemi and Zahediasl, 2012). Specifically, this could be linked to outliers in the group scoring perhaps higher marks that skewed the mean to a higher value. These considerations will be discussed in more detail in the limitations section (7.5).

#### **7.4 Teaching associate reciprocal interview**

Results from the reciprocal interview revealed several interesting patterns, which support findings from the questionnaires and course evaluation for the Pilot Scheme in SA. Teacher observations from the Pilot Scheme in SA noted an increase in student confidence with statistics. In addition, students enjoyed the Pilot Scheme in SA, engaging with the critical thinking elements of the course (as identified in the course evaluations).

Differences in teaching style and approaches were identified, specifically in relation to the main aims of the course. The TA focused on the students' mathematical skills to support statistical techniques being delivered, while I focused on statistical principles and critical thinking. The differences in the TA and my own perceptions as to what statistics is could explain these slightly divergent approaches. These different loci could have had some bearing on the outputs from the questionnaire data (mathematics and critical thinking questionnaires and course evaluations). For example, the focus of the TA on mathematical skills could



have contributed to the increased levels of mathematical confidence observed in experimental group 1. Whereas the areas I concentrated on (statistical techniques and critical thinking) could have contributed to the increases in enjoyment of statistics and also the increased levels of agreement with the responses from the critical thinking questionnaire (e.g. ability to think of possible results before they take action and also whether they can tell what they did was right or wrong).

It was interesting to reflect on the different approaches taken by the teaching associate and myself, on the Pilot Scheme in SA course. When I handed over the course content and scheme of work to the teaching associate, as well as discussing the course aims etc., I wanted to ensure that the teaching associate felt comfortable enough to put her own stamp on their sections of the course to be delivered. I didn't want her to feel like they had to follow a prescribed way of delivering the course. And this was indeed the case; the teaching associate produced different teaching resources and materials for the second half of the course (for example: Appendix 4.5). The teaching associate's interpretation of the courses aims translated to providing slightly more mathematics than I had covered in the previous year's group. These differences could have given the course a different identity to the previous year, which might have had an impact on the participant's responses to the course evaluation, and also their attitudes to mathematics and critical thinking.

The implications of these differences in teaching style raise several issues that need to be addressed. Firstly, the approach I adopted, giving the teaching associate flexibility to select her own contexts and style of teaching (within a given curriculum – Appendix 4.2), is a generally uncommon approach adopted within

secondary schools in England and Wales (Donaldson, 2015). Teachers currently follow prescribed national curriculum and A' Level curriculum syllabi constructed by local authorities and examining bodies (Donaldson, 2015). If this course were to be rolled out on a larger scale, there is the propensity for teachers to feel overwhelmed and perhaps unconfident with having so much freedom to teach a less constrained curriculum. In addition, there is evidence to suggest that teachers struggle when new government initiatives are introduced, raising standards in preparation for mathematical elements of the PISA examinations for example (described in chapter three) (Andrews, 2011). In this particular case, Tanner and Jones (2013) highlighted how teachers battled to keep up with yet more change in mathematics curricula and styles of teaching. This evidence brings into question the success rate of attempting to not only introduce a statistics course that draws on a range of contexts (the Pilot Scheme in SA), but also a variety of pedagogical styles and increased teacher freedom. There is however a curriculum included with the Pilot Scheme in SA course, and examples of handouts and activities for teachers to follow. These guidelines could help teachers become familiar with the curriculum content, while at the same time giving them enough space to design their own student activities and handouts. Achieving the right balance of teacher freedom and guidance for teachers to feel confident in delivering a distinct course, such as the Pilot Scheme in SA, will require careful construction of teacher training programmes that exemplify successful approaches, that were identified using evaluative approaches (teacher observations for example) adopted in chapter four.

The different emphases placed on the course in terms of delivery, noted between the teaching associate and myself, potentially reduced the likelihood that any differences in student attitudes and abilities were primarily down to my own

teaching style and pedagogical practices. The teaching associate used the same curriculum that I would have followed, created by the TPS. Using the same scheme of work could be operationalised differently by different teachers, in the form of different handouts or activities for example. Having these practical insights could inform future training programmes for other teachers, giving them the space to be creative and come up with their own worksheets, but at the same time giving them examples of how different teachers used the scheme of work to deliver the course in potentially different ways (Appendices 4.1-4.5). Recommendations will be made in chapter eight, with specific reference to pedagogical approaches that were successful during the Pilot Scheme in SA course.

There is no right or wrong approach in terms of adopting and operationalising the scheme of work for the Pilot Scheme in SA (Appendix 4.2). The decision I made to focus more on statistical concepts and critical thinking, especially during the earlier stages of the course, were perhaps partly out of fear not to expose students to too much mathematical content. Being mindful of the societal negative attitudes towards mathematics could have influenced the approaches I decided to focus on. After reviewing the reciprocal interview data and course evaluations, it appears that a combination of the two approaches have been successful in terms of improving mathematical confidence and also enjoyment with statistics.

Teachers would also need to be convinced of the benefits to the students who would take this course, if it were to be rolled out, as well as benefits to their own teaching practice. These benefits could include increases in mathematics teacher's ability to draw on different contexts linked to the underlying mathematics that support the statistics. Evidence from this research study support this approach,

since the Pilot Scheme in SA students reported that they found the examples interesting and engaging. This movement away from clinging to prescribed curricula and towards focusing on teaching skills (mathematical, statistical and critical thinking skills) is also a prominent recommendation made by and Porkess (2013), Donaldson (2015) and Smith (2017).

Student feedback on the length and time of the course suggest modifications should take place to enable better attendance in future iterations of the course. A 21 week extra curricula course in the evening is a big commitment for 16-18 year old students. After discussing these issues with the TA and the TPS, suggestions to shorten the course into a ten week block could make it more appealing.

### **7.5 Limitations and future research**

The majority of the limitations discussed here will be with reference to the quasi-experiment method selected, although other considerations will also be discussed. The small-scale quasi-experiment took place within Cardiff, involving participants from two educational institutes. Issues pertaining to generalisability and conflicts arising and the advantages afforded by insider research (Mercer, 2007; Drake, 2010) were covered in chapter five (5.2.1 and 5.10). Partially removing myself from the research environment (helping become somewhat more objective and making the familiar strange, partially mitigating problems that can arise with insider research), could have contributed to a deeper level of reflexivity (Delamont and Atkinson, 1995; Delamont, 2002; Van Heugten, 2004; Mercer, 2007; Greene, 2014). Since I delivered half of the Pilot Scheme in SA course however, the problem with insider research still remains. Drawing on the work of Brannick and Coghlan (2007), Drake (2010) and Mercer (2007), objectivity is close to impossible

when investigating sociological phenomena, and to think otherwise would be naive. Researchers draw on their own social, cultural and historical background, which is a strategy I adopted and increasingly reflected upon when collecting and analysing data from this research project (Brannick and Coghlan, 2007). For example, as a statistically literate biologist, I perhaps undervalued the benefits of the Pilot Scheme in SA to students studying A' Levels in humanities subjects. However, the critical thinking elements of the course could have helped to nurture valuable transferrable skills that all students from a variety of disciplinary backgrounds could draw upon, especially when applying for HE courses.

Issues relating to the generalisability of findings from this small-scale project call for the research project to be expanded and repeated (described in chapter eight). This will help to ascertain if the impacts of the Pilot Scheme in SA identified in this research project can be replicated in other groups of students from the same and different educational establishments across Wales. In addition, more studies over time will have the propensity to increase the statistical power in relation to any future inferences made.

Further issues that could have had an impact on the validity of the data include whether the groups themselves had equal statistical abilities (Gersten *et al.*, 2000; Maxwell, 2004). From the results the St David's group appear to have the lowest ability. However their results were captured and included as a useful comparison (being a less statistically able group), ascertaining if their attitudes were different to the other groups.

Results from the ATMI and critical thinking questionnaires are at times potentially contradictory, with respect to the changes in percentage pre and post as a result of dropout of students. For example in Figure 2 (Appendix 6), from pre to post, there is a drop of two students in the agree response, which is an increase of 3% when comparing pre and post results as a proportion of the sample sizes pre and post. If there is a drop in number of participants' pre to post, using the method of data collection selected for this study, there is no way of knowing if the difference is due to student dropout. Only if there were an increase in student numbers would we know for sure that students changed their mind from other options selected pre to post intervention. However, due to differences in sample size, pre to post, it was still felt more appropriate to display the results as percentages versus student numbers.

Another issue that could have impacted on the results relates to whether a participant was in year 12 or 13. The actual numbers of year 12 and 13 students in the quasi-experiment were roughly equal. These students were mixed and not always in separate classes, since many of them were completing an A' Level in a year (so they would have been in both AS and A2 classes). In future quasi-experiments with larger numbers of participants the results for each year group could be considered and comparisons made.

An additional limiting factor throughout the quasi-experiment was the problem of participant dropout (discussed in chapter five – 5.2 and 5.10). From the data, dropout did occur, which could have had an impact on the characteristics of the group, i.e. participants who dropped out could have differed systematically from the characteristics of the remaining group members (Gibbons *et al.*, 1993; Slavin,

2008). And the perceived differences in attitude and ability could just be a product of the students left on the course being perhaps more pro mathematics and better at statistics (Gibbons *et al.*, 1993). The results seem to suggest that this isn't necessarily the case, since several students on the Pilot Scheme in SA group still reported they didn't enjoy statistics at the end, and the shift in positive response to questions in the course evaluation were greater than the dropout rate, which means that students must have changed their opinion (i.e. it wasn't just the case that the students who didn't like the course dropped out – which made it appear that the group had become more positive towards the course). Reasons for students dropping out of the course include; wanting to focus more on their A' Level studies, personal reasons linked to ill health and also other out of school commitments taking precedence over the Pilot Scheme in SA course.

The method used to collect data at various time points did lead to small sample sizes. Choosing to take data from individuals present during data collection points, discussed in section 5.3.2 and 5.10 (chapter five), effectively resulted in missing data points causing the sample size to drop even further. Gibbons *et al.*, (1993) and Daniels *et al.*, (2011) suggest the use of baseline and end point data to create Bayesian models to calculate an estimate of the missing observations (described in chapter five). However, adopting this strategy could prove to be problematic, due to the many extraneous variables that would need to be built into the model, as well as accounting for the interactional effects of the variables from the baseline and end-point data (Gibbons *et al.*, 1993; Daniels *et al.*, 2011). To elaborate further, the characteristics of the participants in this study included an insufficiency of data, socioeconomic class and gender for example, due to the scope and time restraints being limited. To create an accurate model that could predict

responses from the questionnaires included in this study would also require larger sample sizes from multiple populations, necessitating research funding to facilitate the increased activity of work.

Other external factors (discussed in chapter five – under violation of assumptions) that could have had an impact on the students' attitudes could be numerous and even unknown. Controlling for such factors, within the social world, is difficult and perhaps even undesirable (Maxwell, 2004; Saba, 2000). Reflecting upon and being mindful of potential external factors is a useful research strategy, adopted throughout this study (Slavin, 2008). For example, the educational institute each of the participants came from, their past experiences with mathematics (a question present in the attitude questionnaires), the participants current A' Level profiles, were all reflected upon. In addition, the A' Level profiles of many of the participants included several science courses, although there were cases of students taking more humanity based subjects. This could have influenced their attitude towards the usefulness of mathematics, dependent upon how much they encountered during their studies (Roth, 2014). The educational institute the participants came from in particular could have a profound impact on the way students are taught mathematics and statistics. Do students have different attitudes to mathematics and science more generally within Catholic schools/sixth form colleges, versus FE colleges? The interactional effects of these external factors could be investigated in future studies and perhaps built into a Bayesian model (mentioned above), or other regression models that could be used to estimate the impacts of various identified external factors that could influence attitudes and ability to mathematics and statistics (Gibbons *et al.*, 1993; Daniels *et al.*, 2011).



The questionnaires selected for this study – ATMI and critical thinking, included a series of questions measuring attitudes to mathematics and critical thinking. The main aims of the Pilot Scheme in SA are to enhance students' statistical and critical thinking skills. As already discussed (chapter three), public perception in relation to the differences between mathematics and statistics suggest they elide them together, imprinting negative mathematical attitudes onto statistics (Gal and Ginsberg, 1994; Franklin, 2013; Fitzmaurice, 2014; Gibbison, 2017; National Numeracy, 2017). For these reasons, a questionnaire exploring mathematics attitudes was deemed to be a useful way to investigate if students changed their attitudes to mathematics after engaging with a contextualised statistics course. If a questionnaire was used to measure purely statistical attitudes, there was a concern that certain attitudes might not be captured accurately. And as already discussed, statistics is underpinned by mathematical principles and procedures. Differences were observed between experimental and control groups in relation to their attitudes to mathematics pre and post intervention. However, the level of negative mathematical attitudes imprinted onto statistics goes beyond the scope of this thesis, and would require additional data with modified questionnaires to investigate if this phenomenon exists in the types of populations investigated during this study.

The ATMI and critical thinking questionnaires also included a neutral category (described in chapter five), a strategy encouraged by Linacre (2002). There are disadvantages to using a neutral category, where there is a propensity for participants to gravitate towards selecting this option (Linacre, 2002). This could have therefore resulted in a dilution of the results, eroding the potential for

patterns to emerge. The results did reveal changes in mathematics attitudes pre and post intervention, even with the neutral category option being made available.

Questionnaires were used as the primary instrument of data gathering, which produced several interesting patterns when comparing the experimental and control groups. Although I am mindful that perhaps a more mixed methods approach would help to drill down and expand on the current findings, potentially enabling a deeper understanding of mathematics and statistics attitudes in A' Level students, however this was not within the scope of this research (Trautwien *et al.*, 2006; Schilling and Applegate, 2012). In particular, teasing apart where subject anxieties are present using focus groups for example, could ascertain if there is a possibility that participants in the experiment imprinted perhaps negative mathematical attitudes onto statistics. This would be an area for potential future research.

The use of Cohen's  $d$  facilitated useful data comparison between groups, however the variability in experimental group 1 F3 results (Table 6.12) does bring into question the normality of this set of data, which would violate a key underlying assumption (described in chapter five and six) (Ghasemi and Zahediasl, 2012). Specifically, this could be linked to outliers in the group scoring perhaps higher marks that skewed the mean to a higher value. This doesn't negate the fact experimental group 1 had a higher mean than the other groups for the F3 results. The higher scores achieved by several students for the F3 test could be partly explained by the positive impacts of the Pilot Scheme in SA course, or it could be due to them have higher statistical abilities from the onset of the experiment. There is no way to know for certain what the explanations are for this, however it

does present an opportunity for modifications to be made to the experimental design in terms of data collection, for future research (discussed in the recommendations section in chapter eight).

Patterns were identified and carefully examined in the experimental and control groups, with sources of experimental biases consistently reflected upon. As previously mentioned in the methods chapter, the Hawthorne effect could have potentially influenced the way participants behaved during the study. However, as stated by McCambridge *et al.*, (2014) accurately measuring the impact of this effect on the results can be difficult to achieve due to the complexity of the experimental design adopted (McCambridge *et al.*, 2014).

## **7.6 Conclusion**

This chapter has discussed potential explanations for the results presented in chapter six. These discussions were presented within two overarching themes at the heart of the research elements of the project. The limitations of the research have also been discussed in detail.

The final chapter will present a series of recommendations, personal reflections and then a final conclusion and overview of the contribution of the thesis.



## Chapter 8 Recommendations and Conclusion

### **8.1 Introduction**

This final chapter will begin with a review of the outcomes of the research. This will be followed by a series of recommendations, taking into consideration implications from the discussion and also the practical insights gained from the development of the Pilot Scheme in SA described in chapter four. A reflection section will then be presented, followed by a final conclusion and the contribution of the thesis.

### **8.2 Outcomes of the research**

The research focused on the development and evaluation of a contextualised statistics course called the Pilot Scheme in SA. The evaluation of the course used a quasi-experimental approach, with the use of questionnaires as the primary instrument to generate data. The findings showed that by engaging year 12 and 13 students with a contextualised statistics course (Pilot Scheme in SA), their attitudes and abilities with respect to mathematics, statistics and critical thinking led to a series of measurable changes. The course has potentially contributed to increases in their mathematical and statistical confidence and ability. In comparison, students in both control groups who didn't receive the treatment, showed mostly negative differences in their attitudes and abilities with respect to mathematics, statistics and critical thinking.

### **8.3 Recommendations**

The recommendations proposed in relation to the discussion chapter (chapter seven) from the main findings of the research project, are presented here under two sections: recommendations for practice (relating to the Pilot Scheme in SA course, teacher training and how organisations can work together more closely) and recommendations for future research.

#### **8.3.1 Practice**

##### *Expansion of the Pilot Scheme in SA*

As a result of the main findings from the research project, a number of recommendations with reference to statistics education in particular have been identified. The positive outcomes identified call for an expansion of the course (increasing student numbers), to enable other students to enhance their abilities in critical thinking and statistical analyses. These skills will also benefit students embarking on HE courses across an increasing range of subjects, as well as being identified as highly valuable skills by a multitude of employers (Gal, 2002; Nunez, 2006, pp.160-181; Schleppegrell, 2007; Walshaw and Anthony, 2008; Durrand-Guerrier, 2015, pp.453-457). Statistical education in its current form (in schools) underprepares students for HE, as outlined by the recent ACME recommendations to the Department for Education (ACME, 2011). Even with the proposed changes to statistics curricula within the new A' Level mathematics, for first teaching in September 2017, there are still concerns that more work needs to be done to ensure the course is fit for purpose and prepares students to apply statistical skills and concepts across a range of disciplines (Forman, 1996; Dowling, 1998; Mercer and Sams, 2006; ACME, 2011; Porkess, 2013; RSS and ACME, 2015; Smith, 2017).

Therefore, a wider rollout of the Pilot Scheme in SA could help to prepare students to apply statistical skills across different subject areas.

The positive outcomes experienced by the participants, potentially due to the Pilot Scheme in SA, calls for the course to be expanded and offered to other schools and FE colleges across Wales and potentially England. The results outlined benefitted a small group of students from two educational establishments in Cardiff, and the quasi-experiment on the whole was conducted on groups with relatively small numbers of participants. However, the course that ran in 2014/15 resulted in similar positive course evaluations, and although there is no comparable data, it does suggest that the benefits students experienced in both cohorts calls for the course to be made available for others.

Expansion of the course will also provide further opportunities to conduct educational research to investigate its effectiveness, which could include action research strategies (Bryden-Miller *et al.*, 2003; Hine, 2013). Action research is a process of systematic enquiry, which includes cycles of planning, observing and reflecting to improve educational practices (Hine, 2013). The use of action research also encompasses useful strategies to enable educational theory (constructivism in this case) to be translated into praxis, in essence doing something (i.e. curriculum construction, development and utilisation of pedagogical practices) and then reflecting upon those actions, i.e. were they successful? Can they be improved upon? (Bryden-Miller *et al.*, 2003; Hine, 2013). Using these approaches could help to develop the course further, which would facilitate the need to engage with the relevant literature surrounding these strategies in more depth.

However, plans to develop practitioner researchers to facilitate the expansion of educational action research within Wales are already underway, as a direct response to recommendation 3 (to establish a National Centre of Excellence for Mathematics, in Table 3.2) from the Mathematics Task and Finish Group report (Griffiths, 2015). This board, called the National Network for Excellence in Mathematics (NNEM) is currently made up of regional consortia representatives, HE lecturers in mathematics education both from a teacher training perspective and also as discipline specific mathematics lecturers, and also primary and secondary school teachers from across Wales (NNEM, 2016). The board is responsible for coordinating and delivering professional training for best practice, and also building on evidence-based research to support and help inform mathematics teaching (NNEM, 2016).

As a nominated board member, I will be creating a proposal to the NNEM, which could support action research strategies to investigate the impacts of contextualised statistics on student confidence in statistics and mathematics. Data generated in this research project involved students from the FE sector and a sixth form college. Further evidence needs to be gathered to ascertain if the same positive benefits exist, when year 12 and 13 students from different educational settings engage with a contextualised statistical course. Recommendations to the NNEM could include expansion of the course to several other educational centres, which could include secondary schools, to help generate more evidence to see if the positive outcomes identified in this research study are replicated.

Significant elements of the Pilot Scheme in SA are currently available as a series of QCF level 2 and 3 units, via the awarding body Agored Cymru (Agored, 2017:



available at: <http://www.agored.cymru/Units-and-Qualifications/Units/Search/Results?qstring=social+analytics&level=&credit=0-0&ssa=&minage=-1&UG=0&qual=0&daysold=&submit=Search>). These units are available for the majority of ACCESS to HE courses (over 3000 learners in Wales), which embodies the contextualised statistical nature of the Pilot Scheme in SA. To promote these courses, I have visited six FE colleges across Wales, as well as presenting at Agored Cymru's annual conference in July 2016, that welcomed over 70 FE lecturers. Currently three FE colleges across Wales are delivering the access units in Social Analytics, supported by the teaching associate and myself in terms of checking assessment materials. One of the centres delivering the units includes lecturers on the TPS, who played an active role in creating the Pilot Scheme course in SA. This places that particular centre in an advantageous position; being able to deliver elements of a course they created.

Chapter four presented a reusable template, underpinned by a constructivist approach to learning, which included a scheme of work, worksheets and other resources. This could be used by secondary school teachers or FE lecturers, and with guidance, implemented alongside existing programmes. In addition, Q-Step centres across the UK should consider adopting a similar approach to FE and schools' engagement as demonstrated by the Cardiff Q-Step centre. It is hoped that the evidence presented as part of this thesis, in the form of the quasi-experiment results and also the operational and practical insights described in chapter four, will be used by other Q-Step centres to help encourage more young people to study quantitative methods at university.

### *Teacher training in contextualised mathematics and statistics*

Expansion of the Pilot Scheme in SA course will require additional investments to ensure the expansion is resourced well. As stated above, a proposal will be made to the NNEM board to fund this area of activity. In addition, teacher training will enable the transmission of this style of contextualised statistical course and associated resources to be adopted more widely across secondary schools and FE colleges. The quality of teachers has been repeatedly shown to be more important than any other factor of schooling in predicting student academic outcomes (Petty, 2006, p.311). Teachers are often underprepared and under skilled to teach numeracy, an increasingly important part of many subject areas on a global scale (Dolphin, 2015; Smith, 2017). By investing in teacher training programmes to up-skill teachers in the areas of contextualised statistics, there is the potential a knock-on effect that addresses several of the key issues identified by Petty (2006, p.311), Dolphin (2015), Donaldson (2015) and Smith (2017) highlighted above. By creating a teacher workforce that can draw on engaging context, underpinned by statistics and critical thinking, students will become confident consumers of data, potentially leading to an enhanced preparedness for HE and employment (Forman, 1996; Dowling, 1998; Mercer and Sams, 2006; ACME, 2011; Porkess, 2013; RSS and ACME, 2015).

The different emphases placed on the course in terms of delivery, noted between the teaching associate and myself in section 6.5, provided practical insights into the different teaching style and pedagogical practices adopted. The teaching associate used the same curriculum that I would have followed, which was created by the Teacher Placement Scheme. From the 2015/16 delivery of the Pilot Scheme in SA course, the evidence suggests that the same scheme of work was

operationalised slightly differently, for example in the form of different handouts and activities. Having these practical insights could inform future training programmes for other teachers, giving them the space to be creative and develop their own worksheets, but at the same time giving them examples of how different teachers (e.g. the TA and myself) used the scheme of work to deliver the course in different ways (Appendices 4.1- 4.5).

Chapter four provided a detailed description of what worked and what didn't work during two runs of the Pilot Scheme in SA course (2014 -2016). By reflecting on the delivery of the 2014/15 run of the Pilot Scheme in SA course, the pedagogical methods identified as being successful (originally driven by constructivism and then highlighted by student evaluations, reflecting on teacher observations and discussing activities with the TPS) included: incorporating more hands on approaches, engaging students with data visualisation techniques using laptops, working in groups to design IQ tests, and also working in groups to solve puzzles and games. These strategies were all successful in generating interest and engaging the learners. The results from this quasi-experiment also seem to support this observation, whereby participants on the Pilot Scheme in SA showed increases in their enjoyment towards statistics and could see the relevance of it to their other studies. In the context of statistics teaching, some approaches, for example using data visualisation techniques for example, are relatively new (Porkess, 2013). These pedagogical approaches should therefore feature strongly in a teacher training programme to support the delivery of the Pilot Scheme in SA.

As stated in the discussion, there are many challenges with implementing change, particularly in mathematics and statistics education (Andrews, 2011; Tanner and

Jones, 2013; Roth, 2014; Smith, 2017). These challenges include restraints on time and lack of support for teachers to actively engage and implement a change in their practice (Andrews, 2011; Tanner and Jones, 2013; Smith, 2017). To support teachers across Wales, the Cardiff School of Social Sciences are currently developing a master's level research skills module, which includes a mixture of quantitative and qualitative skills. This course is funded by the Central South Consortia, and overlaps with the work of the NNEM, building capacity of practitioner researchers in mathematics and numeracy. Since the Pilot Scheme in SA aims to develop student researcher skills, such as learning the scientific method and developing statistical and critical thinking skills, these masters level modules and the NNEMs plans to build capacity in practitioner researchers should also prepare them to teach significant elements of the Pilot Scheme in SA. These initiatives could align to support the expansion of the Pilot Scheme in SA course.

For secondary school teachers to actively engage with and deliver the Pilot Scheme in SA course, the WJEC have been approached to accredit this qualification as well as support to gain UCAS points, so it can be recognised by HEI's. This would greatly add to the legitimacy of the course, in terms of students gaining academic credit to enable them to include it on their UCAS applications. Numerous attempts have been made to persuade the WJEC to do the above, however communications ultimately broke down and ceased.

The challenges of engaging teachers with teacher training initiatives, even if the course were to be accredited by the WJEC, are varied and complex. As well as restraints on time and financial implications of training costs, issues pertaining to the effectiveness of teacher development activities need to be addressed. There is

an assumption that training sessions will lead to immediate changes in practice, tackling an acute problem across the teacher workforce, which includes a numeracy skills deficit (Dolphin, 2015; Donaldson, 2015; Girvan *et al.*, 2016). Teacher training programmes in Social Analytics will need to be carefully constructed, taking into consideration the above. Teacher expectations and potential fears need to be considered, especially in light of the anxieties mathematical based subjects can create not only in students, but also in society more generally (Smith, 2004; Swan, 2005; Tanner and Jones, 2013). To help alleviate restraints on teacher time, resources for the Pilot Scheme in SA course will be freely available, currently in digital formats that can easily be uploaded onto a drop box folder, or emailed directly to teachers.

Collaboration with Agored Cymru has proven to be a great success, which is where future resources and engagement will continue to grow. The units created in SA with Agored were designed to give FE lecturers the freedom to use different pedagogical approaches. Some of these tried and tested approaches used in the Pilot Scheme in SA have been suggested to FE lecturers currently delivering these units. Building an evidence base as to what works pedagogically is essential, in order to convince FE lecturers and secondary school teachers more widely to adopt these successful approaches.

#### *Q-Step and Core Mathematics programme to work more closely together*

The findings from this research project have identified positive outcomes for the students, potentially due to participation on the Pilot Scheme in SA. Positive outcomes for the students could be explained by the distinct nature of the course, which included the development of learner experiences and pedagogical

approaches outlined in chapter four. This involved the Cardiff Q-Step centre working closely with teachers from different disciplinary backgrounds as well as experience of teaching different age groups (TPS group). It is hoped that this evidence of effective collaborative practice supports the recommendation for Q-Step centres located within UK HEI's and the Core Mathematics programme (an organisation that is teacher led) to work more closely together, which is described in more detail below:

There appears to be common ground between the mathematics deficit in the UK, particularly in Wales, and the quantitative deficit within the social sciences. Many of the negative attitudes towards mathematics reported by Swan (2005) and Noyes (2007) could explain the antipathy of students within the social sciences towards quantitative methods. Students on social science degree courses within the UK are likely to label methods courses as being too mathematical, not as useful or interesting as qualitative methods, and perhaps at odds with their view of social science as being more of an arts than a scientific subject (Williams *et al.*, 2008).

Since the Q-Step initiative includes 15 Q-Step centres across the UK, designing and modifying courses in politics, geography, social sciences, child-hood studies, criminology, economics, history, anthropology and population health, this rich mixture of statistical context could be utilised by the Core Mathematics programme (Table 2.1). Core Mathematics has been designed as a supportive post-16 subject, facilitating subjects that require a certain level of mathematics skills. For example, the natural sciences, psychology, business studies, geography and increasingly sociology, require students to develop statistical analysis techniques, as well as data analysis skills (Porkess, 2013). These qualifications are

slightly biased towards mathematical procedural tasks, and should emphasise quantitative reasoning skills more prominently. In addition, the teacher resources lack engaging context (Core Mathematics, 2015). There seems to be a missed opportunity here for both initiatives to work more closely together, since there is tremendous potential for both schemes to feed into each other significantly.

Curriculum construction, at both pre-university and university level, across the Core Mathematics programme and the Q-Step centres, should ensure learner experiences are carefully constructed to include interesting context. Chapter four provided detailed descriptions of how this was achieved with the Cardiff Q-Step and the TPS group, in relation to the creation of the Pilot Scheme in SA. Following this example of collaborative practice to construct engaging learner experiences could be adopted by both programmes. These approaches should also inform the pedagogical methods developed and delivered to effectively engage students.

### **8.3.2 Future research**

#### *Further quasi-experiments to evaluate the Pilot Scheme in SA*

Due to the replicable nature of quasi-experiments, further quasi-experiments will enable the collection of more data, increasing the statistical power to conduct a meta-analysis. In addition, additional data could help to ascertain if the tentative positive outcomes identified in the Pilot Scheme in SA group are replicated with other groups of participants. Experimental group sample sizes also need to be large enough to account for participation drop out (Gersten *et al.*, 2000). This in itself can be difficult to achieve for a variety of reasons, for example: working with unique populations that are difficult to recruit (special needs students for example) (Gersten *et al.*, 2000). The need for larger sample sizes and multiple

groups to engage with the intervention (Pilot Scheme in SA), add to the need for further research to be conducted in this area of mathematics and statistics educational research.

In addition, the use of baseline and end point data could help to create a Bayesian model to calculate an estimate of the missing observations (Gibbons *et al.*, 1993; Daniels *et al.*, 2011). To do this, additional information on the characteristics of the participants in future quasi-experiments would need to be collected. These could include: socioeconomic class, gender previous experiences with mathematics and what their views were on the differences between mathematics and statistics. Post stratification of the data could also help to increase the sample size in some of the smaller groups in this study, control group 2 for example (Gelman, 2007). There are concerns however that having such a small sample size to begin with would represent a challenge in developing multilevel probability models that could yield reasonable Bayesian inferences (Gelman, 2007). Agresti and Hitchcock (2005) have written extensive guidance on generating Bayesian estimations of multinomial parameters for categorical data analysis, applicable to the data collected in this study. These statistical techniques could be further examined and utilised with data from multiple quasi-experiments, in the future. This would also require a substantial research programme (and funding) to ensure an accurate model could be created.

Ideally, random assignment of year 12 and 13 students to receive the Pilot Scheme in SA training, versus being placed into control groups, would enable the incorporation of randomised control trial experimentation (Clegg, 2005; Cartwright, 2007; Slavin, 2008). This would have the added benefit of



strengthening the validity of the experimental approach, in terms of identifying explanations to changes in student attitudes to and abilities in mathematics and statistics. Since the students will not be self-selecting onto the Pilot Scheme in SA course, this will help to reduce potential experimental bias, for example; the students will be randomly selected potentially having a mixture of pro and anti-mathematics and statistics attitudes. Therefore any positive changes in attitude are less likely to be due to the students being pro mathematics in the first place.

Changes to the method of collecting data at snapshots pre and post the intervention, effectively ignoring the non-responses, could also improve the reliability and internal validity of future research. For example, tracking individual students and collecting data at various time points throughout a future RCT or quasi-experiment could enable better comparisons to be made. This would be especially helpful with data obtained from the formative tests for example. As discussed previously, results from the mean values for experimental group 1 in F3 were probably skewed to a higher value – which brought into question its normality and subsequent appropriateness as part of the Cohen's  $d$  calculations. Looking at individual, as well as group differences, could give greater insights into the research questions posed during this study.

*Longitudinal study to assess impacts of Pilot Scheme in SA into their HE, and also into employment*

Additional forms of evidence would enable a deeper level of evaluation of the Pilot Scheme in SA. This could include the tracking of students who engage with the course, through future HE or employment engagements. This would have the

added benefit of ascertaining if there have been any permanent or long lasting effects of engaging with the Pilot Scheme in SA.

Again, this could add to the evidence base to support the Pilot Scheme course in SA's positive outcomes for year 12 and 13 students found in this study, and hopefully persuade teachers, FE lecturers and senior managers to adopt this course as part of the qualifications they have on offer.

Mathematics phobia is well documented within the UK, with mathematics anxiety being widespread throughout society (Harrison, 2014; National Numeracy, 2017). In addition, public perception in relation to the differences between mathematics and statistics suggest they elide them together, imprinting negative mathematical attitudes onto statistics (Gal and Ginsberg, 1994; National Numeracy, 2017). Future research to explore perceptions of the differences between statistics and mathematics, in similar populations investigated during this study, could help to investigate whether negative mathematical attitude imprinting does exist in relation to statistics. These findings could then be compared to the findings of other similar investigations that included different populations of participants (university students) (Musch and Broder, 1999; Vigil-Colet and Condon, 2008; Jordan *et al.*, 2014). For example, the investigation conducted by Jordan *et al.*, (2014) that looked into mathematical and statistical anxieties as separate entities with dyslexic university students. Their findings suggest participants saw little or no difference between mathematics and statistics, resulting in similar levels of recorded anxiety (Jordan *et al.*, 2014).

## **8.4 Reflections**

The professional doctorate I embarked on over six years ago has culminated in an unexpected end point, accompanied by a change in my own attitudes and beliefs of the social world. My own academic roots reside in the biological sciences, as well as a sizable portion of my professional career as a lecturer in clinical biochemistry and physiology. The research I have been involved with throughout the doctorate forced me to see the world with a completely different pair of eyes.

Several of the benefits stated by Porter *et al.*, (2009), with respect to reciprocal interviewing, led to the production of extremely useful data. This enabled comparisons to be made between the teaching associate and my own interpretations of what the course entailed. In addition, I welcomed the opportunity to partially step back from the research experiment, which helped to strengthen my own objectivity, an integral strategy in educational research (Evans, 2002). In stepping back from the research setting, my role began to change from that of a practitioner, into a researcher practitioner.

The research components of the doctorate provided an analytic lens over my professional working life as a lecturer in Quantitative Methods in FE in the Cardiff School of Social Sciences. In particular, the curriculum construction of the Pilot Scheme in SA was a new and unfamiliar endeavor I engaged with as part of my academic duties. Working with teachers from different disciplines and educational institutes to create a course to aid in student transition to university was extremely thrilling and at times overwhelming. To have such varied expertise in one room did, at times, proved to be a challenge to manage. The professional relationships developed with the teachers came from a base of passion and a

commitment to help their students' access higher education. It was this passion that helped give the research project sufficient momentum, in generating evidence to highlight the benefits of the course.

The tensions that exist with curriculum construction, as discussed in chapter four, have many root causes. Creating a skills or context focus both come with their merits and downfalls. After delivering the Pilot Scheme course in SA for two years, it has become evident that a mixture of the two is essential to keep students engaged and interested. These considerations are personal reflections I will most likely draw upon in future course and module developments.

Throughout my own professional career I have witnessed many disciplinary tensions, for example: between the biological and social sciences, theoretical and applied knowledge and qualitative versus quantitative methods. From my own observations and personal experiences, these tensions usually stem from strong beliefs in one's own position, as well as a certain level of intransigence. I try to keep an open mind and acknowledge the merits and limitations from both sides, while at the same time being prepared to defend one's own position. This research project has reviewed the quantitative deficit in the social sciences, which exists within the UK. I hope when I'm nearing retirement, I'll be able to look back on the deficit as a thing of the distant past.

### **8.5 Final conclusion and contribution of the thesis**

This research project has provided useful data that has responded to the request made by the RSS and ACME (2015), to investigate student experiences in

mathematics and statistics during their educational journey. A distinct course was created using a group of secondary school teachers and FE lecturers, from a wide range of disciplines to construct a course to better prepare year 12 and 13 students in being able to analyse data and think critically. The course presented statistical concepts and procedures in a unique and distinct form, potentially creating a different identity to traditional statistical content found within mathematics courses. Students' attitudes and experiences have been captured throughout this research project, with tentative causal inferences made. In addition, participants on the Pilot Scheme in SA applied to Cardiff University to study a range of HE courses, which include 50% of students from the 2014/15 cohort and also 50% of students from 2015/16 cohort. I have also been informed that several students have applied to and are now studying on Q-Step courses in other Q-Step centres in England. It is hoped that the Pilot Scheme in SA has in some way enabled these young people to realise the exciting nature of statistics, encouraging them to apply for statistics related courses at university.

The main aim of this research project was to generate evidence to explore student attitudes to mathematics and statistics. After careful construction of a contextualised statistics course, a quasi-experiment was then set up in order to investigate the impacts of this course on year 12 and 13 attitudes to mathematics and statistics as well as statistical abilities. Results suggest the course potentially contributed to changes in the students' mathematics attitudes, becoming more positive. In addition, their statistical abilities also seem to have improved, in comparison to the two control groups.

In light of the findings and discussion, recommendations have been made with reference to professional practice and also future research. These included expanding the course to more year 12 and 13 students across Wales, and also to integrate existing plans to increase the numbers of practitioner researchers in numeracy and mathematics to include a training programme to ensure teachers have the right professional skills to deliver the course. In expanding the Pilot Scheme in SA course, this will provide additional research opportunities, which could include more quasi-experiments and if possible RCTs and extended longitudinal studies.

In terms of adding to existing statistics education literature, this research has generated data to explore the impacts of delivering a contextualised statistics course to a group of A' Level students from two local education institutes in the Cardiff region. As well as adding to this field of research, the information produced suggests there are several benefits to A' Level students when they engage with a contextualised statistics course. Many researchers in this field have reported on the negative attitudes towards statistics, especially in HE. However this research has gone one step further, exploring whether a contextualised statistics course can change mathematical and statistical attitudes, as well as critical thinking skills of year 12 and 13 students (Richardson and Woolfolk, 1980; Marsh, 1988; Kitchen *et al.*, 1997; Swan, 2005; Minard, 2013; Ward-Penny *et al.*, 2013; Cole, 2015). There is a well established body of knowledge on mathematics anxiety, however more work needs to be carried out in elucidating the differences between statistical and mathematical anxiety in pre-university students.



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# Appendix

## **Appendix 4.1. Level 3 Pilot in Social Analytics learning outcomes (Unit 1 and 2)**

### **Unit 1 – Social Science in Practice (SSP) Module outline**

This unit includes the following topics:

1. Health and disease
2. Science, technology and the real world
3. Crime and deviance

#### 1. Health and disease

Learners should:

- (a) Explain how health and disease can be measured within and between populations
- (b) Explain the strengths and weaknesses of different methods used to measure health and disease
- (c) Discuss how biological health markers can change within a population over time
- (d) Describe factors that can influence the spread of disease
- (e) Outline the importance of health professionals in maintaining good health within a population
- (f) Discuss the changing role of health professionals over time
- (g) Be able to design relevant research questions and hypotheses to explore issues linked to health and disease
- (h) Perform simple t tests to compare secondary data sets, linked to health and disease

#### 2. Science, technology and the real world

Learners should:

- (a) Describe the importance of scientific research to society
- (b) Outline the major breakthroughs of the 21<sup>st</sup> century, and how these discoveries have affected society
- (c) Discuss the impact of new technologies on the environment
- (d) Be able to carry out a Chi squared test and analysis of variance, linked to science and technology data sets (primary and secondary data)
- (e) Be able to discuss the nature of evidence, to include its reliability and validity

#### 3. Crime and deviance

Learners should:

- (a) Discuss the role of crime within society
- (b) Explore how evidence is used in law
- (c) Explain how criminal punishments have changed over time
- (d) Evaluate the effectiveness of interventions aimed at tackling crime rates
- (e) Be able to perform simple regression analysis, between 2 variables
- (f) Explore concepts linked to causation and correlation

## Unit 2 – Applied Statistics (AP) Module outline

This unit includes the following topics:

1. Psychology of learning
2. Mass media and journalism
3. Becoming an effective researcher

### 1. Psychology of learning

Learners should:

- (a) Be able to discuss how intelligence can be measured
- (b) Outline factors that can influence intelligence, such as diet, gender and genetic makeup
- (c) Evaluate the effectiveness of different learning styles
- (d) Be able to formulate meaningful research questions to explore factors that can influence intelligence
- (e) Carry out primary research to explore factors that can influence intelligence

### 2. Mass media and journalism

Learners should:

- (a) Explore several different types of media used to disseminate current topical news
- (b) Describe how science is reported in the media, and how it has changed over time
- (c) Discuss the power of the media, as a form of societal control
- (d) Explore the future of the media, and its role within society
- (e) Outline the strengths and weaknesses of primary and secondary data

### 3. Becoming an effective researcher

Learners should:

- (a) Develop their presentation skills, which will involve students presenting to their peers
- (b) Have a thorough grounding in the scientific method, to include a discussion of its strengths and weaknesses
- (c) Develop their critical analytical skills, of their own work as well as their peers – in a constructive manner



## **Appendix 4.2. Scheme of Work: Level 3 Pilot in Social Analytics**

Course: **Unit 1 – Social Science in Practise (SSP)**

**Unit 2 – Applied Statistics (AP)**

Scheme of Work **2015/16** (4-6pm)

<u>Week</u>	Date (Week commencing)	Topic		Statistics covered	Notes
		Unit 1 SSP (4-5pm)	Unit 2 AP (5-6pm)		
	05/10	Introduction to the course and designing research questions		Designing research questions	
	12/10				
	19/10	Epidemiology	Genes and learning	Designing research questions and hypothesis testing	
	26/10	Half Term break			
	02/11	Data analysis and visualisation Coursework and presentation guidance		Normal distribution, levels of measurement, SD and Z scores	
	09/11				
	16/11				
	23/11	Gender and Health professionals	Boys vs girls	t tests	
	30/12	Science tech and the real world introduction	Mass media and journalism introduction	t tests	
	07/12	What is science?	Science in the media	t tests	
	14/12	Data collection, visualisation and analysis		Review	Mid-course evaluation
	21/12	Christmas & New Year Break			




### **Appendix 4.3. Lies Damned Lies and Statistics module outline**

#### **Methods of Teaching**

The module will be taught using a blended learning format of lectures, seminars and self-directed work.

Lectures for the module will take place weekly and will provide core information about the critical consumption of quantitative social science evidence. These lectures will be supported by a programme of seminars in which you will be able to practically explore the concepts and techniques taught in the lectures. These seminars will be supervised by a trained graduate teaching assistant and there will be five seminars per semester.

Seminar group lists will be posted on the SOCSI year two noticeboard on the ground floor of the Glamorgan Building and via Learning Central.

Please note that seminar attendance is an essential requirement for this module. If you miss a lecture or seminar then you will have difficulty in completing the assessments. The module delivery team will be happy to help you catch-up if you have a genuine reason for not attending, but do not expect them to give up their time for unexplained absence.

#### **Semester 1 – Lectures**

Week:	Date:	Lecture Topic:	Lecturer:
1	29 Sep	Course Introduction: The use of data in the media	HY
2	6 Oct	Critical Reading: Guidelines and worry questions when evaluating reports (8 Steps)	HY
3	13 Oct	Critical Reading: Guidelines and worry questions when evaluating reports (7 Critical Components)	HY
4	20 Oct	Samples and Populations: Non-sampling errors and an introduction to sampling variability	HY

5	27 Oct	Margin of Error	HY
6	3 Nov	Experiments	WB
7	10 Nov	Observational Studies	WB
8	17 Nov	Risk and assessing differences	MP
9	24 Nov	Statistical significance	MP
10	1 Dec	Assessment week	MP/HY
11	9 Dec	Semester Summary: Report preparation	HY

### Semester 1 – Seminar Programme

*Please see the noticeboard to find out which seminar group you have been allocated to*

Week:	Seminar Topic:	Venue:
1	<b>NO SEMINAR IN WEEK 1</b>	
2	“There are three kinds of lies: lies, damned lies and statistics:” Evaluating media articles using the guidelines and worry questions	Glam
3	<b>NO SEMINAR IN WEEK 3</b>	
4	“Why do they call it common sense? It isn’t that common”: Evaluating the nature of the measurements made or the questions asked	Glam
5	<b>NO SEMINAR IN WEEK 5</b>	
6	“The Mark of a Criminal Record:” Experimental design	Glam
7	<b>NO SEMINAR IN WEEK 7</b>	
8	“Only those who will risk going too far can possibly find out how far they can go:” Using statistical terms for different measurements of risk	Glam
9	<b>NO SEMINAR IN WEEK 9</b>	

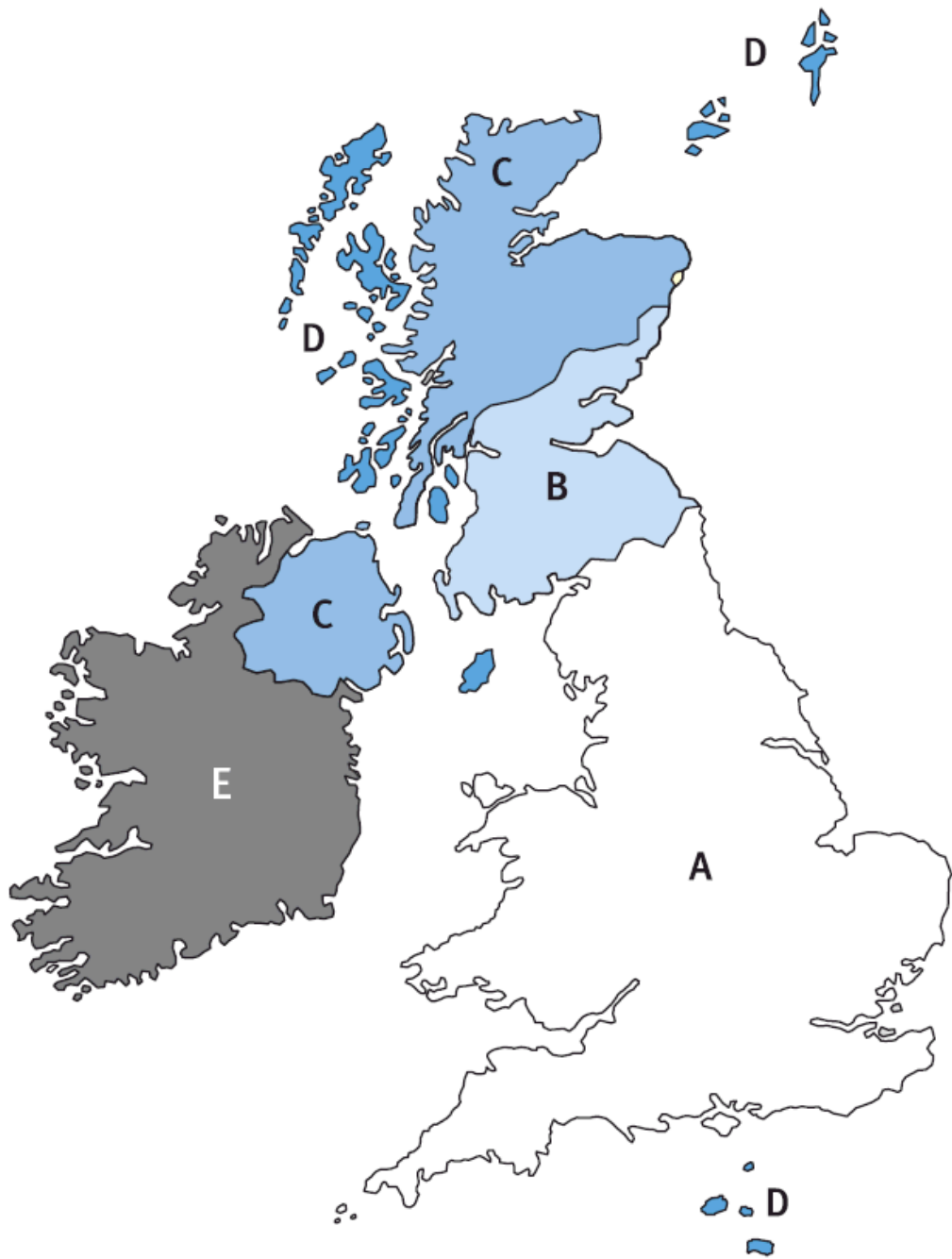
10	In Class Test	Glam
11	<b>NO SEMINAR IN WEEK 11</b>	

## Semester 2 – Lectures

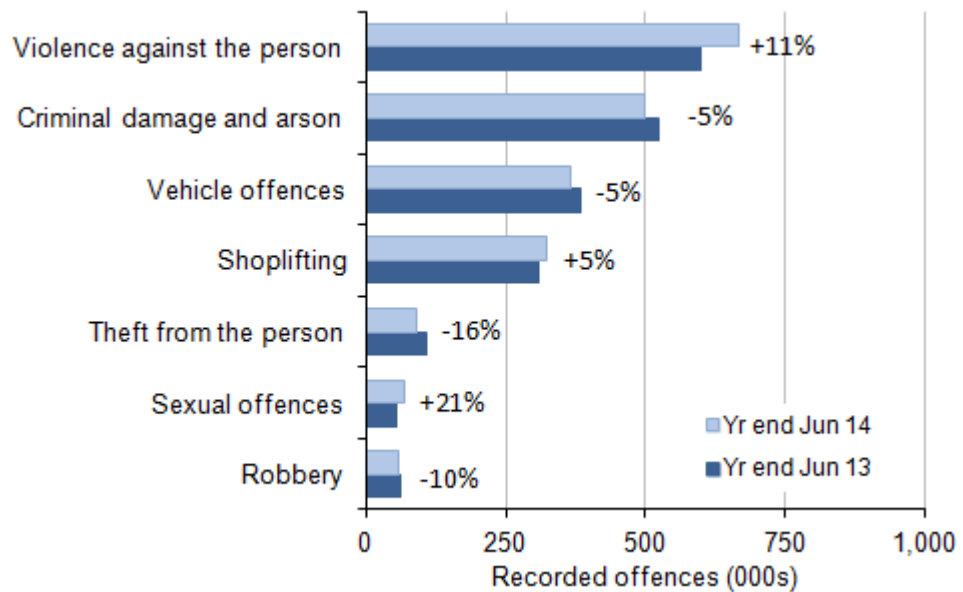
NB: The second semester begins on **Monday 26<sup>th</sup> January 2015**. The first lecture will be held on this date.

Week:	Date:	Lecture Topic:	Lecturer:
1	26 Jan	Data visualisations: understanding plots, graphs and pictures	MP
2	2 Feb	Data visualisations: creating plots, graphs and pictures	MP
3	9 Feb	Writing the news: constructing statistically sound statements	HY
4	16 Feb	Writing the news: constructing media reports	WB
5	23 Feb	Heuristics and fallacies: Probability and confusion of the inverse	LS
6	2 Mar	Heuristics and fallacies: Psychological influences on personal probabilities	LS
7	9 Mar	Unwarranted inferences	HY
8	16 Mar	Coincidences and Clusters	SYC
9	23 Mar	Regression to the Mean	HY
10	20 Apr	Eye Witness Testimony	HY
11	27 Apr	Semester Summary	HY

**Appendix 4.4. Where's the crime at game**



- 1D6
- A = 1+2
- B = 3
- C = 4
- D = 5
- E = 6



Use 2D6 – **each crime recorded = x cases (taken as a mean value from all crime rates in that region)**

Zone Ax = 1000

2-6 = Violence against a person

7-8 = Crime damage and arson  
person

9-12 = Shoplifting

Zone Bx = 15

2-3 = Violence against a person

4-6 = Crime damage and arson  
against a person

7-10 = Shoplifting

11-12 = Sexual offences

damage and arson

Zone Cx = 10

2-5 = Theft from a person

6-8 = Robbery

9-12 = Shoplifting

Zone D x = 5

2-4 = Shoplifting

5-12 = Theft from a

Zone E x = 40

2-5 = Shoplifting

6 = Violence

7-8 = Sexual offences

9-10 = Crime

11 = Robbery

12 = Theft from a person



## Instructions

1. Construct an appropriate table to record crime rates.
2. Using page 1, roll a 1D6 to identify the zone you are recording
3. Now roll 2D6 to identify the type of crime. Record this in your table.
4. Do this 100 times and answer the questions below:

## Questions

1. What are the most frequent crimes for each zone?
2. What are the least frequent crimes for each zone?
3. Why are the crime rates weighted differently for each zone?
4. Why do you think zone A accounts for rolling a 1 and 2 on 1D6?
5. Calculate the percentage or proportion of each crime within each zone – as a function of all crimes for that zone.
6. Which type of crime is common in all zones?
7. Why do you think different zones have different types of crime?
8. Graphically display crime rates for shoplifting, from all zones. Explain the distribution of crime across zones.
9. The value of  $x$  was defined as - **each crime recorded =  $x$  cases (taken as a mean value from all crime rates in that region)**. Explain the potential pitfalls of using a mean value for all crime rates in each region. What other value might you want to use?
10. Do you think there is a correlation between type of crime and the zone it occurs in?

Appendix 4.5. Zin obelisk game

Work started on Aquaday.	The working day has nine Schlibs.
The basic measurement of time in Atlantis is a day.	Day five in the Atlantian week is called Daydoldrum.
The height of the Zin is one hundred feet.	There are three and a half feet in a megalithic yard.
The width of the Zin is ten feet.	Each gang includes two women.
Green has special religious significance on Mermaidday	Each worker takes rest periods during the working day totalling sixteen ponks.

<p>The Zin is built of stone blocks.</p>	<p>There are eight ponks in a schlib.</p>
<p>Each block is one cubic foot.</p>	<p>The Zin is made of green blocks.</p>
<p>A cubitt is a cube, all the sides of which measure one megalithic yard.</p>	<p>At any time when work is taking place, there is a gang of nine people on site.</p>
<p>Day two in the Atlantian week is called Neptiminus.</p>	<p>One member of each gang has religious duties and does not lay blocks.</p>
<p>There are five days in an Atlantian week.</p>	<p>No work takes place on Daydoldrum.</p>
<p>A working day starts at daybreak.</p>	<p>Day three in the Atlantian week is called Sharkday.</p>

Does work take place on Sunday?	Each block costs two gold fins.
What is a Zin?	What is a cubitt?
Only one gang is working on the construction of the Zin.	Day one of the Atlantian week is called Aquaday.
Workers each lay 150 blocks per schlib.	Day four in the Atlantian week is called Mermaidday.
The length of the Zin is fifty feet.	There are eight gold scales in a gold fin.
Which way up does the Zin stand?	An Atlantian day is divided into schlibs and ponks

**Instructions for the task.**

In the ancient city of Atlantis a solid rectangular object called a Zin was built in honour of the goddess Tina.

The structure took less than two weeks to complete.

The task of your team is to determine on which day of the week the obelisk was completed.

You will be given cards with information related to this task.

## **Zin Obelisk Solution**

**Solution from the Maths Challenge Group, Colyton**

**Grammar School**

As a start, we organised the cards into categories:

Facts about the obelisk  
Facts about time measurement  
Facts about workers

We also found that there were a number of cards that were irrelevant to the solution.

Given the dimensions of the obelisk, we found that its volume is  $100 \times 50 \times 10 = 50,000$  cubic feet.  
As each block is 1 cubic foot, this would require 50,000 blocks to make.

As the group size was 9, but one could not work, 8 people would be working on the obelisk.

In addition, as the day was nine schlibs long, but the workers rest for sixteen ponks (which equates to two schlibs), each worker would be building for seven schlibs a day.

They would each be able to lay 150 blocks per schlib, and per day this is  $150 \times 7 = 1050$ .

The whole group would therefore be able to lay  $1050 \times 8 = 8400$  blocks a day.

Consequently, the obelisk would take a total of six days to complete, as in six days they could lay  $8400 \times 6 = 50,400$  blocks (in five days this total would only be 42,000 blocks).

The Atlantian week has 5 days but only 4 of those would be spent working, so the work would be completed on the 2nd day of the 2nd week, which is Neptiminus.

OR another solution presented by Karim from Wilson's School

1. The dimensions of the zin indicate that it contains 50,000 cubic feet of stone blocks.
2. The blocks are 1 cubic foot each, therefore, 50,000 blocks are required.
3. Each worker works 7 schlibs in a day (2 schlibs are devoted to rest).
4. Each worker lays 150 blocks per schlib, therefore each worker lays 1050 blocks per day.
5. There are 8 workers per day, therefore 8,400 blocks are laid per working day.
6. The 50,000th block, therefore, is laid on the sixth working day.
7. Since work does not take place on Daydoldrum, the sixth working day is Neptiminus.



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**Appendix 5.1. ATTITUDES TOWARD MATHEMATICS INVENTORY**

Name \_\_\_\_\_ School \_\_\_\_\_

Teacher \_\_\_\_\_

Directions: This inventory consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Please think about how you feel about each item. Enter the letter that most closely corresponds to how each statement best describes your feelings. Please answer every question.

PLEASE USE THESE RESPONSE CODES:

A – Strongly Disagree

B – Disagree

C – Neutral

D – Agree

E – Strongly Agree

1. Mathematics is a very worthwhile and necessary subject.

2. I want to develop my mathematical skills.

3. I get a great deal of satisfaction out of solving a mathematics problem.

4. Mathematics helps develop the mind and teaches a person to think.

5. Mathematics is important in everyday life.

6. Mathematics is one of the most important subjects for people to study.

7. High school math courses would be very helpful no matter what I decide to study.

8. I can think of many ways that I use math outside of school.

9. Mathematics is one of my most dreaded subjects.

10. My mind goes blank and I am unable to think clearly when working with mathematics.

11. Studying mathematics makes me feel nervous.

12. Mathematics makes me feel uncomfortable.

13. I am always under a terrible strain in a math class.

14. When I hear the word mathematics, I have a feeling of dislike.

15. It makes me nervous to even think about having to do a mathematics problem.

16. Mathematics does not scare me at all.

17. I have a lot of self-confidence when it comes to mathematics.

18. I am able to solve mathematics problems without too much difficulty.
19. I expect to do fairly well in any math class I take.
20. I am always confused in my mathematics class.
21. I feel a sense of insecurity when attempting mathematics.
22. I learn mathematics easily.
23. I am confident that I could learn advanced mathematics.
24. I have usually enjoyed studying mathematics in school.
25. Mathematics is dull and boring.
26. I like to solve new problems in mathematics.
27. I would prefer to do an assignment in math than to write an essay.
28. I would like to avoid using mathematics in college.
29. I really like mathematics.
30. I am happier in a math class than in any other class.
31. Mathematics is a very interesting subject.
32. I am willing to take more than the required amount of mathematics.
33. I plan to take as much mathematics as I can during my education.
34. The challenge of math appeals to me.
35. I think studying advanced mathematics is useful.
36. I believe studying math helps me with problem solving in other areas.
37. I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math.
38. I am comfortable answering questions in math class.
39. A strong math background could help me in my professional life.
40. I believe I am good at solving math problems.
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**Appendix 5.2. CRITICAL THINKING (AGES 12-18)**

Directions: The following statements describe how you might think about certain things in your daily life. Select the answer that corresponds to how often you have done what is described in the last 30 days. For example, if you select 5 under "Always" for an item that means you regularly do what is described in the statement. You always do it.

#	Item	1 Never	2 Rarely	3 Sometimes	4 Often	5 Always
1.	I think of possible results before I take action.					
2.	I get ideas from other people when having a task to do.					
3.	I develop my ideas by gathering information.					
4.	When facing a problem, I identify options.					
5.	I can easily express my thoughts on a problem.					
6.	I am able to give reasons for my					



	opinions.					
7.	It is important for me to get information to support my opinions.					
8.	I usually have more than one source of information before making a decision.					
9.	I plan where to get information on a topic.					
10.	I plan how to get information on a topic.					
11.	I put my ideas in order by importance.					
12.	I back my decisions by the information I got.					
13.	I listen to the ideas of others even if I disagree with them.					
14.	I compare ideas when thinking about a topic.					

Page 1 of 2

#	Item	1 Never	2 Rarely	3 Sometimes	4 Often	5 Always
15.	I keep my mind open to different ideas when planning to make a decision.					
16.	I am aware that sometimes there are no right or wrong answers to a question.					
17.	I develop a checklist to help me think about an issue.					
18.	I can easily tell what I did was right or wrong.					
19.	I am able to tell the best way of handling a problem.					
20.	I make sure the information I use is correct.					

Replicates the Critical Thinking in Everyday Life Scale (Mincemoyer, C., Perkins, D.F., & Munyua, C., 2005).

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**Appendix 5.5.1. Pilot scheme Level-3 Social Analytics mid-course Evaluation Form –**

**Dec 2015**

Please estimate your attendance on this module:	Strongly Agree	Agree	Disagree	Strongly Disagree
0-49%	50-74%	75-100%		
1. The aims and objectives of the course were made clear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. I can see the value of the course to my other studies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. The course covers material in my other studies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. The statistics is linked well with relevant examples	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. The course is sufficiently challenging	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. There is enough hands on work	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. I enjoy the statistical elements of the course	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. The resources for the course are good	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. The course is enjoyable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. A variety of teaching techniques are used	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. The methods used have helped to facilitate my learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. I enjoyed the sessions from guest speakers/postgraduate students	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13. What do you like about this course				
14. What do you dislike about this course?				

15. How could this course be improved?
16. Any other comments?

**Appendix 5.5.2. Pilot scheme Level-3 Social Analytics End of course evaluation**

**form – March 2016**



A step-change in quantitative social science skills  
Funded by the Nuffield Foundation, ESRC and HEFCE



Cardiff School of Social Sciences



Please estimate your attendance on this module:	Strongly Agree    Agree    Disagree    Strongly Disagree			
	0-49%	50-74%	75-100%	
1. The aims and objectives of the course were made clear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. I can see the value of the course to my other studies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. The course covers material in my other studies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. The statistics is linked well with relevant examples	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. The course is sufficiently challenging	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. There is enough hands on work	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. I enjoy the statistical elements of the course	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. The resources for the course are	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. The course is enjoyable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. A variety of teaching techniques are used	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. The methods used have helped to facilitate my learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. I enjoyed the sessions from guest speakers/postgraduate students	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

13. What did you like about this course

14. What did you dislike about this course?

15. How could this course be improved?

16. Are you considering going to university to study? If yes – which one, and which course?

17. Are you going to apply to Cardiff University? If yes – which course?

18. Any other comments?

**Appendix 5.8. Prof Doc Ed - Interview with teaching associate of the pilot scheme in**

**SA**

Crosscheck responses with student feedback from the pilot scheme in SA (student course evaluation forms from December 2015 and March 2016)

Describe the pilot scheme course? What were the course aims?

Teaching strategies used – what worked? What didn't?

Student attitudes and confidence to mathematics/stats and critical thinking – did it change during the course?

Comment on student ability

Did the students enjoy the course?

Notice any difference in the students – linked to their A' Level subject choice? Did this impact on their learning? Could you tell what they were studying?

**Appendix 5.10.1. Student consent form to use data for research purposes**

You are invited to participate in educational research, exploring student attitudes towards mathematics/statistical context rich courses. The research will also explore whether these types of courses can have an impact on other subjects students study post-16.

The data taken from you will be anonymised which means it cannot be traced back to you as an individual, and it will be stored on an encrypted (password protected) USB pen drive. In compliance with the Cardiff School of Social Sciences research ethics committee guidelines; anonymised student data will be kept for a minimum of 5 years.

By signing this document you agree that your anonymised data can be used for research purposes.

Information on student data to be collected

Research data will include the following:

Evaluation of student progress in their mathematical/statistical abilities using a series of formative tests and worksheets (“real life mathematics”). Student marks will be expressed as raw marks, and as a percentage.

Evaluation of student progress in their A’ Levels, comparing their predicted and actual AS/A’ Level grades. This will be coded/transformed into ordinal data.

Exploration of student attitudes to real life maths before and after the pilot scheme. Short answer responses to a series of exploratory questions.

Investigate students intended and actual destinations after their AS and A’ Level courses.

If you require further explanation about any of the information provided here please contact the course leader, Rhys Jones (see end of form for contact details).

Thank you

Student Title: Mr / Miss / Ms First Name:.....

Surname or Family Name:.....

School or college name: .....

Year 12/13: .....

Date of Birth: (DD/MM/YY) ...../...../..... Age:..... Male Female  
(please tick)

Student signature: .....

Please return to: Rhys Jones, Lecturer in Quantitative Methods FE, Cardiff School of Social Sciences

Glamorgan Building 1.11

King Edward VII Avenue

Cardiff

CF10 3WT

Email – jonesrc10@cardiff.ac.uk

**Appendix 5.10.2. Teacher consent form to use personal data for research**

**purposes - Pilot Scheme Level-3 in Social Analytics participants**

During the Pilot scheme in social analytics, certain forms of data will be used for research purposes. Part of the research will involve comparing student comments and also attainment in formative statistics tests, between different groups. For example, students taking part on the pilot scheme will be compared to matched students in their schools/colleges, studying similar courses (called the control group). By signing this document you agree to assist the course leader in collecting data from both research groups, including predicted and final A 'Level grades. Your comments on perceived impacts on students taking the pilot scheme in social analytics may also be asked for in the future. All data collected will be anonymised and stored on an encrypted USB pen drive. In compliance with the Cardiff School of Social Sciences research ethics committee guidelines; anonymised student data will be kept for a minimum of 5 years. We also require a senior member of staff within your institution sign the document. If you require any further information please contact the course leader, Rhys Jones (see bottom of form for contact details).

Thank you

Teacher Name and signature:.....

Position:.....

Email:  
.....

School or college name: .....

Senior member of staff name and signature: .....

Email:  
.....

Please return to: Rhys Jones, Lecturer in Quantitative Methods FE, Cardiff School of Social Sciences

Glamorgan Building 1.11

King Edward VII Avenue

Cardiff

CF10 3WT

Email – jonesrc10@cardiff.ac.uk



## Appendix 6 ATMI and Critical thinking questionnaire results

### ATMI results for Experimental group 1

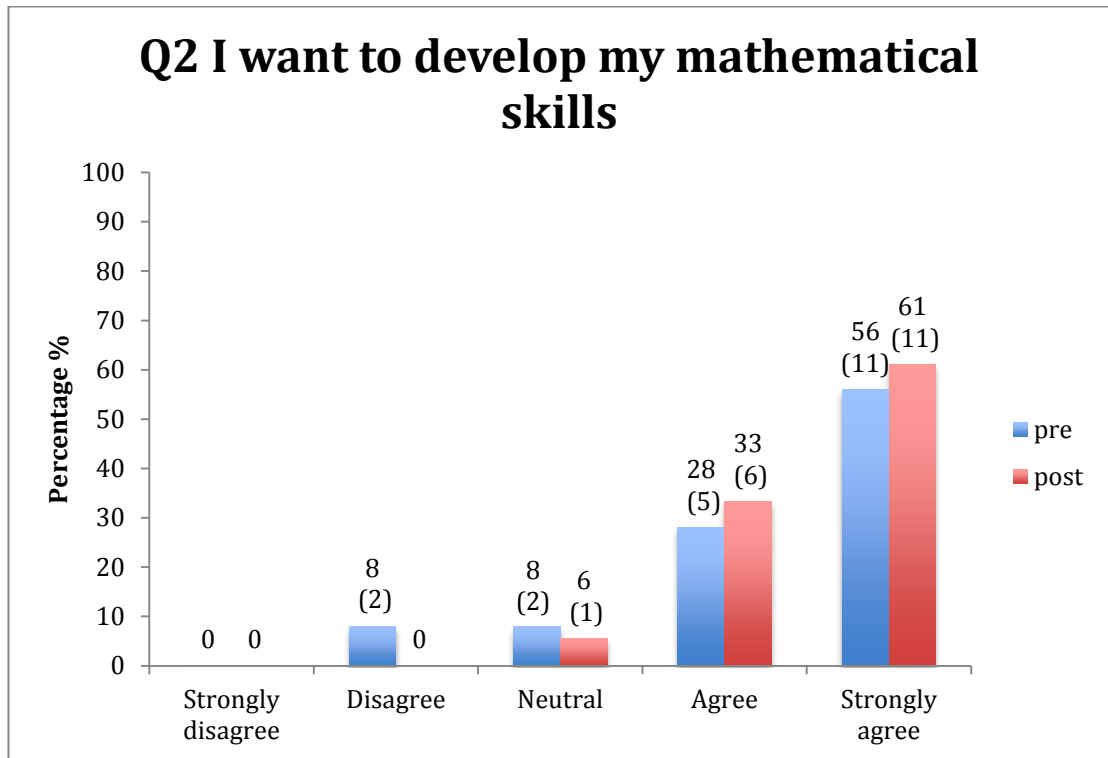


Figure 1 ATMI questionnaire responses for experimental group 1: I want to develop my mathematical skills (expressed as a percentage and also numbers of students in brackets).

Students in experimental group 1 revealed a slight shift in their desire to develop their mathematical skills in the strongly disagree and disagree options, with 8% disagreeing with Q2 pre intervention, leading to 0% disagreeing, post intervention.

Students agreeing and strongly agreeing with Q2 stayed roughly the same, with pre intervention values being 28% and 56%, changing to 33% and 61%, post intervention. The percentage of students who gave a neutral response changed from 8%, pre intervention to 6%, post intervention.

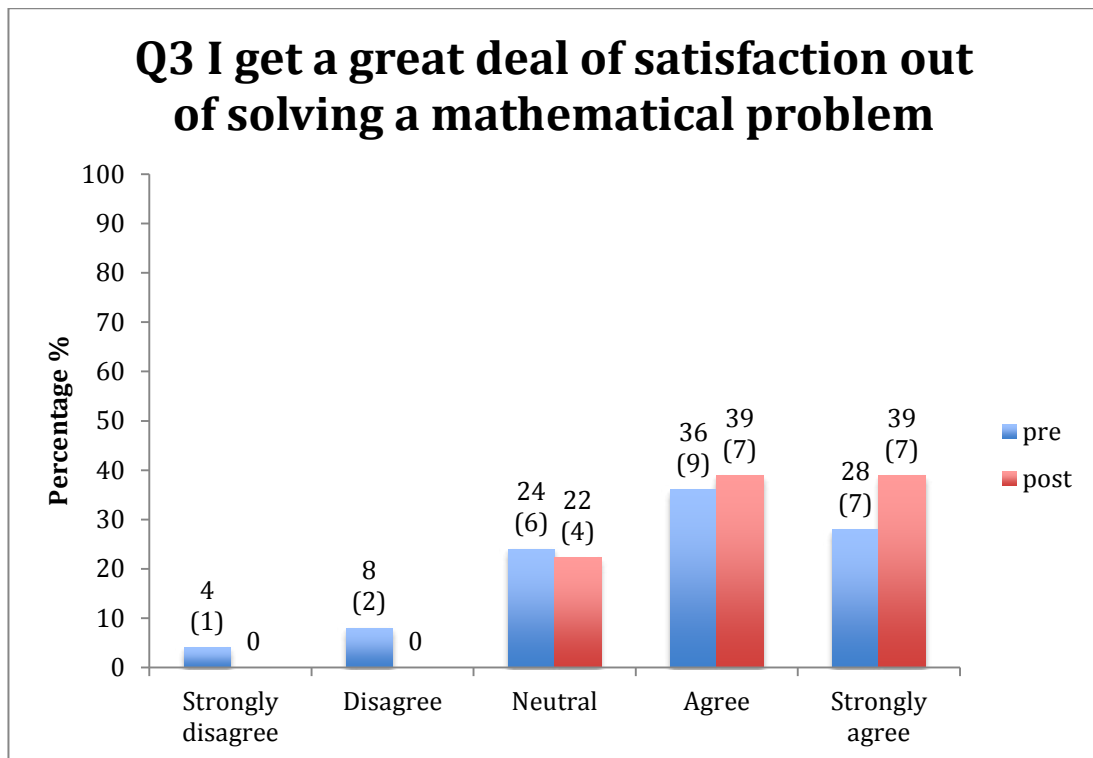


Figure 2 ATMI questionnaire responses for experimental group 1: I get a great deal of satisfaction out of solving a mathematical problem (expressed as a percentage and also numbers of students in brackets).

Student satisfaction in experimental group 1, with solving mathematical problems, also revealed a shift in the strongly disagree and disagree options, with 4% strongly disagreeing and 8% disagreeing pre intervention, changing to 0% strongly disagreeing or disagreeing, post intervention. Students agreeing or strongly agreeing stayed roughly the same, with pre intervention percentages being 36% and 28%, changing to 39% and 39%, post intervention. The percentage of individuals who gave a neutral response changed from 24%, pre intervention to 22%, post intervention.

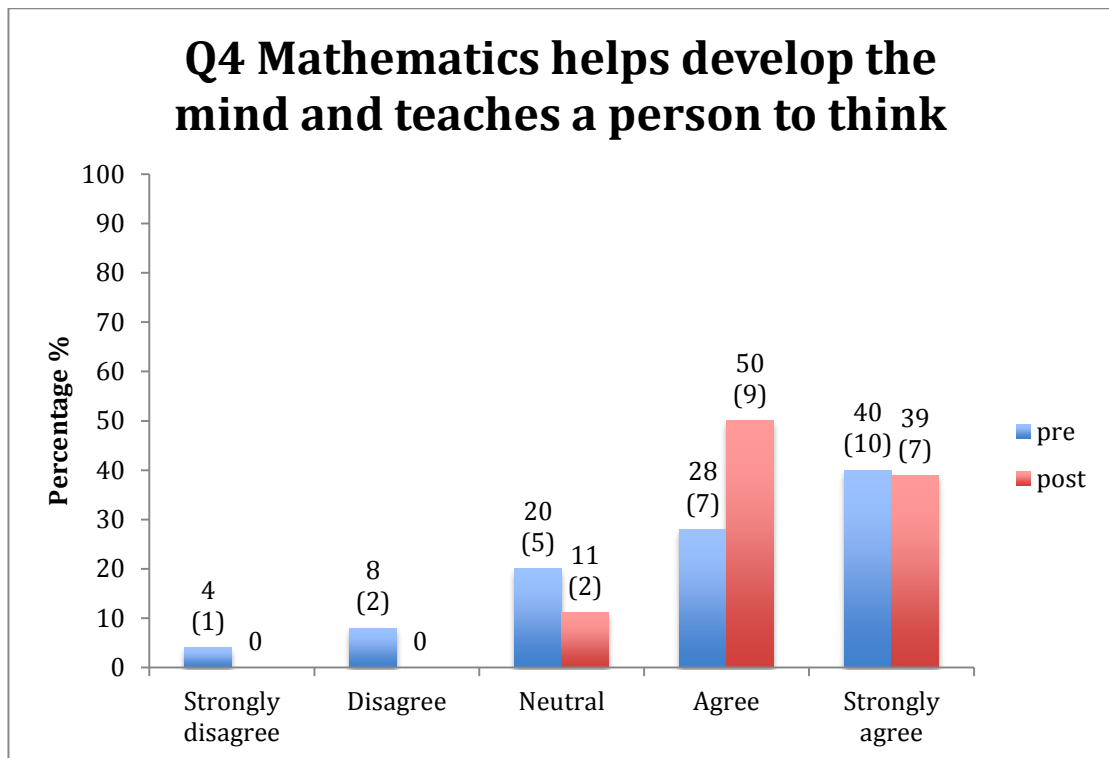


Figure 3 ATMI questionnaire responses for experimental group 1: Mathematics helps develop the mind and teaches a person to think (expressed as a percentage and also numbers of students in brackets).

Student perceptions on the value of mathematics as a way to teach people to think, in experimental group 1, revealed a shift in attitude, with 4% strongly disagreeing and 8% disagreeing, pre intervention. Post intervention, this changed to 0% for both options. Students agreeing and strongly agreeing with Q4 stayed roughly the same, with pre intervention percentages being 28% and 40%, changing to 50% and 39%, post intervention. The percentage of individuals who gave a neutral response changed from 20%, pre intervention to 11%, post intervention.

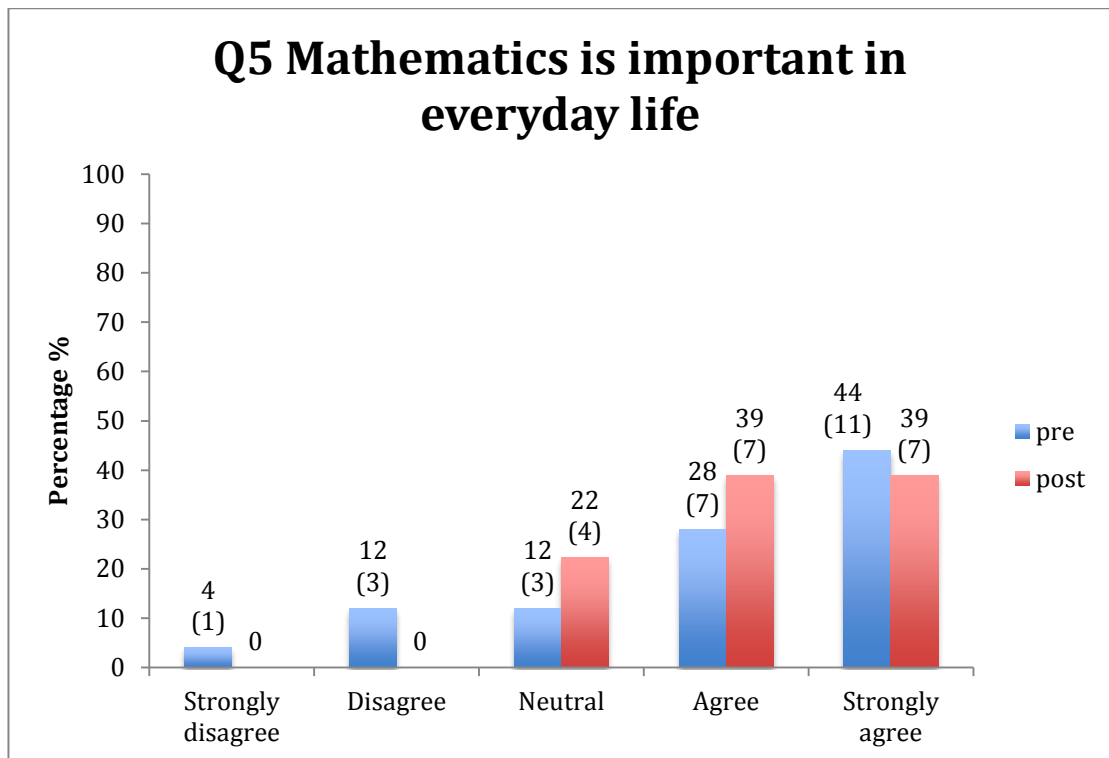


Figure 4 ATMI questionnaire responses for experimental group 1: Mathematics is important in everyday life (expressed as a percentage and also numbers of students in brackets).

Student perception on the importance of mathematics in everyday life in experimental group 1 revealed a shift in attitude, with 4% strongly disagreeing and 12% disagreeing, pre intervention. Post intervention, this changed to no students. Students agreeing and strongly agreeing with Q5 revealed changes, with pre intervention percentages being 28% and 44%, changing to 39% and 39%, post intervention. The percentage of individuals who gave a neutral response changed from 12%, pre intervention to 22%, post intervention.

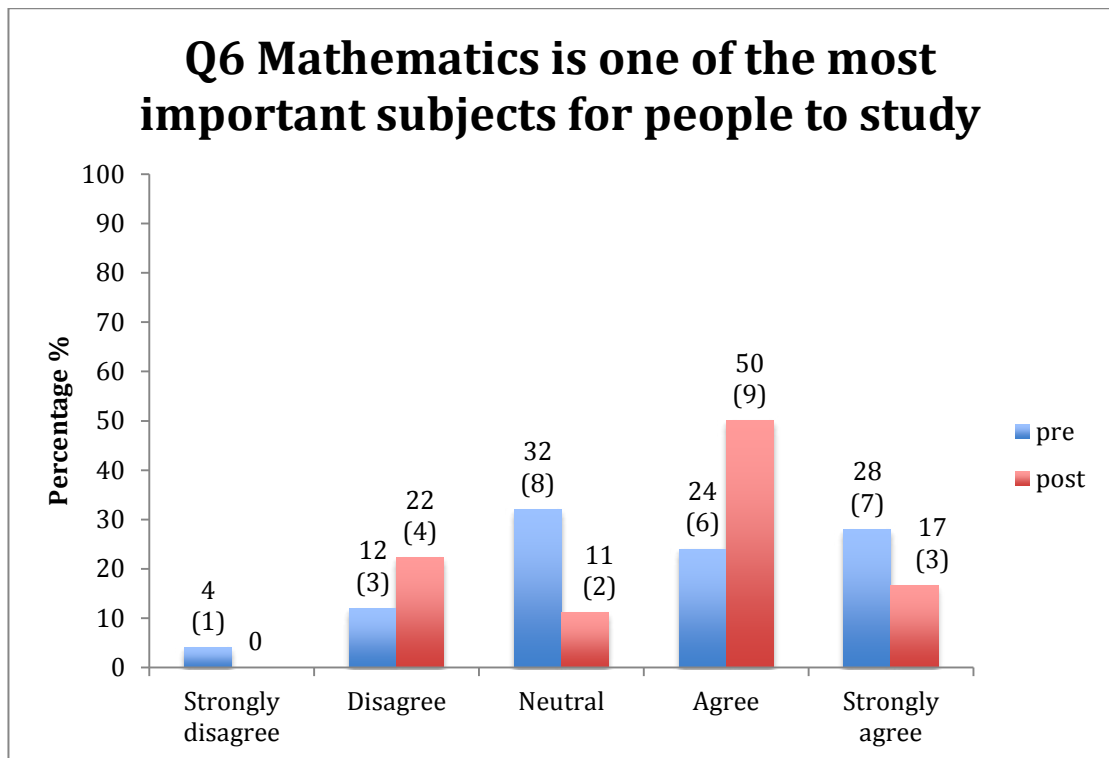


Figure 5 ATMI questionnaire responses for experimental group 1: Mathematics is one of the most important subjects for people to study (expressed as a percentage and also numbers of students in brackets).

Student perception on mathematics being viewed as one of the most important subjects for people to study in experimental group 1 in the strongly disagree and disagree options, revealed a shift in attitude, with 4% strongly disagreeing and 12% disagreeing, pre intervention. Post intervention this changed to 0% strongly disagreeing and 22% disagreeing. Students agreeing and strongly agreeing with Q6 saw some movement, with pre intervention percentages being 24% and 28%, changing to 50% and 17%, post intervention. The percentages of individuals who gave a neutral response changed from 32%, pre intervention to 11%, post intervention.

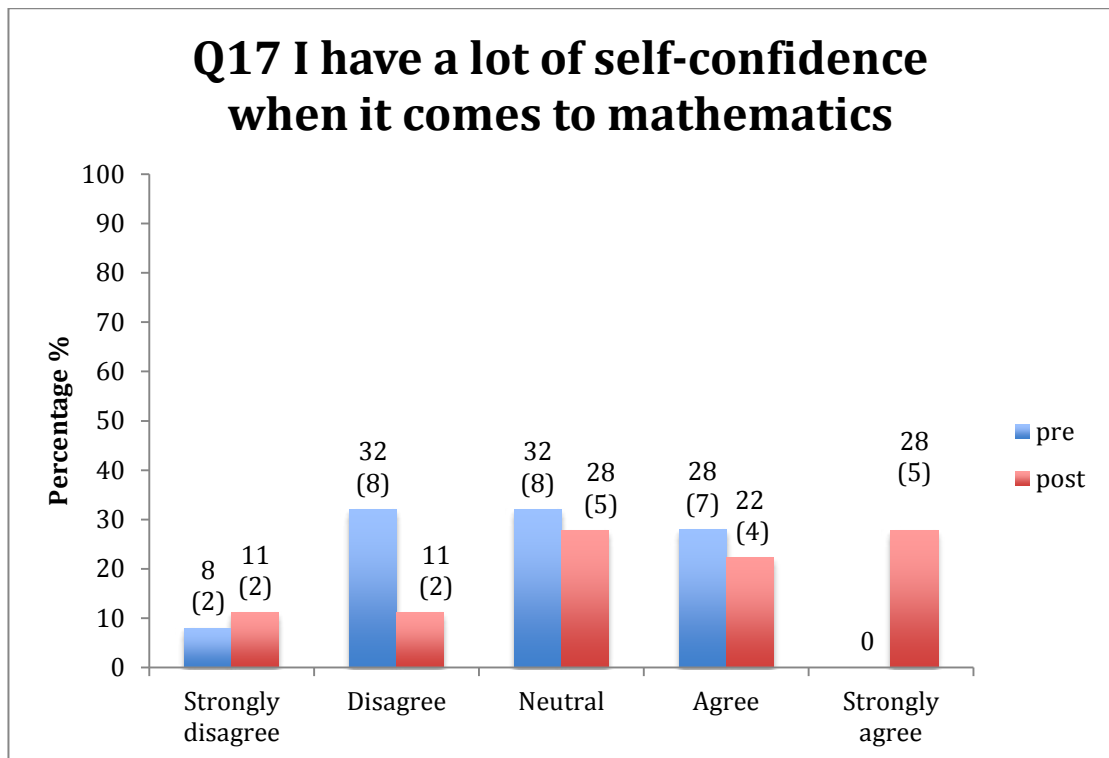


Figure 6 ATMI questionnaire responses for experimental group 1: I have a lot of self-confidence when it comes to mathematics (expressed as a percentage and also numbers of students in brackets).

Student self-confidence when it comes to mathematics in experimental group 1 in the strongly disagree and disagree options, revealed a shift in attitude, with 8% strongly disagreeing and 32% disagreeing, pre intervention. Post intervention, this changed to 11% strongly disagreeing, whereas students disagreeing revealed a decrease to 11%. Students agreeing and strongly agreeing with Q17 revealed differences, with pre intervention percentages being 28% and 0%, changing to 22% and 28%, post intervention. The percentage of individuals who gave a neutral response changed from 32%, pre intervention to 28%, post intervention.

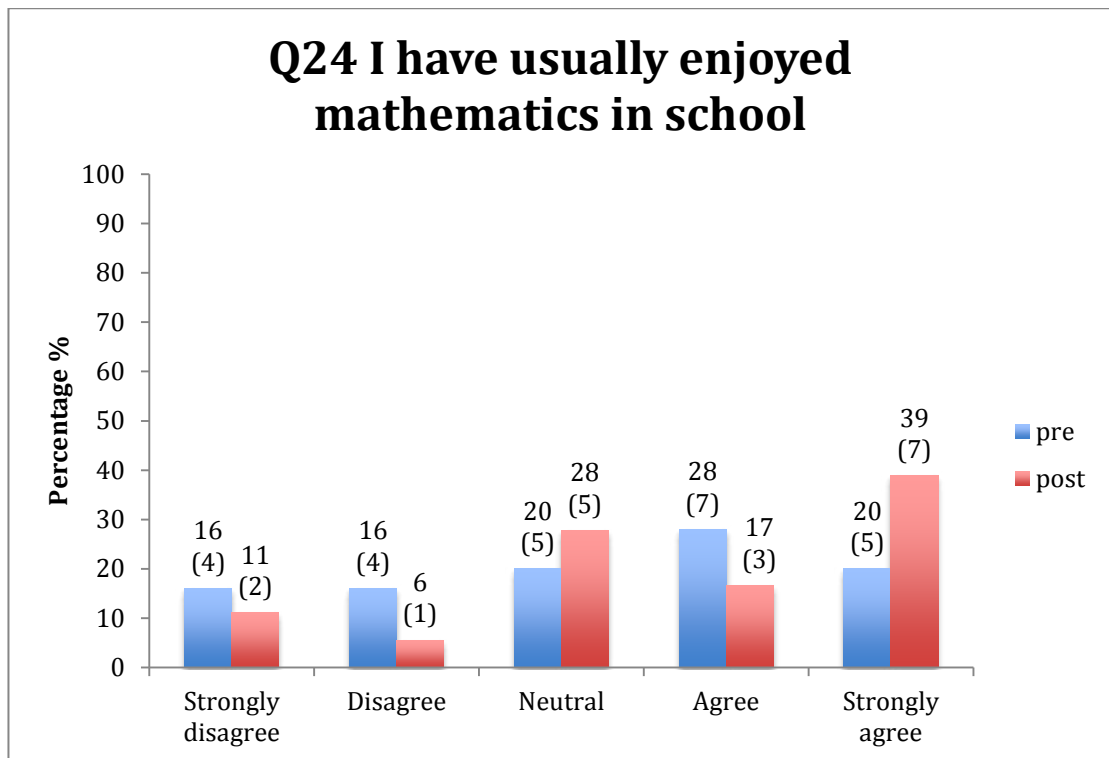


Figure 7 ATMI questionnaire responses for experimental group 1: I have usually enjoyed mathematics in school (expressed as a percentage and also numbers of students in brackets).

Student enjoyment with mathematics in school in experimental group 1 in the strongly disagree and disagree options, revealed a shift in attitude, with 16% strongly disagreeing and 16% disagreeing, pre intervention. Post intervention, this changed to 11% strongly disagreeing and 6% disagreeing. Students agreeing and strongly agreeing with Q24 revealed changes, with pre intervention percentages being 28% and 20%, changing to 17% and 39%, post intervention. The percentage of individuals who gave a neutral response changed from 20%, pre intervention to 28%, post intervention.

## ATMI results for control group 2

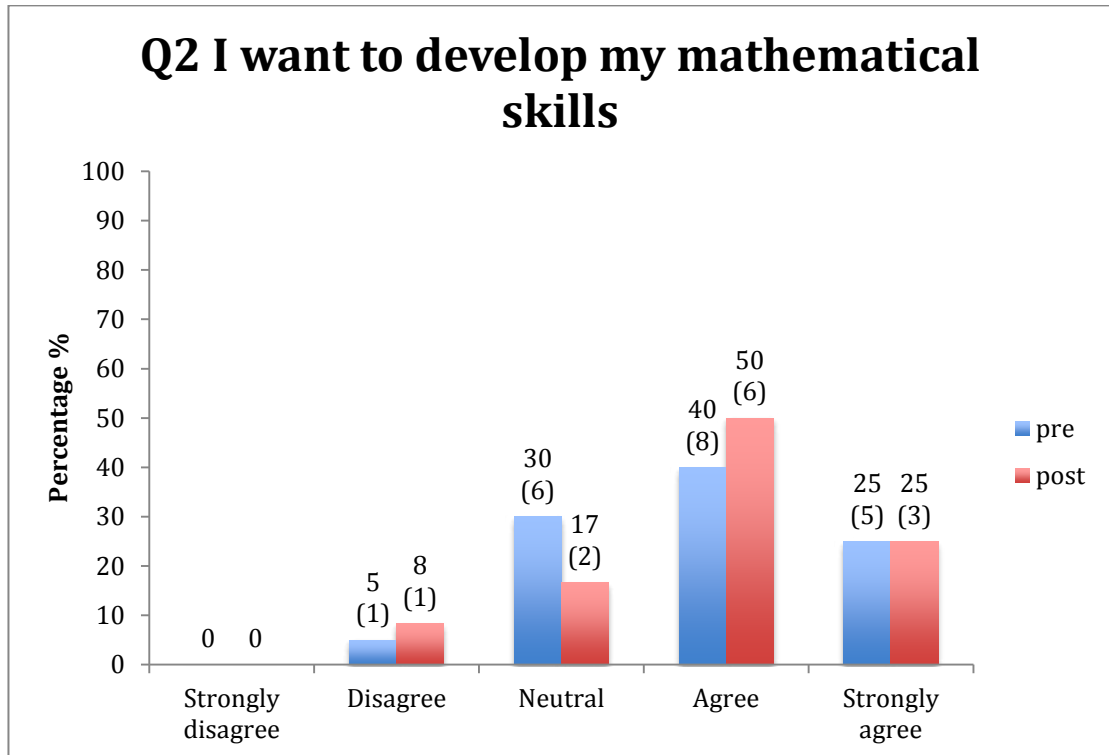


Figure 8 ATMI questionnaire responses for control group 2: I want to develop my mathematical skills (expressed as a percentage and also numbers of students in brackets).

Students in control group 2 revealed little change in their desire to develop their mathematical skills in the strongly disagree and disagree options, with 0% strongly disagreeing and 5% disagreeing pre intervention, staying the same at 0% for strongly disagreeing and increasing to 8% disagreeing, post intervention. Students agreeing and strongly agreeing with Q2 saw some changes, with pre intervention percentages being 40% and 25%, changing to 50% and staying the same at 25%, post intervention. The percentage of individuals who gave a neutral response changed from 30%, pre intervention to 17%, post intervention.



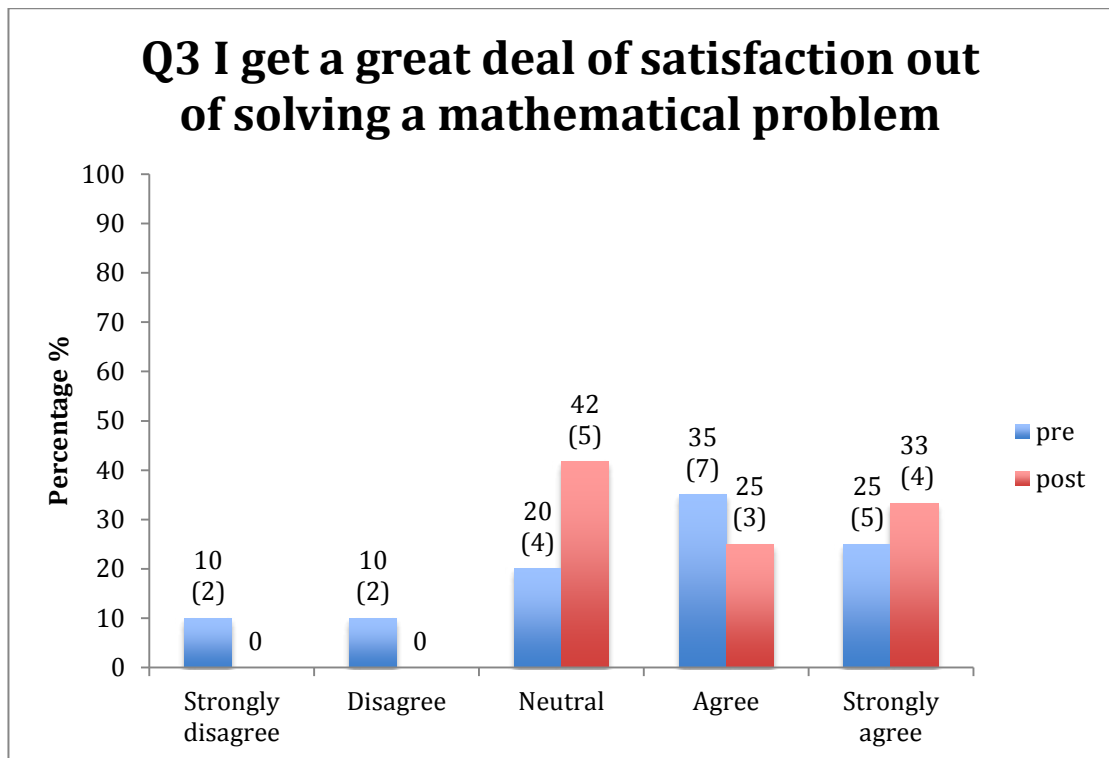


Figure 9 ATMI questionnaire responses for control group 2: I get a great deal of satisfaction out of solving a mathematical problem (expressed as a percentage and also numbers of students in brackets).

Student satisfaction with solving mathematical problems in control group 2 in the strongly disagree and disagree options, revealed a change in the strongly disagree and disagree options, with 10% strongly disagreeing and 10% disagreeing pre intervention, changing to 0% for both categories post intervention. Students agreeing and strongly agreeing with Q3 revealed changes, with pre intervention percentages being 35% and 25%, changing to 25% and 33%, post intervention. The percentage of individuals who gave a neutral response increased from 20%, pre intervention to 42%, post intervention.

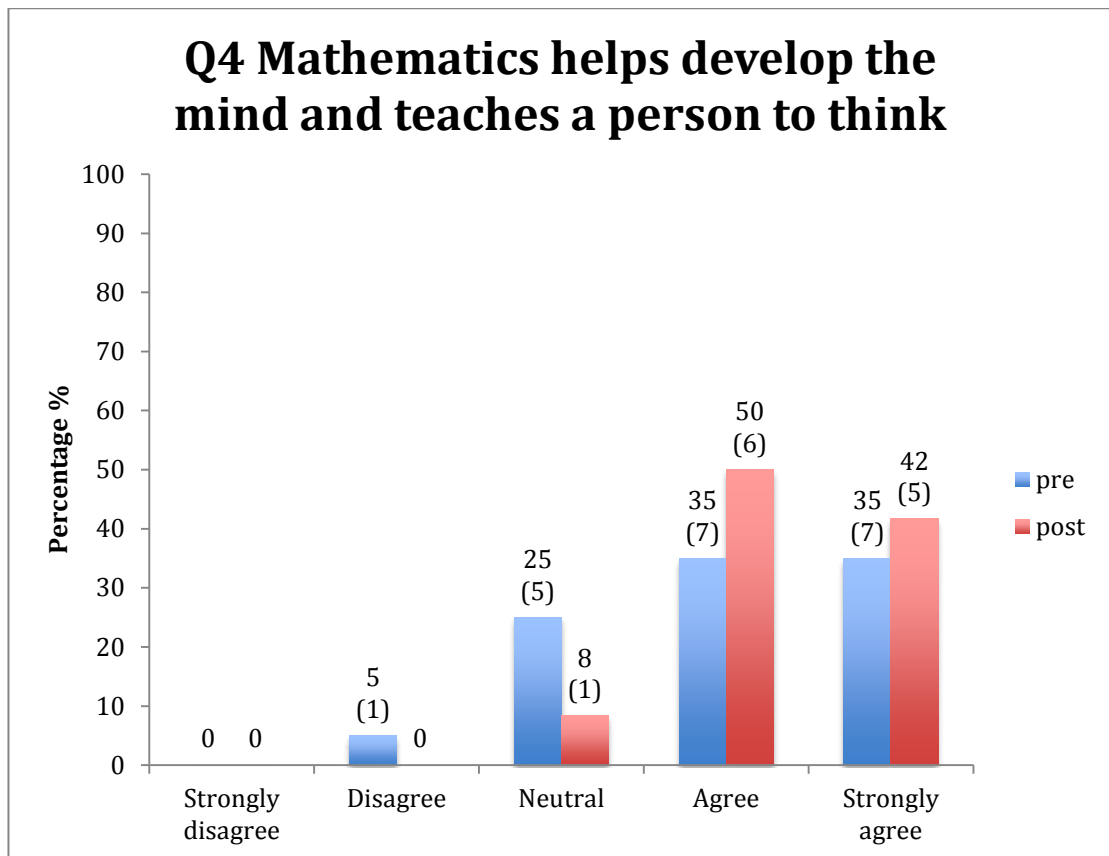


Figure 10 ATMI questionnaire responses for control group 2: Mathematics helps develop the mind and teaches a person to think (expressed as a percentage and also numbers of students in brackets).

Student perception on the value of mathematics as a way to teach people to think in control group 2 in the strongly disagree and disagree options, revealed a slight shift in attitude, with 0% strongly disagreeing and 5% disagreeing, pre intervention. Post intervention, this changed to 0% for both options. Students agreeing and strongly agreeing with Q4 revealed moderate changes, with pre intervention percentages being 35% and 35%, changing to 50% and 42%, post intervention. The percentage of individuals who gave a neutral response changed from 25%, pre intervention to 8%, post intervention.

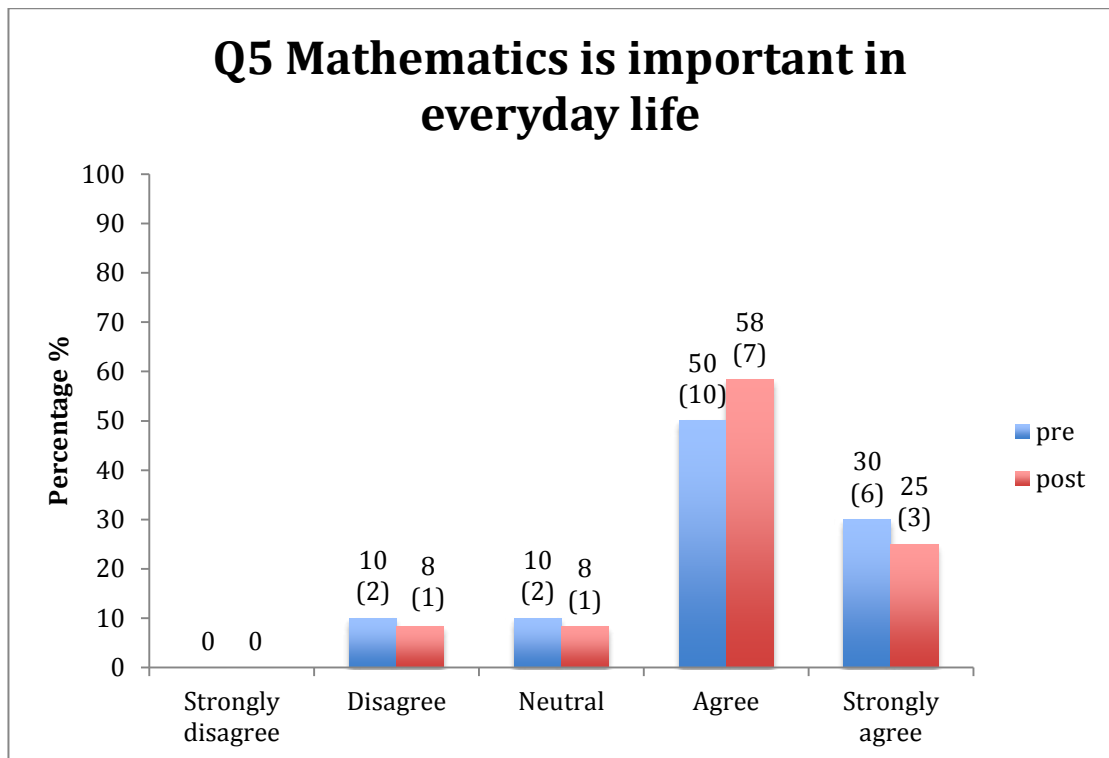


Figure 11 ATMI questionnaire responses for control group 2: Mathematics is important in everyday life (expressed as a percentage and also numbers of students in brackets).

Student perception on the importance of mathematics in everyday life in control group 2 in the strongly disagree and disagree options, revealed a slight shift in attitude, 0% strongly disagreeing and 10% disagreeing, pre intervention. Post intervention, this stayed the same for the strongly agreeing option, although the number of students disagreeing dropped slightly to 8%. Students agreeing and strongly agreeing with Q5 changed somewhat, with pre intervention percentages being 50% and 30%, changing to 58% and 25%, post intervention. The percentages of individuals who gave a neutral response changed from 10%, pre intervention to 8%, post intervention.

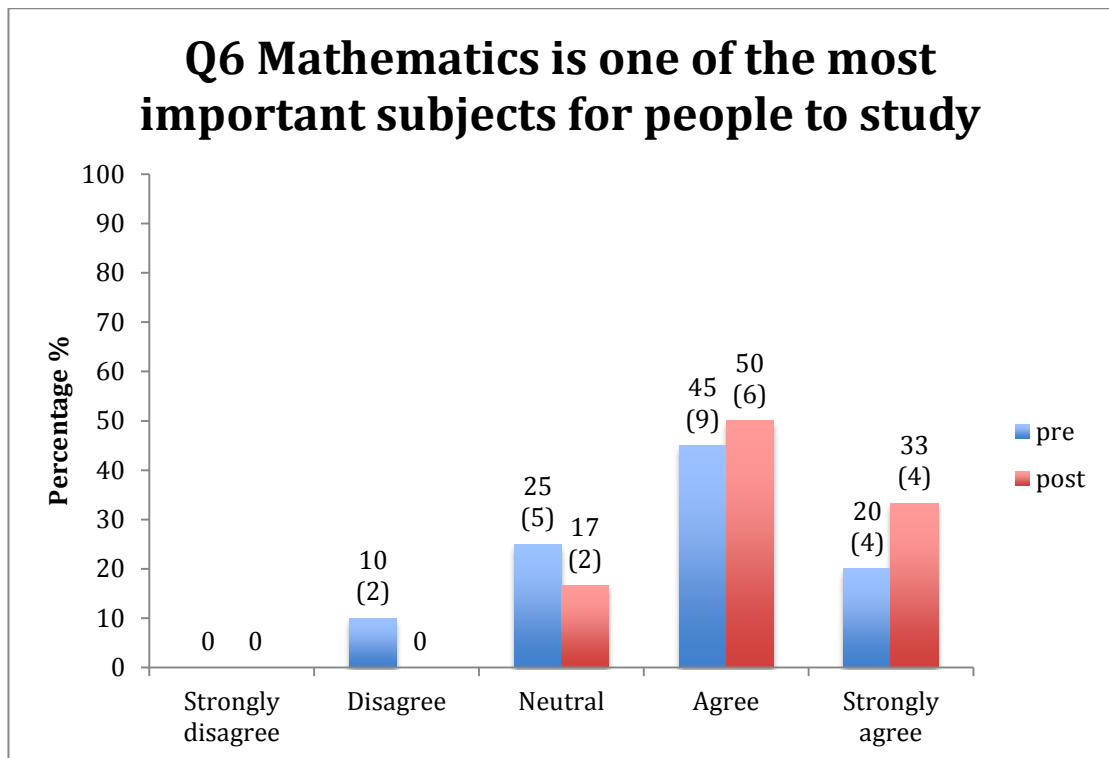


Figure 12 ATMI questionnaire responses for control group 2: Mathematics is one of the most important subjects for people to study (expressed as a percentage and also numbers of students in brackets).

Student perception on mathematics being viewed as one of the most important subjects for people to study in control group 2 in the strongly disagree and disagree options, revealed a slight shift in attitude, with 0% strongly disagreeing and 10% disagreeing, pre intervention. Post intervention, this stayed the same for the strongly agree option, whereas participants selecting the disagree option changed to 0%. Students agreeing and strongly agreeing with Q6 saw some movement, with pre intervention percentages being 45% and 20%, changing to 50% and 33%, post intervention. The percentage of individuals who gave a neutral response changed from 25%, pre intervention to 17%, post intervention.

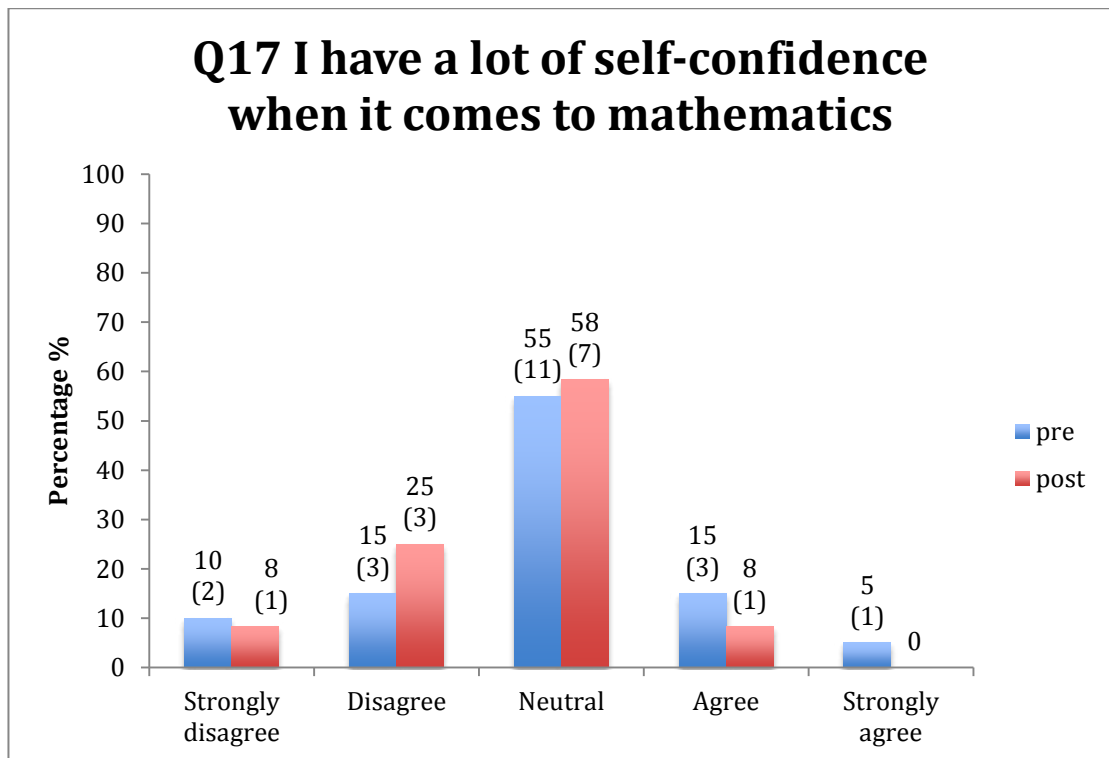


Figure 13 ATMI questionnaire responses for control group 2: I have a lot of self-confidence when it comes to mathematics (expressed as a percentage and also numbers of students in brackets).

Student self-confidence when it comes to mathematics in control group 2 revealed a small change in attitude in the strongly disagree and disagree options, with 10% strongly disagreeing and 15% disagreeing, pre intervention. Post intervention, this changed to 8% strongly disagreeing and 25% disagreeing. Students agreeing and strongly agreeing with Q17 revealed small changes, with pre intervention percentages being 15% and 5%, changing to 8 % and 0, post intervention. The percentage of individuals who gave a neutral response changed from 55%, pre intervention to 58%, post intervention.

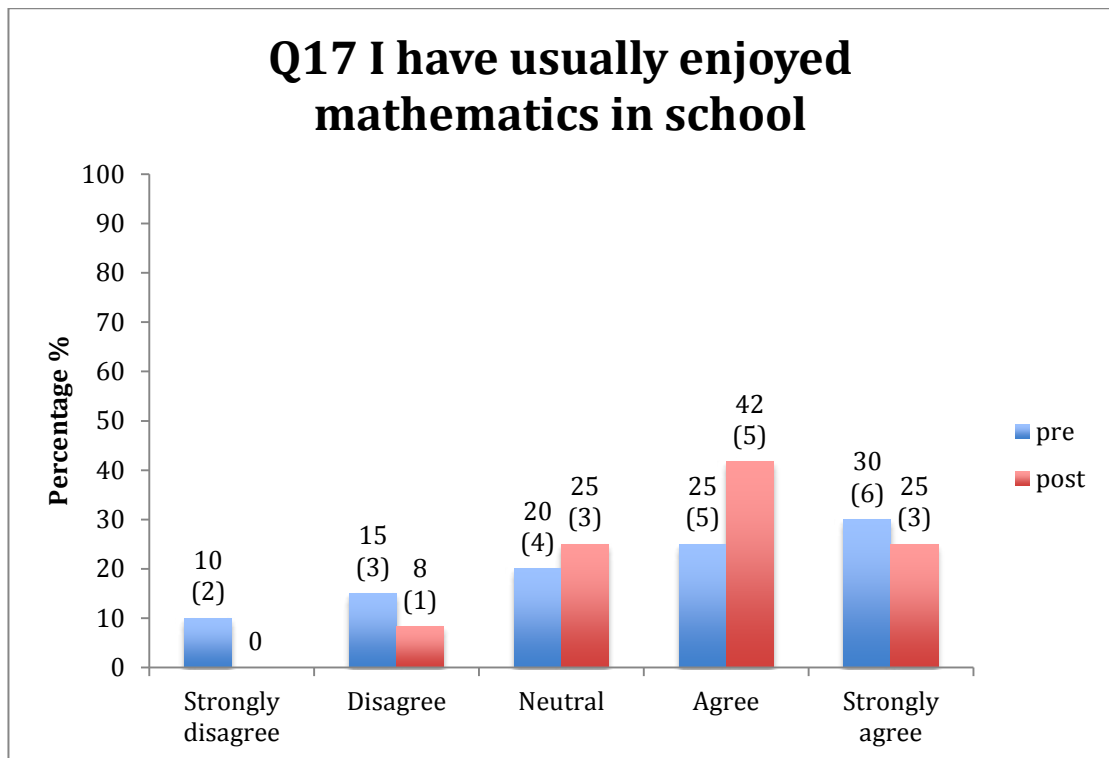


Figure 14 ATMI questionnaire responses for control group 2: I have usually enjoyed mathematics in school (expressed as a percentage and also numbers of students in brackets).

Student enjoyment with mathematics in school in control group 2 in the strongly disagree and disagree options, revealed a shift in attitude, with 10% strongly disagreeing and 15% disagreeing, pre intervention. Post intervention, this changed to 0% strongly disagreeing and 8% of students disagreeing. Students agreeing and strongly agreeing with Q17 revealed some changes, with pre intervention percentages being 25% and 30% changing to 42% and 25%, post intervention. The percentage of individuals who gave a neutral response changed slightly from 20%, pre intervention to 25%, post intervention.

### ATMI results for control group 3

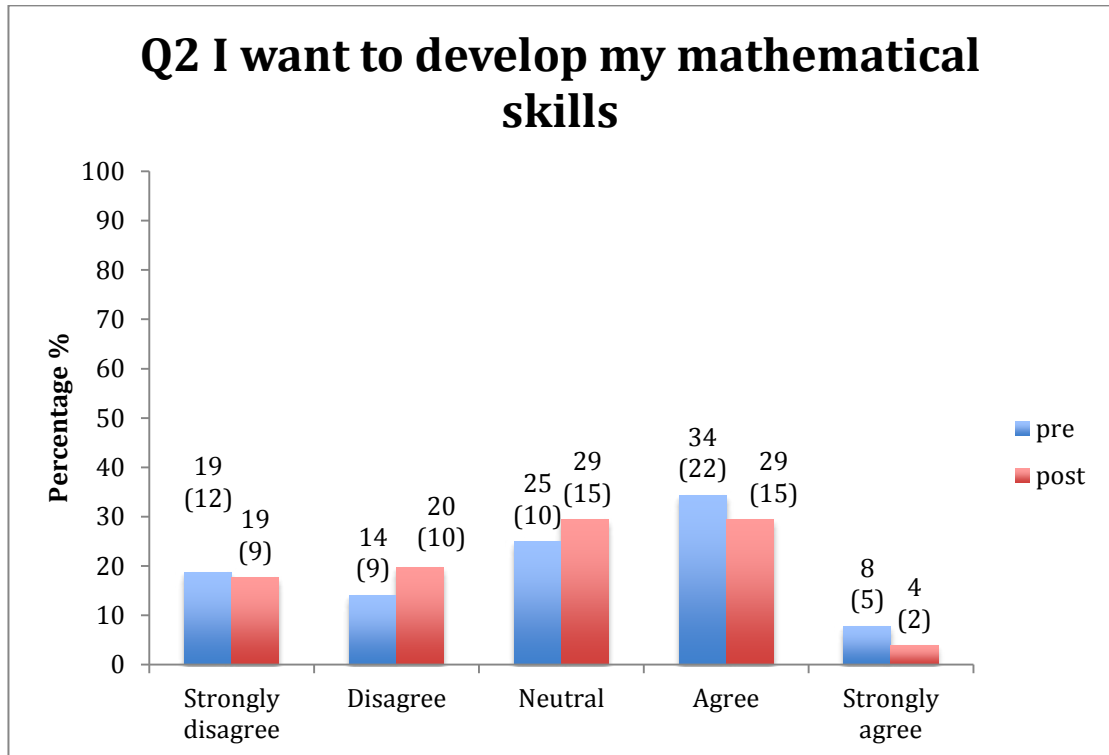


Figure 15 ATMI questionnaire responses for control group 3: I want to develop my mathematical skills (expressed as a percentage and also numbers of students in brackets).

Students in control group 3 revealed some changes in their desire to develop their mathematical skills in the strongly disagree and disagree options, with 19% strongly disagreeing and 14% disagreeing pre intervention, staying the same at 19% strongly disagreeing and increasing to 20% disagreeing, post intervention. Students agreeing and strongly agreeing with Q2 changed somewhat, with pre intervention percentages being 34% and 8%, changing to 29% and 4%, post intervention. The percentage of individuals who gave a neutral response changed from 25%, pre intervention to 29%, post intervention.

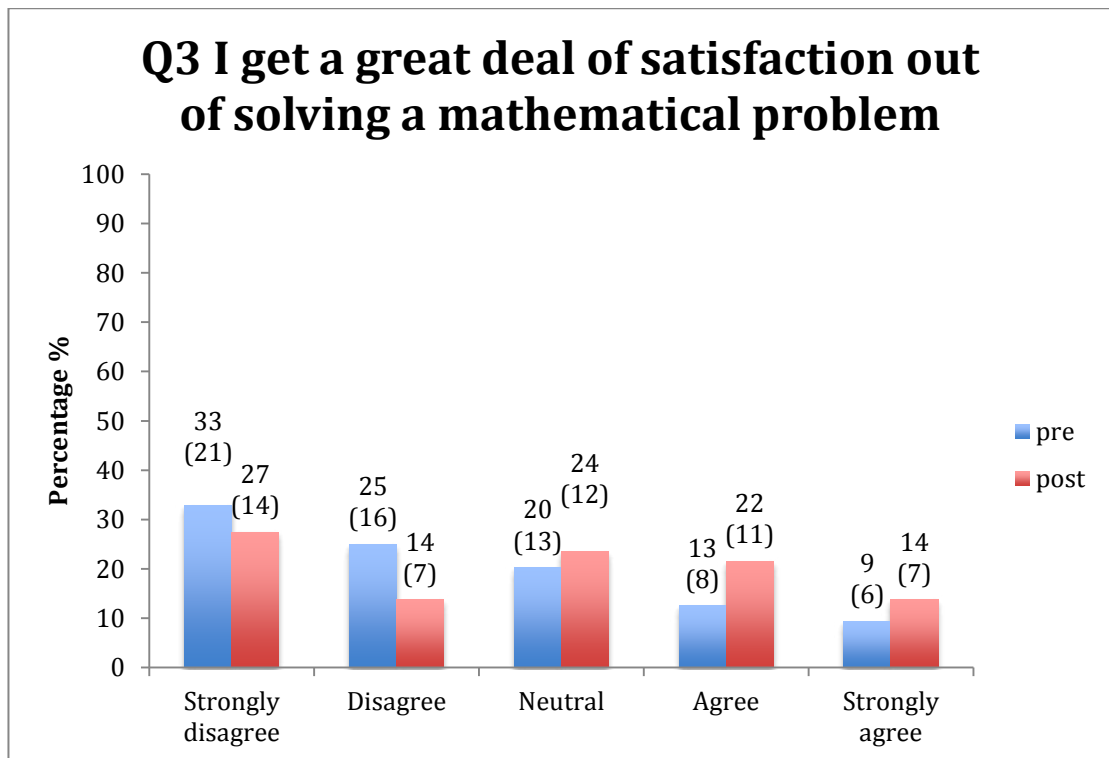


Figure 16 ATMI questionnaire responses for control group 3: I get a great deal of satisfaction out of solving a mathematical problem (expressed as a percentage and also numbers of students in brackets).

Student satisfaction with solving mathematical problems in control group 3 in the strongly disagree and disagree options, revealed changes, with 33% strongly disagreeing and 25% disagreeing pre intervention, changing to 27% strongly disagreeing and 14% disagreeing post intervention. Students agreeing and strongly agreeing revealed differences, with pre intervention percentages being 13% and 9%, changing to 22% and 14%, post intervention. The percentage of individuals who gave a neutral response changed from 20%, pre intervention to 24%, post intervention.



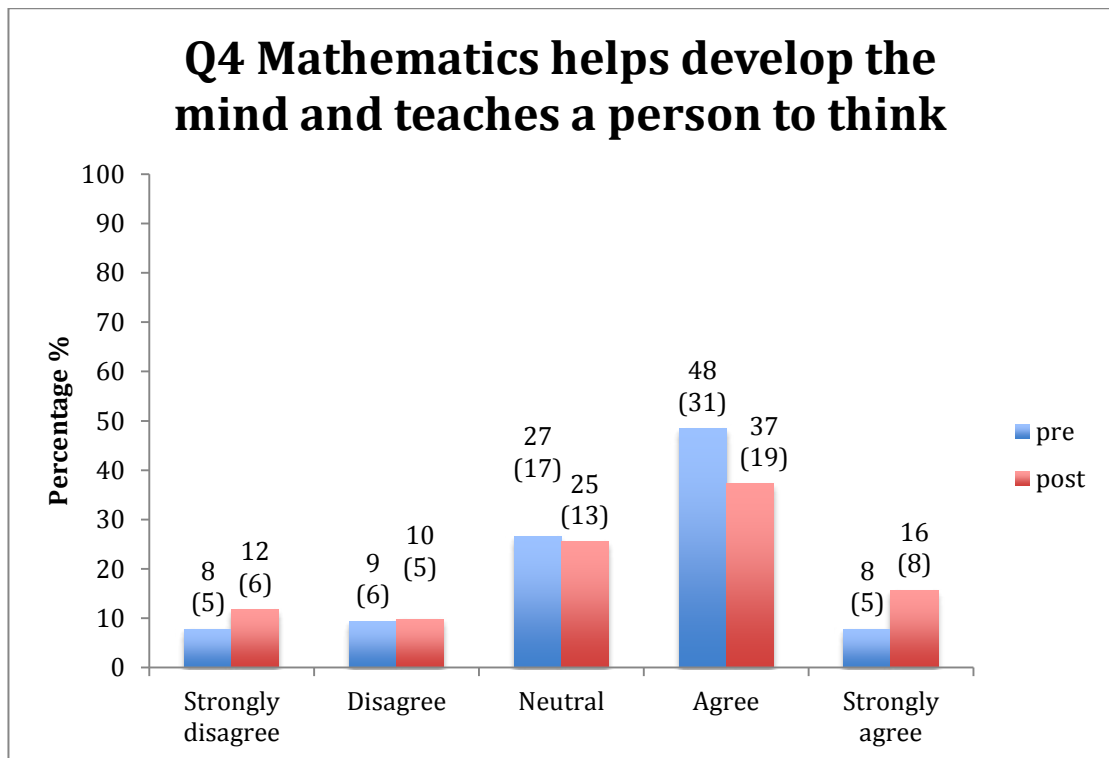


Figure 17 ATMI questionnaire responses for control group 3: Mathematics helps develop the mind and teaches a person to think (expressed as a percentage and also numbers of students in brackets).

Student perception on the value of mathematics as a way to teach people to think in control group 3 in the strongly disagree and disagree options, revealed a slight shift in attitude, with 8% strongly disagreeing and 9% disagreeing, pre intervention. Post intervention, this increased to 12% strongly disagreeing and 10% disagreeing. Students agreeing and strongly agreeing with Q4 changed somewhat, with pre intervention percentages being 48% and 8%, changing to 37% and 16%, post intervention. The percentage of individuals who gave a neutral response changed from 27%, pre intervention to 25%, post intervention.

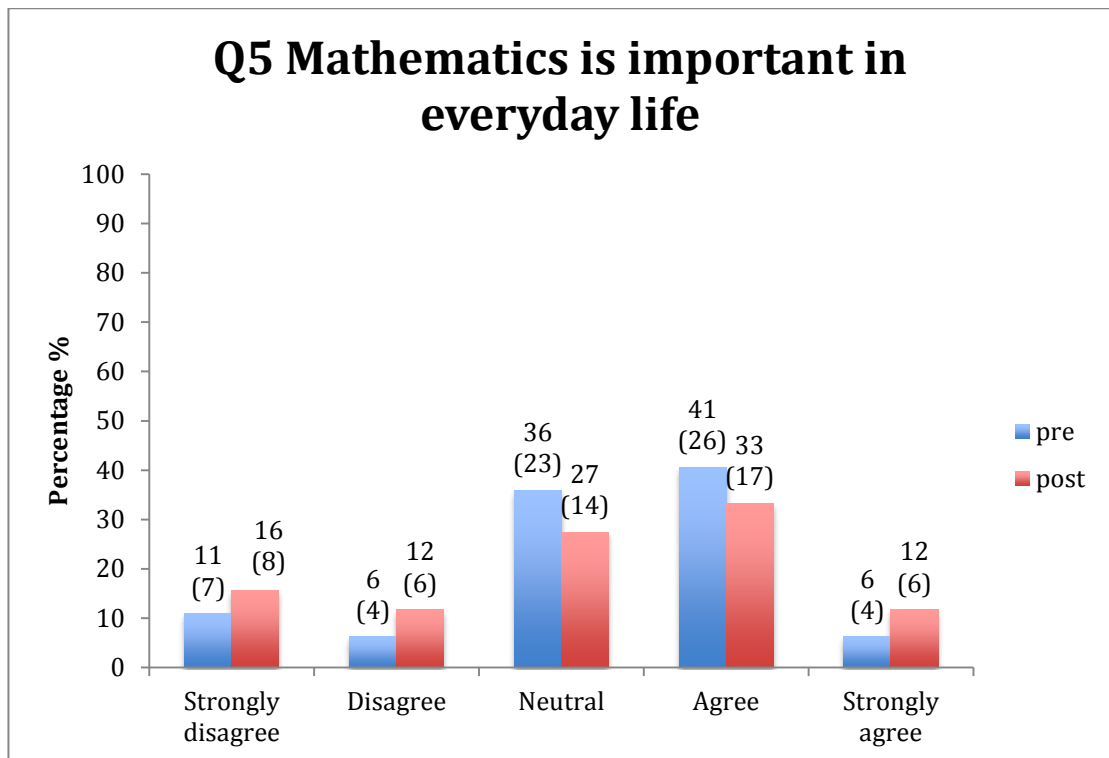


Figure 18 ATMI questionnaire responses for control group 3: Mathematics is important in everyday life (expressed as a percentage and also numbers of students in brackets).

Student perception on the importance of mathematics in everyday life in control group 3 in the strongly disagree and disagree options, revealed a slight shift in attitude, with 11% strongly disagreeing and 6% disagreeing, pre intervention. Post intervention, this changed to 16% strongly disagreeing, and 12% disagreeing. Students agreeing and strongly agreeing with Q5 saw some movement, with pre intervention percentages being 41% and 6%, changing to 33% and 12%, post intervention. The percentage of individuals who gave a neutral response changed from 36%, pre intervention to 27%, post intervention.

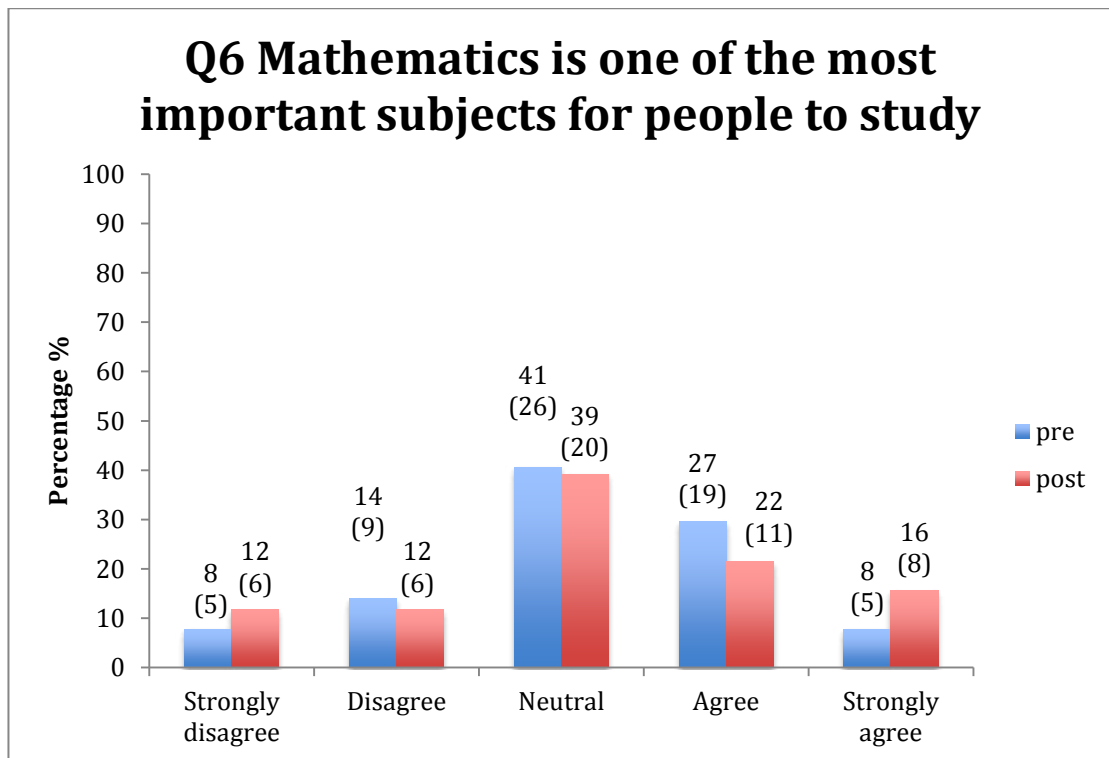


Figure 19 ATMI questionnaire responses for control group 3: Mathematics is one of the most important subjects for people to study (expressed as a percentage and also numbers of students in brackets).

Student perception on mathematics being viewed as one of the most important subjects for people to study in control group 3 in the strongly disagree and disagree options, revealed a slight shift in attitude, with 8% strongly disagreeing and 14% disagreeing pre intervention. Post intervention, this changed to 12% for the strongly agree option, whereas participants selecting the disagree option decreased to 12% students. Students agreeing and strongly agreeing with Q6 saw some movement, with pre intervention percentages being 27% and 8%, changing to 22% and 16% post intervention. The percentage of individuals who gave a neutral response changed from 41%, pre intervention changing to 39%, post intervention.

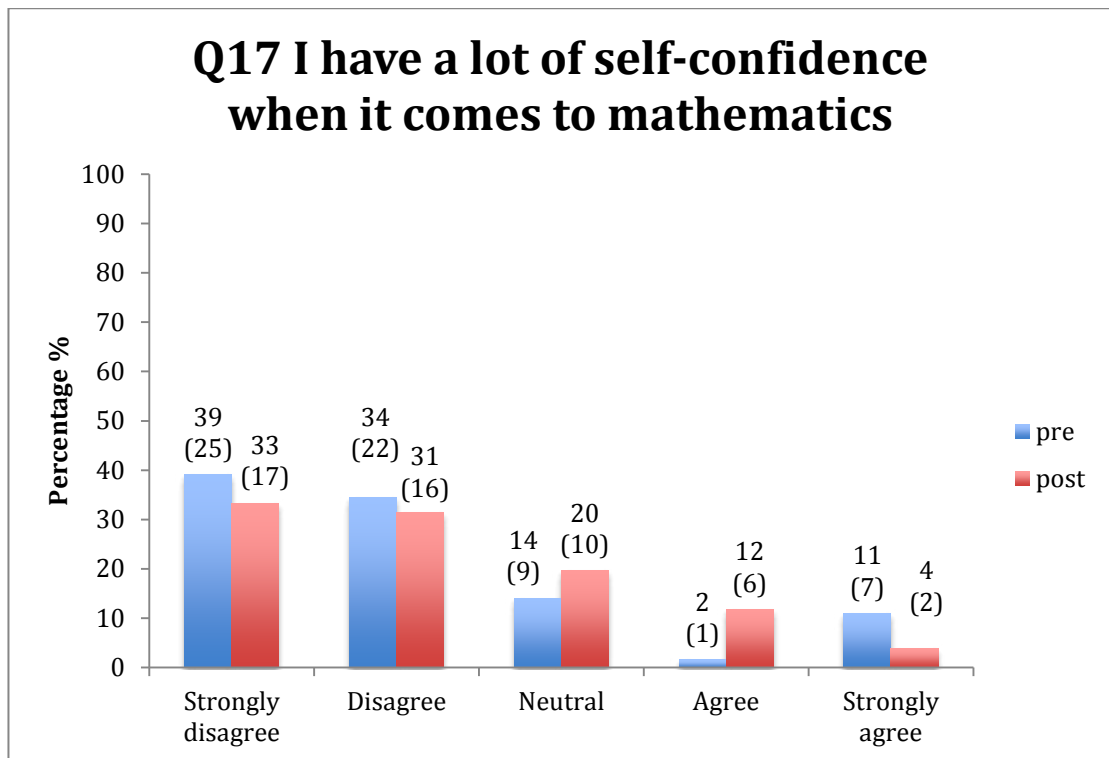


Figure 20 ATMI questionnaire responses for control group 3: I have a lot of self-confidence when it comes to mathematics (expressed as a percentage and also numbers of students in brackets).

Student self-confidence when it comes to mathematics in control group 3 in the strongly disagree and disagree options, revealed slight decreases in attitude, with 39% strongly disagreeing and 34% disagreeing, pre intervention. Post intervention, this changed to 33% strongly disagreeing and 31% disagreeing. Students agreeing and strongly agreeing with Q17 revealed moderate changes, with pre intervention percentages being 2% and 11%, changing to 12% and 4%, post intervention. The percentage of individuals who gave a neutral response changed slightly from 14%, pre intervention to 20%, post intervention.

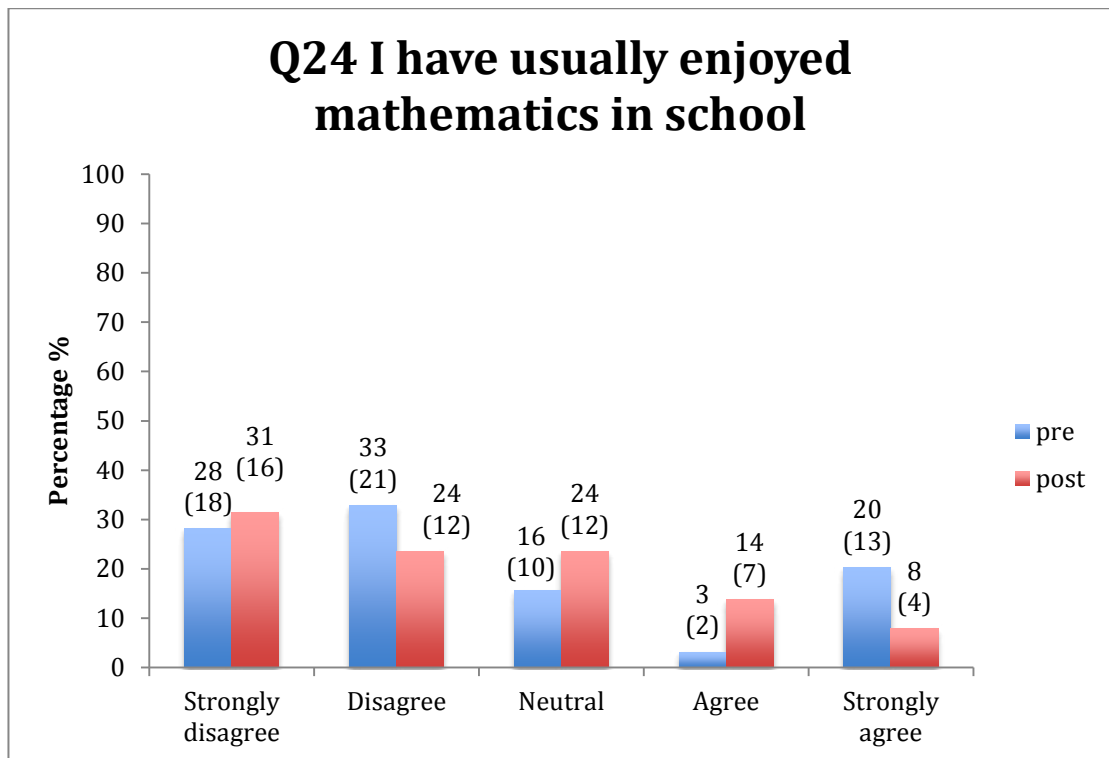


Figure 21 ATMI questionnaire responses for control group 3: I have usually enjoyed mathematics in school (expressed as a percentage and also numbers of students in brackets).

Student enjoyment with mathematics in school in control group 3 in the strongly disagree and disagree options, revealed a shift in attitude, with 28% strongly disagreeing and 33% disagreeing, pre intervention. Post intervention, this changed to 31% strongly disagreeing and a decrease to 24% disagreeing. Students agreeing and strongly agreeing with Q24 revealed changes, with pre intervention percentages being 3% and 20%, changing to 14% and 8%, post intervention. The percentage of individuals who gave a neutral response changed slightly from 16%, pre intervention to 24%, post intervention.

## Critical thinking results for Experimental group 1

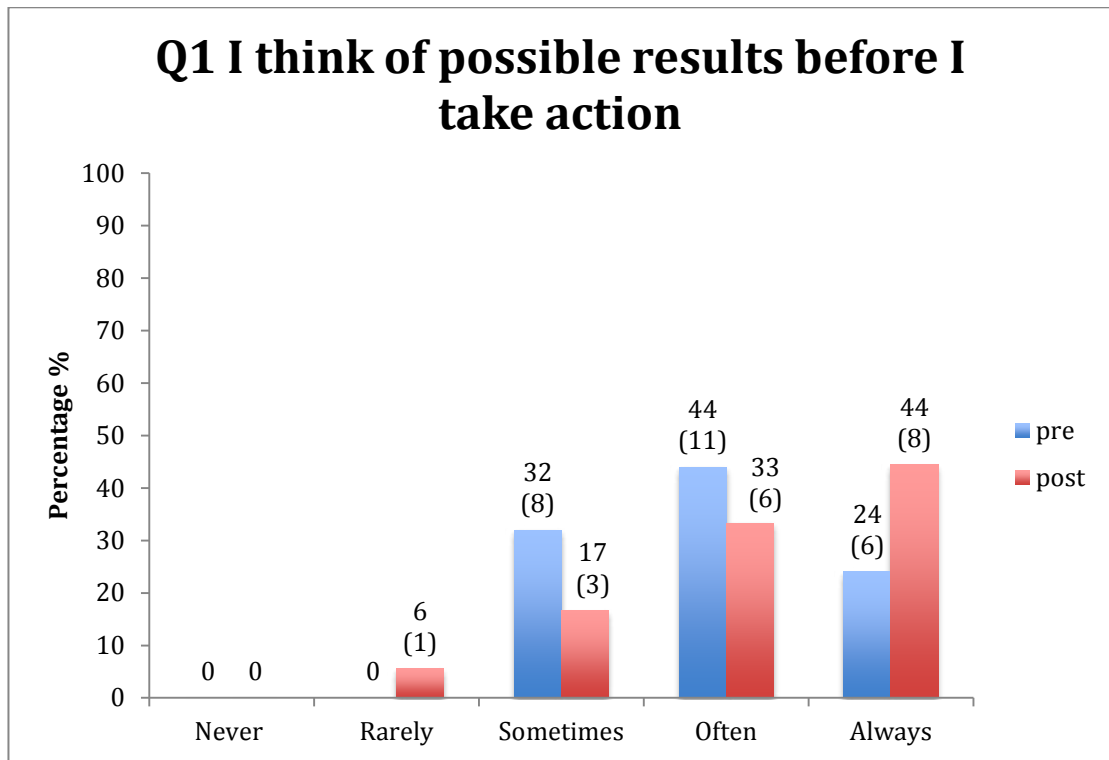


Figure 22 Critical thinking questionnaire responses from experimental group 1: I think of possible results before I take action (expressed as a percentage and also numbers of students in brackets).

Student responses to Q1 from the critical thinking questionnaire, being able to think of possible results before they take action, in experimental group 1 in the never and rarely options, revealed a very small shift in attitude, with 0% selecting the never and rarely options, pre intervention. Post intervention, this stayed the same at 0% selecting never and a small increase to 6% selecting the rarely option. Students selecting often and always with Q1 revealed changes, with pre intervention percentages being 44% and 24%, changing to 33% and 44 %, post intervention. The percentage of individuals who responded sometimes decreased from 32%, pre intervention to 17%, post intervention.

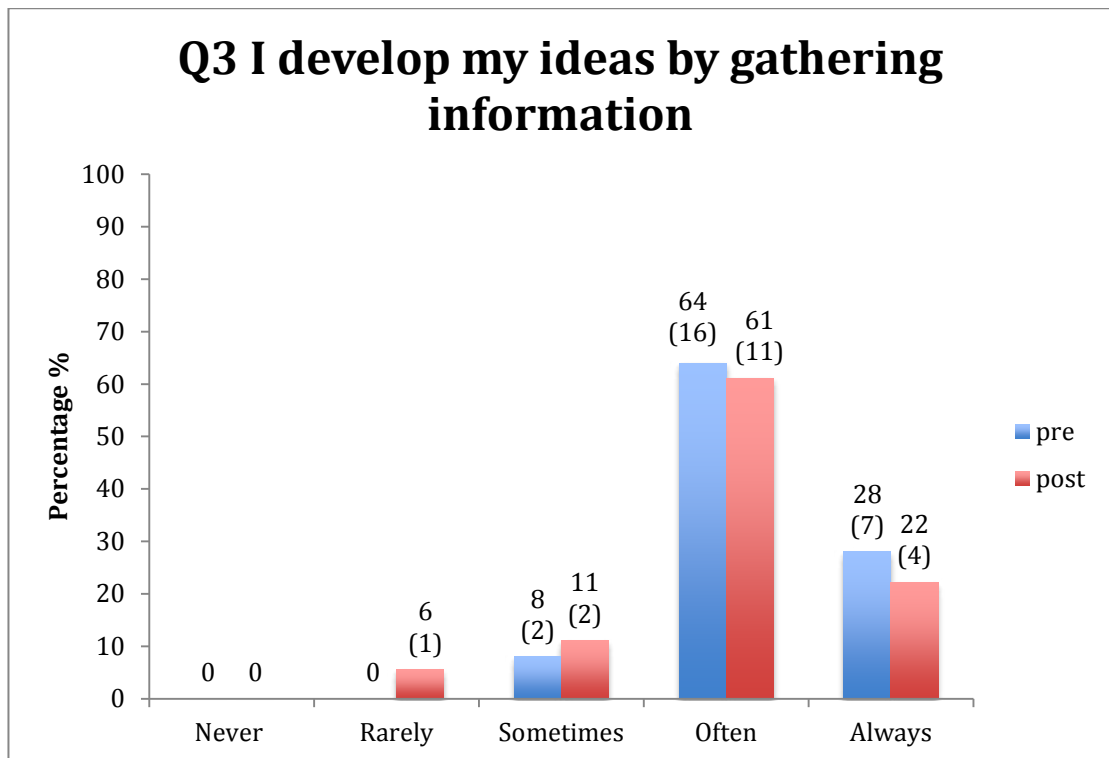


Figure 23 Critical thinking questionnaire responses from experimental group 1: I develop my ideas by gathering information (expressed as a percentage and also numbers of students in brackets).

Student responses to Q3, being able to develop ideas by gathering information, in experimental group 1 in the never and rarely options, revealed a small shift in attitude, with 0% selecting the never and the rarely option, pre intervention. Post intervention, this stayed the same at 0% selecting never and a small increase to 6% selecting the rarely option. Students selecting often and always with Q3 revealed small changes, with pre intervention percentages being 64% and 28%, decreasing to 61% and 22%, post intervention. The percentage of individuals who responded sometimes changed from 8% to 11% post intervention.

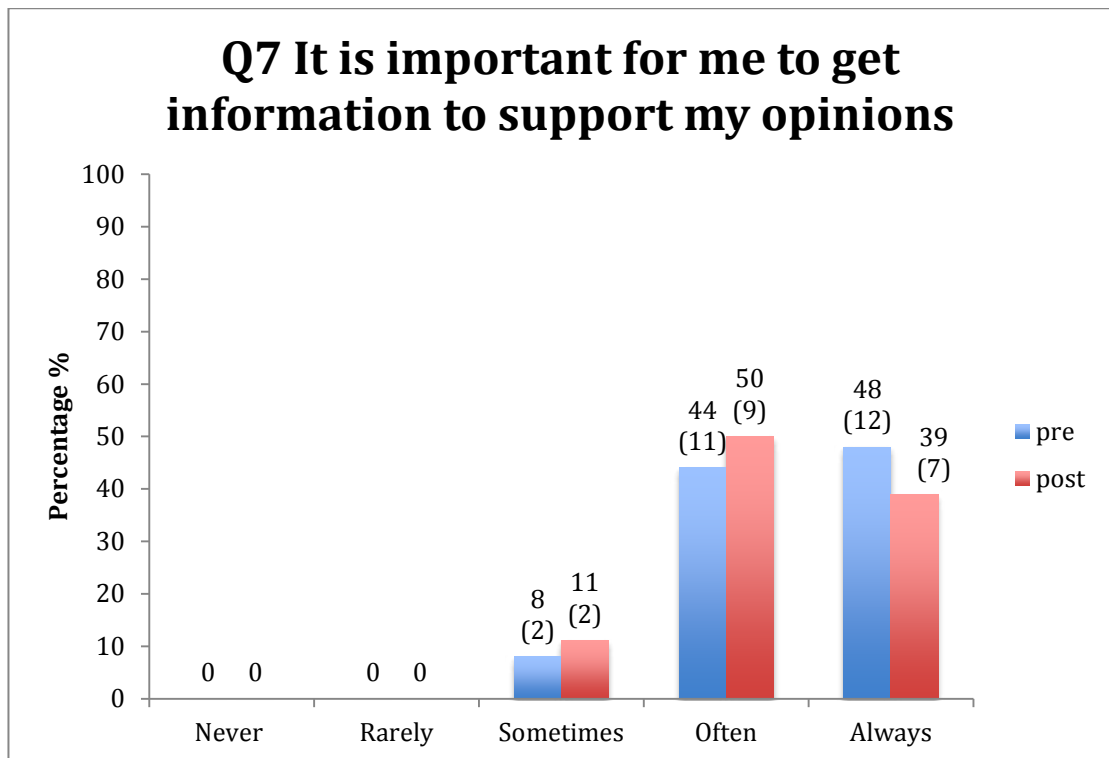


Figure 24 Critical thinking questionnaire responses from experimental group 1: It is important for me to get information to support my opinions (expressed as a percentage and also numbers of students in brackets).

Student responses to Q7, it is important for me to get information to support my opinions, in experimental group 1 in the never and rarely options, revealed no change in attitude, with 0% selecting the never and the rarely option, both pre and post intervention. Students selecting often and always with Q7 revealed moderate changes, with pre intervention percentages being 44% and 48%, changing to 50% and 39%, post intervention. The percentage of individuals who responded sometimes changed from 8% to 11% post intervention.



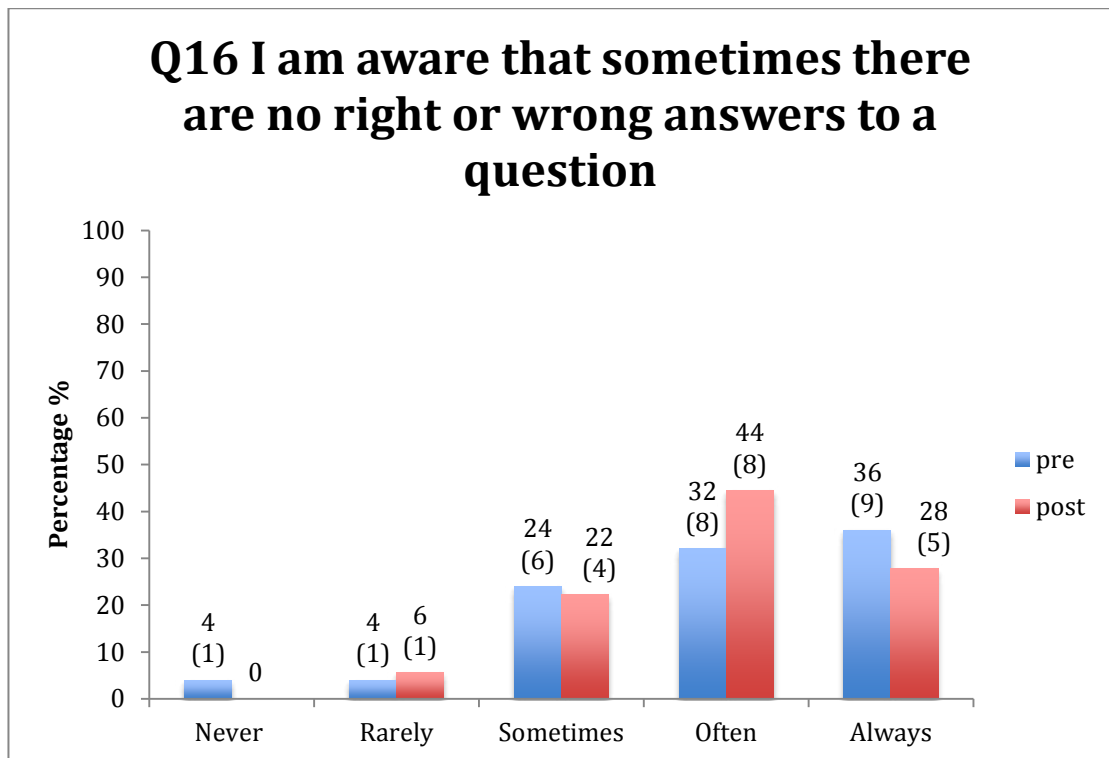


Figure 25 Critical thinking questionnaire responses from experimental group 1: I am aware that sometimes there are no right or wrong answers to a question (expressed as a percentage and also numbers of students in brackets).

Student responses to Q16, I am aware that sometimes there are no right or wrong answers to a question, in experimental group 1 in the never and rarely options, revealed a slight change in attitude, with 4% selecting the never and the rarely option, pre intervention. Post intervention, students selecting the never option dropped slightly to 0%, while the rarely option slightly increased to 6%. Students selecting often and always with Q16 revealed some changes, with pre intervention percentages being 32% and 36%, changing to 44% and 28%, post intervention. The percentage of individuals who responded sometimes decreased slightly, from 24% pre intervention, to 22% post intervention.

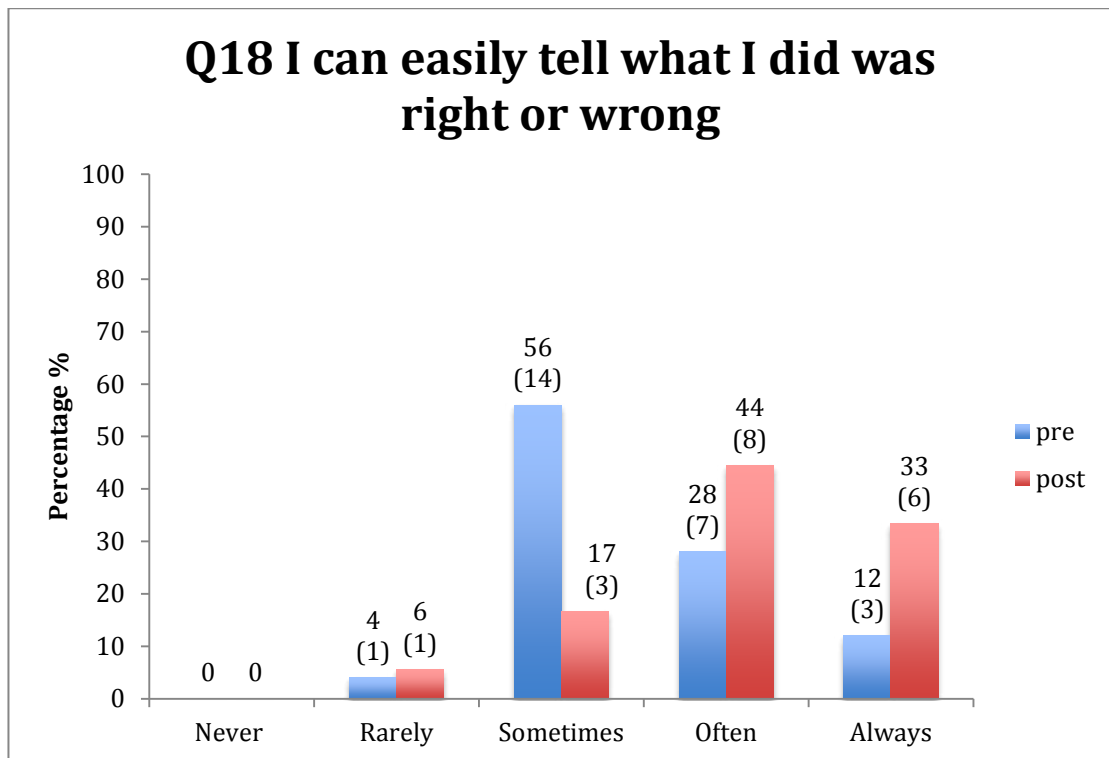


Figure 26 Critical thinking questionnaire responses from experimental group 1: I can easily tell what I did was right or wrong (expressed as a percentage and also numbers of students in brackets).

Student responses to Q18, I can easily tell what I did was right or wrong, in experimental group 1 in the never and rarely options, revealed little change in attitude, with 0% selecting the never option and 4% selecting the rarely option, pre intervention. This increased slightly post intervention for the rarely response, rising to 6%. Students selecting often and always with Q18 revealed changes, with pre intervention percentages being 28% and 12%, increasing to 44% and 33%, post intervention. The percentage of individuals who responded sometimes decreased from 56% pre intervention, to 17% students post intervention.

**Critical thinking results for control group 2**

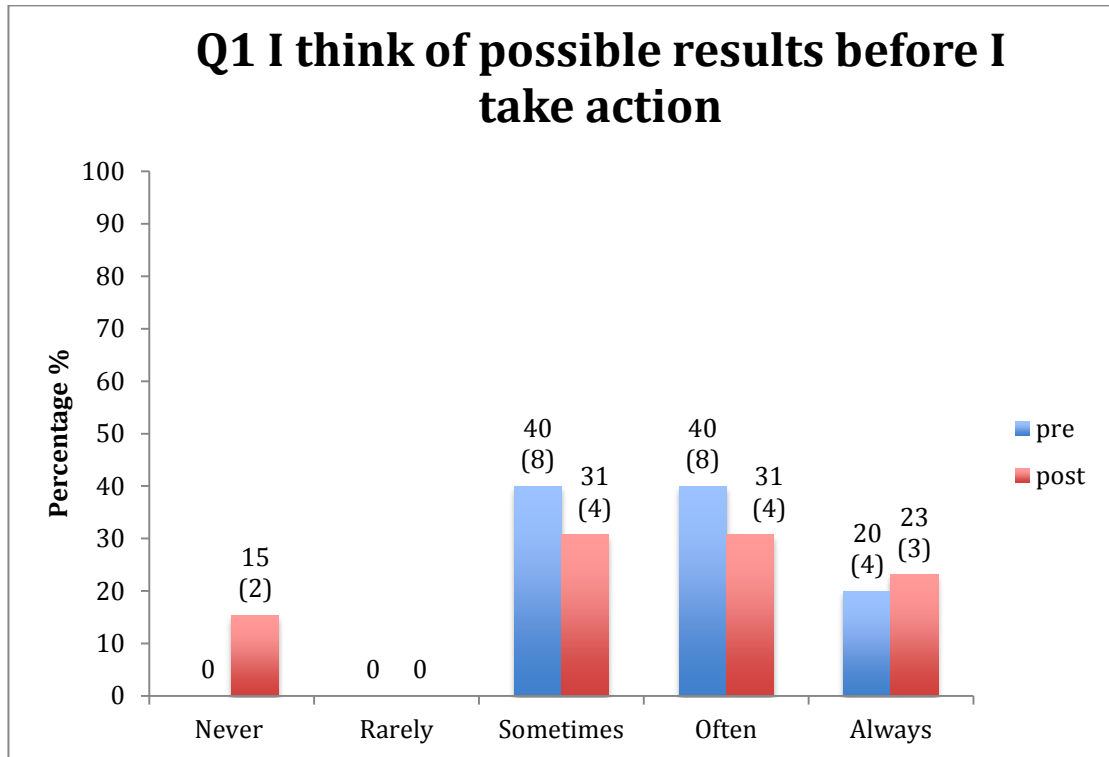


Figure 27 Critical thinking questionnaire responses from control group 2: I think of possible results before I take action (expressed as a percentage and also numbers of students in brackets).

Student responses to Q1 from the critical thinking questionnaire, being able to think of possible results before they take action, in control group 2 in the never and rarely options, revealed a small shift in attitude, with 0% selecting the never and the rarely option with Q1, pre intervention. Post intervention, this changed to 15% selecting never and 0% selecting the rarely option. Students selecting often and always with Q1 revealed moderate changes, with pre intervention percentages being 40% and 20%, changing to 31% and 23%, post intervention. The percentage of individuals who responded sometimes decreased from 40%, pre intervention to 31%, post intervention.

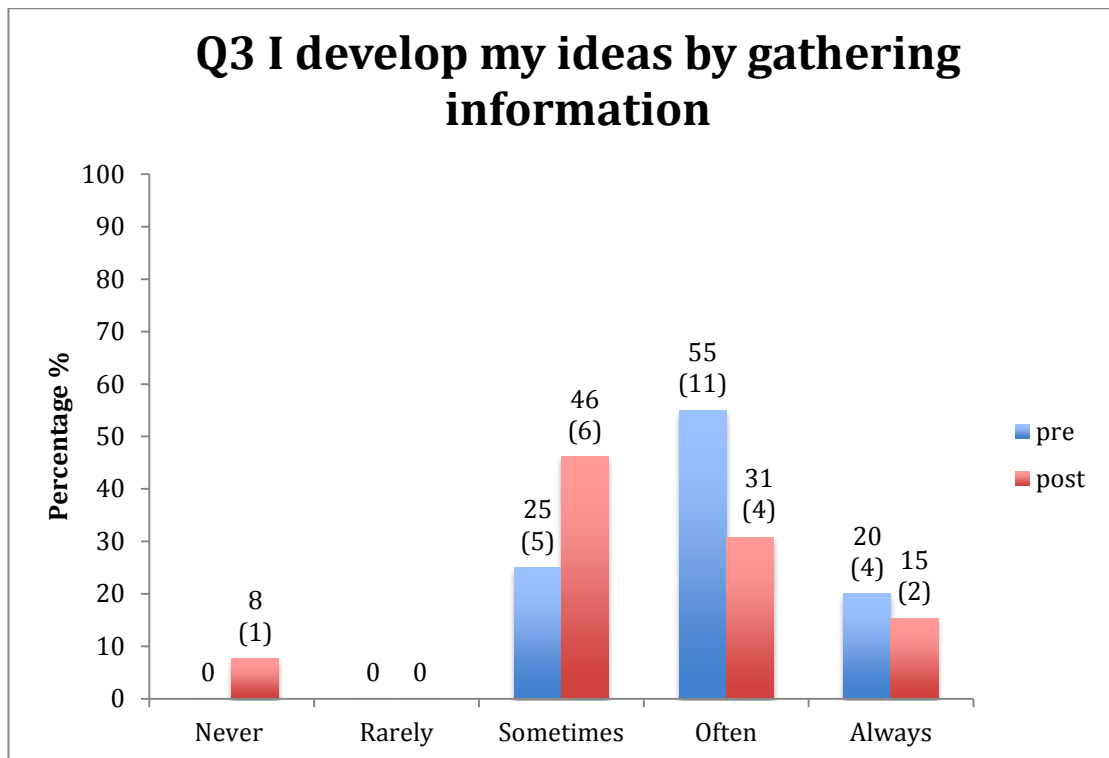


Figure 28 Critical thinking questionnaire responses from control group 2: I develop my ideas by gathering information (expressed as a percentage and also numbers of students in brackets).

Student responses to Q3, being able to develop ideas by gathering information, in control group 2 in the never and rarely options, revealed a small shift in attitude, with 0% selecting the never and the rarely option, pre intervention. Post intervention, this increased to 8% selecting never and 0% selecting the rarely option. Students selecting often and always with Q3 revealed changes, with pre intervention percentages being 55% and 20%, decreasing to 31% and 15%, post intervention. The percentage of individuals who responded sometimes increased from 25% pre intervention, to 46% post intervention.

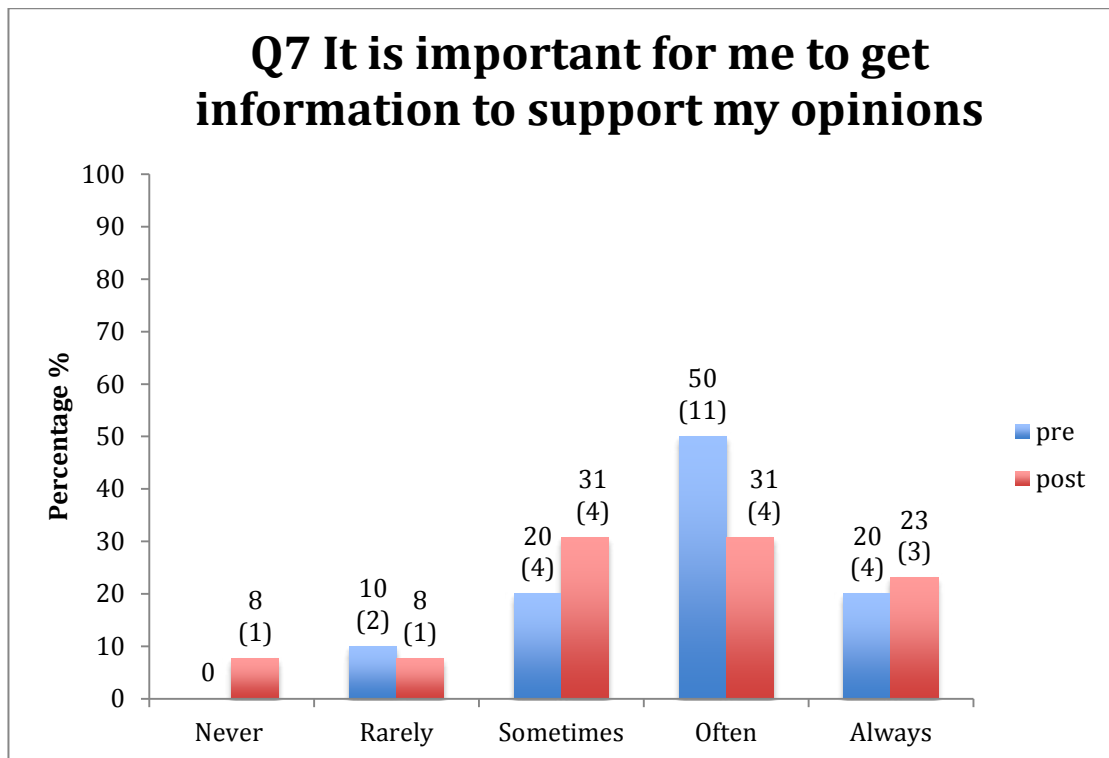


Figure 29 Critical thinking questionnaire responses from control group 2: It is important for me to get information to support my opinions (expressed as a percentage and also numbers of students in brackets).

Student responses to Q7, it is important for me to get information to support my opinions, in control group 2 in the never and rarely options, revealed small changes in attitude, with 0% selecting the never option and 10% selecting the rarely option pre intervention. This changed to 8% selecting never and 8% selecting rarely post intervention. Students selecting often and always with Q7 revealed changes, with pre intervention percentages being 50% and 20%, changing to 31% and 23%, post intervention (Figure 6.29). The percentage of individuals who responded sometimes increased from 20% to 31% post intervention.



Figure 30 Critical thinking questionnaire responses from control group 2: I am aware that sometimes there are no right or wrong answers to a question (expressed as a percentage and also numbers of students in brackets).

Student responses to Q16, I am aware that sometimes there are no right or wrong answers to a question, in control group 2 in the never and rarely options, revealed a slight change in attitude, with 0% selecting the never option and 15% selecting the rarely option, pre intervention. Post intervention, students selecting the never option increased to 15 %, while the rarely option stayed the same at 15%.

Students selecting often and always with Q16 revealed changes, with pre intervention percentages being 40% and 30%, decreasing to 23% and 23%, post intervention. The percentage of individuals who responded sometimes increased from 15% to 23% post intervention.

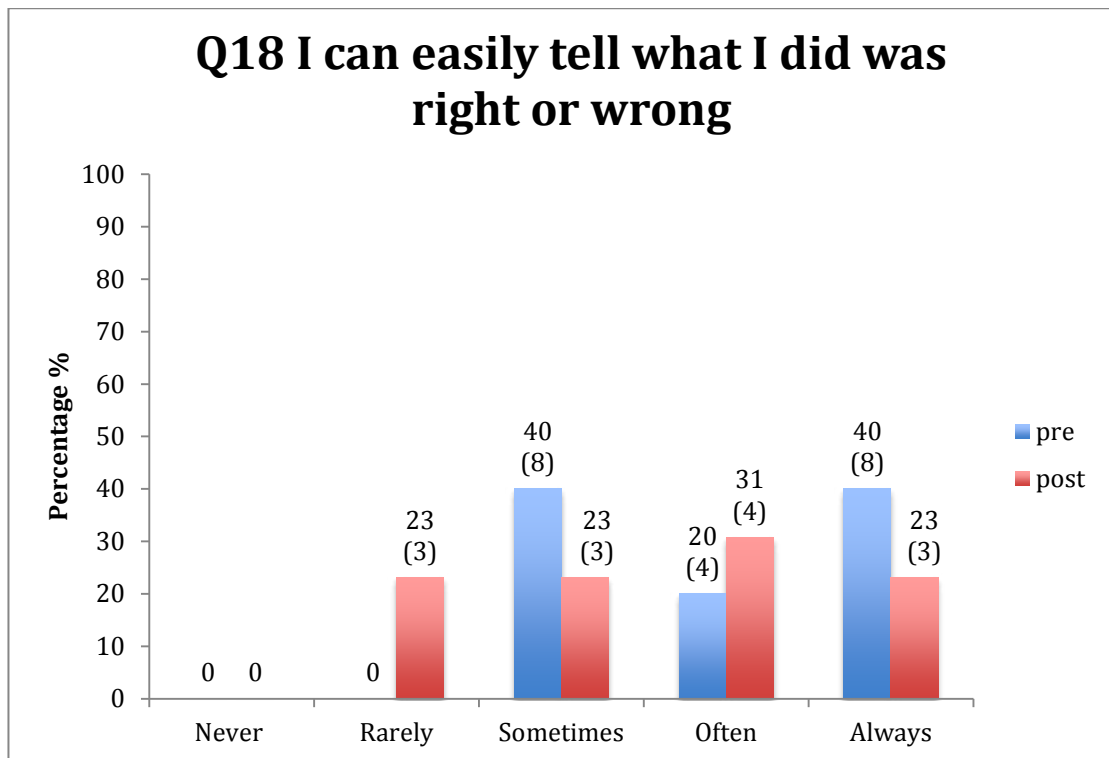


Figure 31 Critical thinking questionnaire responses from control group 2: I can easily tell what I did was right or wrong (expressed as a percentage and also numbers of students in brackets).

Student responses to Q18, I can easily tell what I did was right or wrong, in control group 2 in the never and rarely options, revealed a slight change in attitude, with 0% selecting the never and the rarely option, pre intervention. This stayed the same for the never option, increasing to 23% for the rarely option, post intervention. Students selecting often and always with Q18 revealed changes, with pre intervention percentages being 20% and 40%, changing to 31% and 23%, post intervention. The percentage of individuals who responded sometimes decreased from 40% pre intervention, to 23% post intervention.

### 6.2.7 Critical thinking results for control group 3

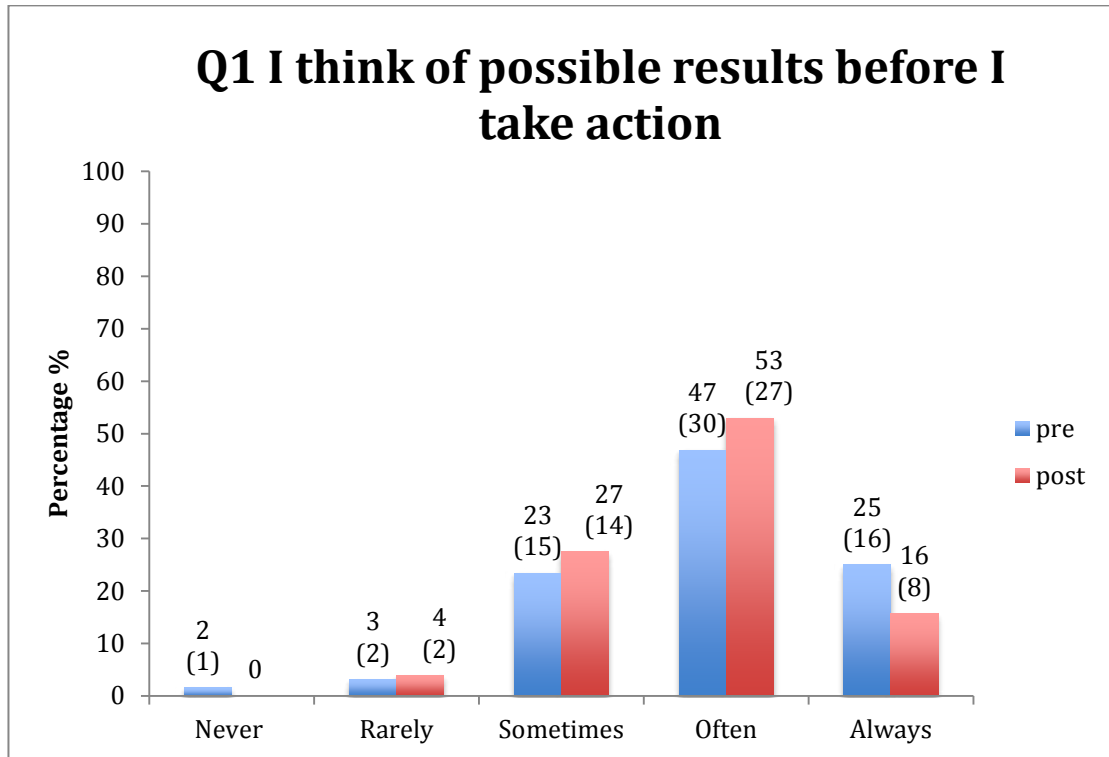


Figure 32 Critical thinking questionnaire responses from control group 3: I think of possible results before I take action (expressed as a percentage and also numbers of students in brackets).

Student responses to Q1 from the critical thinking questionnaire, being able to think of possible results before they take action, in control group 3 in the never and rarely options, revealed a small shift in attitude, with 2% selecting the never option and 3% selecting the rarely option, pre intervention. Post intervention, this changed to 0% selecting never and 4% selecting the rarely option. Students selecting often and always with Q1 revealed moderate changes, with pre intervention percentages being 47% and 25%, changing to 53% and 16%, post intervention. The numbers of individuals who responded sometimes increased from 23%, pre intervention to 27%, post intervention.



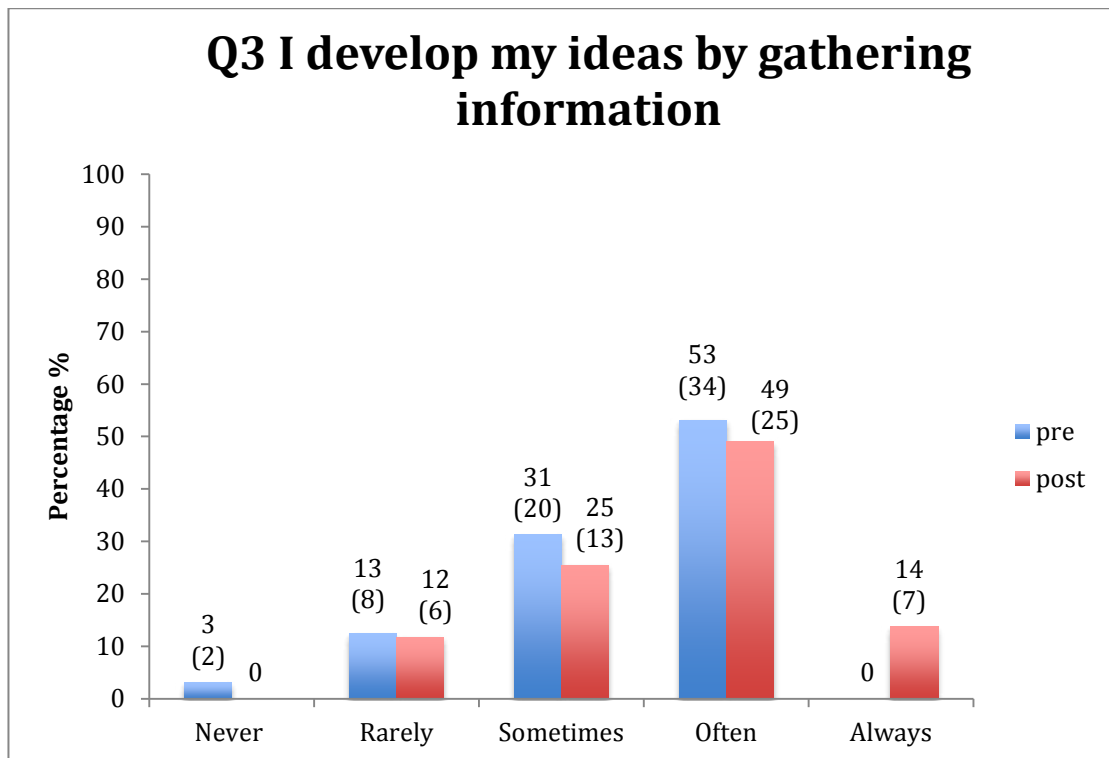


Figure 33 Critical thinking questionnaire responses from control group 3: I develop my ideas by gathering information (expressed as a percentage and also numbers of students in brackets).

Student responses to Q3, being able to develop ideas by gathering information, in control group 3 in the never and rarely options, revealed a small changes in attitude, with 3% selecting the never option and 13% selecting the rarely option, pre intervention. Post intervention, this decreased to 0% selecting never and 12% selecting the rarely option. Students selecting often and always with Q3 revealed moderate changes, with pre intervention percentages being 53% and 0%, changing to 49% and 14%, post intervention. The percentage of individuals who responded sometimes decreased from 31% pre intervention, to 25% post intervention.

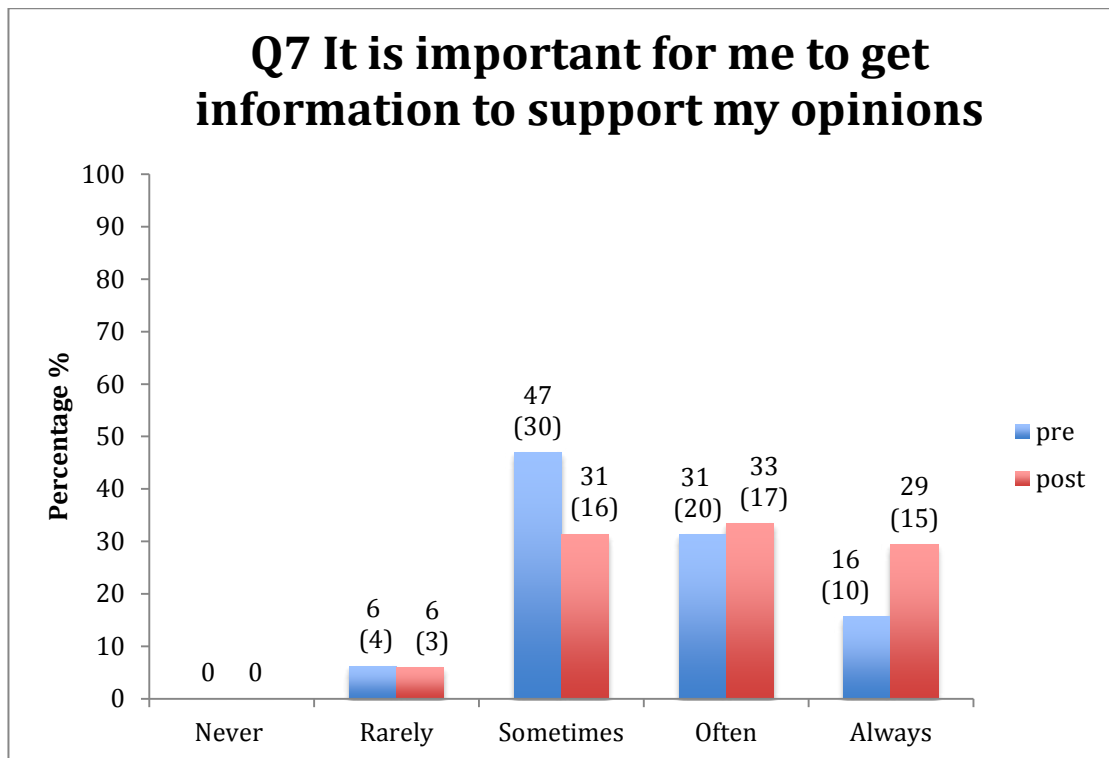


Figure 34 Critical thinking questionnaire responses from control group 3: It is important for me to get information to support my opinions (expressed as a percentage and also numbers of students in brackets).

Student responses to Q7, it is important for me to get information to support my opinions, in control group 3 in the never and rarely options, revealed no changes in attitude, with 0% selecting the never option and 6% selecting the rarely option. This stayed the same at 0% selecting never and 6% selecting rarely, post intervention. Students selecting often and always with Q7 revealed moderate changes, with pre intervention percentages being 31% and 16%, changing to 33% and 29%, post intervention. The percentage of individuals who responded sometimes decreased from 47% pre intervention, to 31% post intervention.

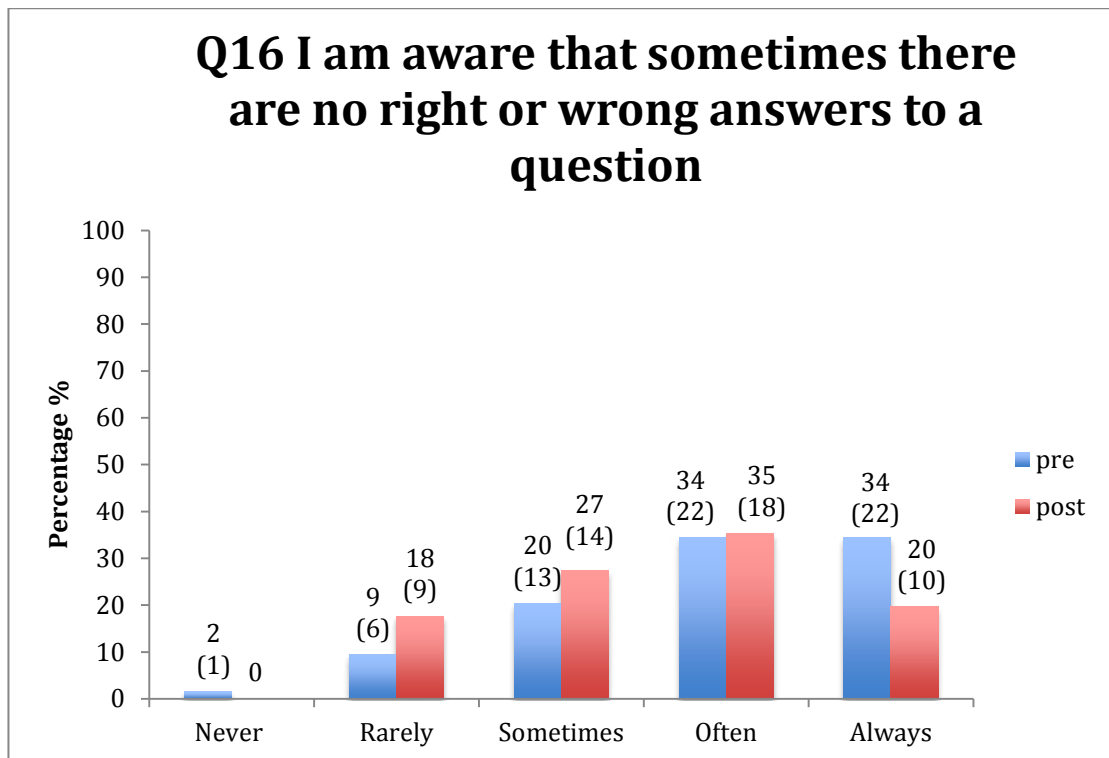


Figure 35 Critical thinking questionnaire responses from control group 3: I am aware that sometimes there are no right or wrong answers to a question (expressed as a percentage and also numbers of students in brackets).

Student responses to Q16, I am aware that sometimes there are no right or wrong answers to a question, in control group 3 in the never and rarely options, were 2% selecting the never option and 9% selecting the rarely option, pre intervention. Post intervention, students selecting the never option decreased to 0%, while the rarely option increased to 18%. Students selecting often and always with Q16 revealed some changes, with pre intervention percentages being 34% for both, changing to 35% and 20%, post intervention. The percentage of individuals who responded sometimes increased slightly, from 20% pre intervention, to 27% post intervention.

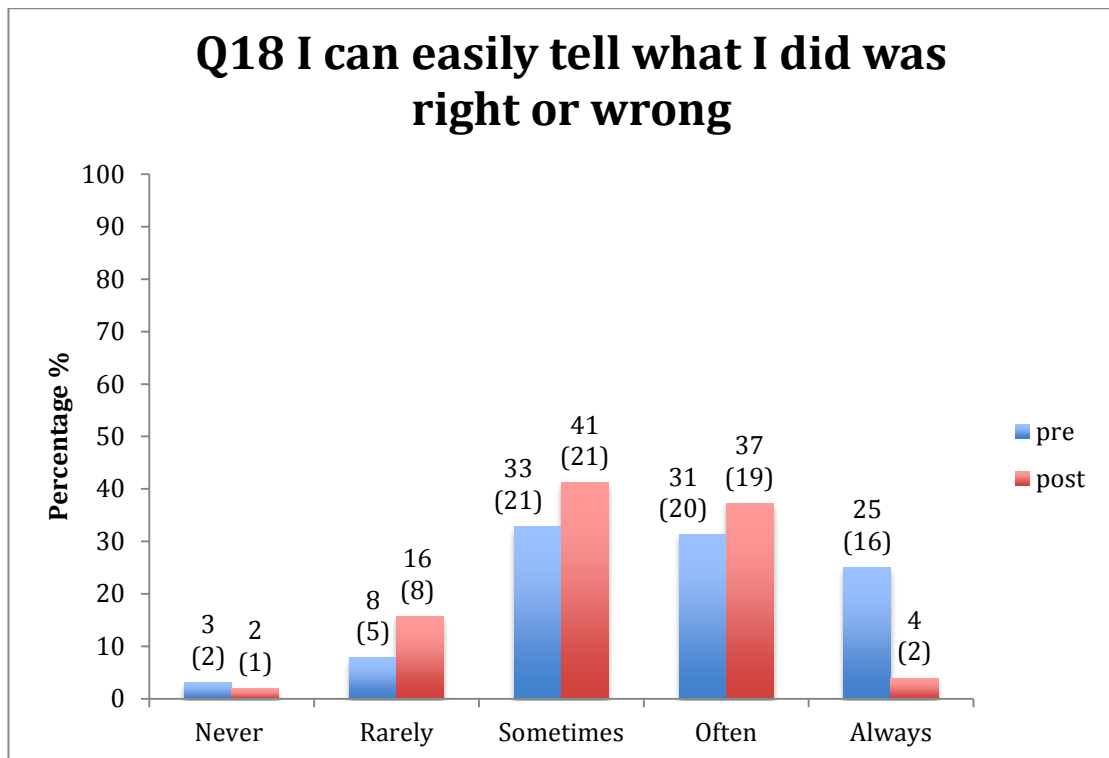


Figure 36 Critical thinking questionnaire responses from control group 3: I can easily tell what I did was right or wrong (expressed as a percentage and also numbers of students in brackets).

Student responses to Q18, I can easily tell what I did was right or wrong, in control group 3 in the never and rarely options, revealed moderate changes in attitude, with 3% selecting the never option and 8% selecting the rarely option, pre intervention. This decreased to 2% for the never option, and increased to 16% for the rarely option, post intervention. Students selecting often and always with Q18 revealed changes, with pre intervention percentages being 31% and 25%, changing to 37% and 4%, post intervention. The percentage of individuals who responded sometimes increased from 33% to 41% post intervention.