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How Do We Change Statistical and Critical Thinking Attitudes in Young People?

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How Do We Change Statistical and Critical Thinking Attitudes in Young People?

Abstract

A quasi-experimental design was used to measure the impacts on student attitudes in statistics, mathematics and critical thinking (16-18 years of age) on a group of students who received a 21-week-long contextualised statistics course (called the Pilot Scheme in Social Analytics), in South Wales. This paper will discuss the development and delivery stages of the course as well as the student recruitment strategies employed. This paper will also discuss the changes in attitudes observed after the course had finished. Results suggest the course did lead to changes in the students' attitudes becoming more positive with respect to statistics, mathematics, and critical thinking in comparison to two control groups. Students in both control groups who didn't receive the treatment, showed mostly no change or negative changes in their attitudes with respect to statistics, mathematics, and critical thinking.

Keywords

statistics education research, interdisciplinary, statistics attitudes, critical thinking

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Cover Page Footnote

Dr Rhys C. Jones is the Director of the Science Scholars programme and a Teaching Fellow in Statistics at the University of Auckland. Rhys has a background in biology and statistics education with research interests in curriculum design and evaluation, especially in interdisciplinary contexts and subjects.

Introduction

The discipline of sociology has seen radical shifts in terms of the primary methodological tools used to generate new knowledge, especially in the UK (Lincoln and Guba 1985 and 1988; Morgan 2007). There has been a paradigm shift towards the use of predominantly qualitative methods, which has had significant implications for the discipline. After decades of social science researchers investigating these implications, many have come to the conclusion that there is a quantitative deficit within sociology 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. One of these is Q-Step, a £19.5 million grant initiative funded by the Nuffield Foundation “to promote a step-change in quantitative social science training in the UK.”¹

Mathematics as a discipline, which forms integral parts of quantitative methods and skills development, has also experienced changes in both applied and theoretical aspects (Nunez 2006, 160–181; Walshaw and Anthony 2008; Durrand-Guerrier 2015, 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, 160–181; Schleppegrell 2007; Walshaw and Anthony 2008; Durrand-Guerrier 2015, 453–457). Being able to demonstrate mathematical critical thinking skills relates to a form of relational understanding, or as Skemp puts it, “knowing what to do and why” (Skemp 1976, 21).

Social scientists and mathematicians advocating greater instruction in applied quantitative topics cite disturbing research on student attitudes. In particular, negative attitudes toward mathematics and statistics, which can act as a barrier to people engaging with quantitative methods, have contributed to an antipathy towards the subject in sociology (Williams et al. 2008; MacInnes 2009; Platt 2012; Payne 2014; Williams et al. 2015). 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). Antipathy towards quantitative methods within the social sciences is potentially rooted within this societal negative attitude.

Societal negative attitudes towards mathematics could be a product of the traditional teaching approaches of mathematics education. Teaching methods have

¹ <https://www.nuffieldfoundation.org/q-step>

potentially contributed to an experience of quantitative problems as having only right or wrong answers, which may in turn lead to the perception that mathematics is a difficult discipline (Porkess 2013; Donaldson 2015). In response to these concerns, significant changes have been made to compulsory mathematics education more recently to encourage greater student uptake post-16 years of age, within England and Wales (Porkess 2013; Donaldson 2015). For example, statistics has gained an increasingly important voice within mathematics education. Statistics also cuts across many disciplines and is increasingly becoming a core subject. In addition, employers are increasingly requesting employees acquire data analysis skills, underpinned by statistical and scientific principles.

Students' attitudes are developed over long periods of time and can have sizeable impacts on their effective engagement, participation, and achievement in mathematics and statistics. While attitudes are formed from experiences and can be changed, they are more stable than emotions and feelings. Moreover, they can have clear influences on participation, because attitudes are formed in response to curriculum and teaching practices (Khoo and Ainley 2005). Attitudes towards statistics are important in statistics education because they have the potential to affect statistical achievement, literacy, or reasoning (Gal and Ginsberg 1994). Gal (2002) states certain attitudes are needed to critically evaluate statistical messages, which are important in statistics instruction. Students' attitudes towards statistics can help statistical thinking as well as influence their utilization of knowledge and skills in a variety of contexts (Gal and Ginsberg 1994). Therefore, attitudes play an important role in the teaching and learning process during class time. Positive attitudes could also influence statistical behaviours outside the classroom and may also motivate students to enrol for further statistics-related courses.

Recognizing this important role of student attitudes in statistical education, 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, 11).

The need for clear evidence to review students' perceptions of mathematics and statistics provides the rationale for this study. To this end, the following research questions were addressed in this study in the context of a newly-created course, the Pilot Scheme in Social Analytics (SA), which was designed to change

students' attitudes toward mathematics, statistics, and critical thinking. Specifically, we explore two questions:

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

Pilot Scheme in Social Analytics

Development, Content, and Delivery

The Q-Step initiative was implemented across 15 British universities which developed 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 course (for ages 16–18) in Social Analytics (i.e., the investigation of social processes using statistical analysis and techniques) began with the creation of the Pilot Scheme in Social Analytics (SA).² This Pilot Scheme was developed with a group of secondary school teachers and Further Education (FE) lecturers. 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 (age 11) through master's and teacher training education levels. This breadth of experience enabled discussions to evolve around the core themes of curriculum design and pedagogy, intersecting several disciplines and student age groups. This range of expertise also enabled the group to decide on the core skills (critical thinking and statistical concepts/analysis in relation to the course aims of SA) students needed to effectively progress from year 10 (15 years of age) onwards, with the end goal of accessing a variety of higher education courses.

The development of critical thinking skills was also central to the course development and was deemed to be good preparation for higher education in a variety of subjects (Landers 1999; Gal 2002; The Critical Thinking Community 2016). Based on the literature, the TPS viewed the ability to objectively evaluate evidence and make judgments as of central importance to enable relational

² The development and content of the SA course is described in more detail in Jones (2018a).

understanding of mathematics and statistics (Skemp 1976; Landers 1999; Gal 2002).

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. Adopting this approach to teaching statistics, focussing on statistical concepts and principles, is also a recommendation reported in the American Statistical Association's GAISE report (Carver et al. 2016). Appendices 1 and 2 include detailed descriptions of course learning outcomes and the scheme of work.

The course itself was 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). St David's Sixth Form Catholic School (St David's) and Cardiff and the Vale College (CAVC) agreed to take on a significant role in the development of the course, as well as promoting the course to their students.³ Students from both institutions made up significant proportions of the course cohort in 2014/15 and 2015/16.

The first run of the Pilot Scheme in SA was delivered by me, starting on the 21/10/2014 and finishing on the 28/03/2015. Postgraduate students also delivered several sessions linked to research design and *t*-tests. The initial delivery enabled the TPS group to utilise primary evidence in the form of teacher observations (by me) 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. Responses from the 2014/15 course evaluations indicated most 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 that statistics content was linked well with relevant examples (41/44 students agreeing or strongly agreeing). In addition, the students enjoyed sessions delivered by postgraduate students in the Cardiff School of Social Sciences. These responses suggested the approaches taken in developing and

³ Senior managers from both institutes gave permission for their schools' names to be used. The inclusion and description of both institutions' names brings to life the research conducted and ensures these institutions receive recognition for their participation and cooperation in the study.

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. For example, the Analysis of Variance content was 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 course participants 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.

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 20 weeks, starting on the 12/10/2015 and finishing on the 21/03/2016. The course was delivered in a series of lectures, workshops, and seminars, with several postgraduate students from the Cardiff School of Social Sciences joining me in 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 as compared with that of 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.

Bodily-kinesthetic learning opportunities were provided as often as possible, especially in the 2015/16 cohort, because 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. Additional forms of different types of data were then collected, including favourite types of food, for example. Questions were then introduced to enable students to critically evaluate the usefulness of the data collected, discussing the merits and disadvantages of both. Other bodily-kinesthetic 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 assess the participants' performance against a student-designed grading criteria grid to help quantify the data. 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 (following the method described in Jones 2019). 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 learning outcomes and scheme of work 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 and to provide 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 United States. Providing a range of learning experiences ensured there was a pedagogically balanced delivery, which 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).

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. Appendix 3 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 work 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-square test for example. The development of critical thinking skills lends itself well to discursive group work with this worksheet.

Most 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, exposed the students to a variety of learning experience typically found in higher education (HE) courses and encouraged the development of higher-level analytical skills.

Student Recruitment Strategies

Members of the TPS were able to promote the Pilot Scheme course within their respective educational institutions, as well as inviting Cardiff University staff from the School of Social Sciences to deliver presentations to their students. Presentations usually included a description of the benefits of the course to students' educational careers by developing critical thinking and statistical analysis skills. This reflected the agreement by TPS that we would describe the course as a way of enhancing students' critical thinking and statistical skills rather than focusing on more procedural statistical calculations. This decision ensured 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. Filtering tools were also needed, for example GCSE grade entry requirements in Mathematics and English, because we were unaware of how many would apply and needed a way to keep the student numbers on the course at a manageable level. The application form included a section for students to explain why they wanted to participate in the course, which enabled an assessment to be made as to whether they understood its learning outcomes and if they had an idea of 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 ensure 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 better prepare them for higher education.

A parental consent form was also distributed as part of the application process because 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, 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.

Methods

Experimental Method

Experimental methods in both education and sociology have a long history, particularly in the United States. Cook and Campbell's research was essential in establishing the experiment as a legitimate research strategy in the evaluation of social and education programmes in the United States (Cook and Campbell 1979). An example of their work involves the evaluation of the US Head Start programme (a programme of early childhood education, health and nutrition, and parent involvement services offered to low-income families), which involves the randomisation of participants into control and experimental groups over a period of time. Their methods often include advanced modelling techniques, and 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).

There are several methodological goals that can be difficult to achieve, including 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 that of randomised control trials (RCTs), the main difference being that the groups are not randomly allocated.

In the context of the research conducted in this investigation, an RCT was not used due to students' self-selection onto the Pilot Scheme; therefore randomisation could not be achieved. 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 accumulate an 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.

Experimental Groups

The two educational establishments selected for the quasi-experiment are in the city of Cardiff. CAVC is one of the largest colleges in Wales. 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 master's level. For entry onto their A Level courses, prospective students need to have a minimum of five GCSEs 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 describes itself as the only Catholic sixth form college in Wales (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 (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 Levels, have additional entry requirements, which include a grade BB at Double Award GCSE Science (higher tier) (St David's 2017).

St David's describes 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, with 24 from St David's and 20 from CAVC. The Pilot Scheme in SA class finished with 29 students, of which 19 were from St David's (number of year 12 students = 11 and number of year 13 students = 8) and 10 were from CAVC (number of year 12 students = 5 and number of year 13 students = 5) (Table 1). Students in the Pilot Scheme in SA formed experimental group 1.

Table 1
Numbers of Students in Year 12 and 13, Arranged into Experimental and Control Groups

Group	Year 12 Student Numbers	Year 13 Student Numbers
Experimental group 1 (Pilot)	16	13
Control group 2 (CAVC)	11	9
Control group 3 (St David's)	30	34

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 1). 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 (WJEC 2017a), sociology (WJEC 2016), and psychology (WJEC 2017) at St David's are WJEC approved specifications.⁴

Data Collection Time-Points

Data were collected at specific points throughout the 21 weeks of the delivery of the Pilot Scheme in SA. Table 2 provides a detailed list of when and what material was collected. Data were collected from those individuals present in class using paper-based copies of questionnaires. 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 (Trautwein et al. 2006; Schilling and Applegate 2012).

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 rule was to ensure that 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 (to avoid duplication of data) and were asked to come to class 30–45 minutes later.

⁴ WJEC is the Welsh examining board.

Table 2

Timeline for the Quasi-Experiment, Including Important Events Relevant to the Research Process and the Relevant Appendix Linked to the Data Being Collected

Approximate Date	Description	Relevant Appendices for the Data Collection Tools
March–August 2015	<ul style="list-style-type: none"> Collection of background information, development of project plan and research design, development of research tools Experimental group 1 (intervention group—taking the Pilot Scheme in SA) and control groups 2 and 3 identified and created 	<ul style="list-style-type: none"> Attitudes to Mathematics Inventory (ATMI) (4) Critical Thinking (5)
September 2015–April 2016	Pilot Scheme in Social Analytics (SA) course delivered (21 weeks)	
September 2015	<ul style="list-style-type: none"> Questionnaires given out to experimental and control groups—attitudes to mathematics and critical thinking 	<ul style="list-style-type: none"> ATMI (4) Critical Thinking (5)
October 2016	Analysis of initial questionnaires	
January 2016	<ul style="list-style-type: none"> Teaching associate takes over teaching the Pilot Scheme in SA course 	
March 2016	<ul style="list-style-type: none"> Questionnaires given out to experimental and control groups—attitudes to mathematics and critical thinking 	<ul style="list-style-type: none"> ATMI (4) Critical Thinking (5)
April 2016	<ul style="list-style-type: none"> Analysis of final questionnaires 	

Data Collection Instruments

Questionnaires were used to gather attitudinal data from the groups in this investigation. Questionnaires have been used widely by a variety of research groups as a legitimate research tool to explore mathematical attitudes (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. Both questionnaires are freely available for use and were cross-checked by teachers from CAVC and St David's to ensure they were appropriate for the target groups. Particular attention was 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 (Appendix 4) (Tapia and Marsh 2004). Several other researchers have also confirmed the validity of using the ATMI, reporting a high reliability of the scale with a high Cronbach's alpha value = 0.963 for the full ATMI and 0.97 for a shorter version (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).

This questionnaire was selected for a variety of reasons including the short completion time of 20 minutes covering 40 questions. The brevity of the assessment was ideal because the control groups completed them during their scheduled A Level classes or during the Pilot Scheme in SA session. (Teachers involved with the research were conscious that student participation shouldn't be time-consuming in their scheduled lesson). 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). Since this questionnaire contained a large number of questions, this strategy of reversed polarity was deemed to be even more important in this case. Questions phrased positively include: questions 1–8, 13, 16–19, 22–24, 26–27, and 29–40). The remainder are phrased negatively. Majeed et al. (2013) have arranged 32 out of the 40 questions from the ATMI questionnaire into four domains of mathematics: Value (questions 1–2 and 3–8), Self-confidence (questions 9–12 and 14, 16–20, 22, and 40), Motivation (questions 23, 28, 32, and 33) and Enjoyment (questions 24–27, 29–31, and 37–38). These domains will be used in the presentation and analysis of the results. In addition, the 5-point Likert scale (*a–e*) enabled participants to produce answers that include strongly disagree, disagree, neutral, agree and strongly agree.

There were no appropriate or valid statistical attitude questionnaires identified for use with the target population of students used in this study. Since public perceptions in relation to the differences between mathematics and statistics suggest they elide the two subjects together, imprinting negative mathematical attitudes onto statistics, it was deemed appropriate to measure mathematical attitudes to encompass statistical attitudes (Gal and Ginsberg 1994; Franklin 2013; Fitzmaurice et al. 2014; Gibbison 2017; National Numeracy 2017).

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 (Appendix 5) (Mincemoyer and Perkins 2005). This questionnaire was selected for a variety of reasons, once again including brevity for in-class completion; the completion time was set at a maximum of 15 minutes covering 20 questions. 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 (Mincemoyer and Perkins 2005). In addition, the 5-point Likert scale enabled participants to produce answers that include never, rarely, sometimes, often, and always.

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's 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).

Questionnaire results were analysed using SPSS to produce descriptive and inferential statistics outputs (Miller et al. 2002). Using inferential statistics on groups with small sample sizes often leads to inconclusive results, with differences between groups being difficult to find, therefore effect size results have also been included (Gersten et al. 2000).

Results

Results from the ATMI and critical thinking questionnaires revealed slight decreases in the number responses, due to either student drop out or illness, from all groups (Table 3). The number of responses, both pre- and post-intervention for the ATMI questionnaire, is highlighted in Table 3.

Table 3
Sample Sizes for ATMI and Critical Thinking Questionnaires, Pre- and Post-Intervention

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

ATMI Results

There were seven items in the Value subscale that were positively worded. These items referred to mathematics as a worthwhile and necessary domain of learning, having a desire to develop skills in mathematics, and appreciating its value in everyday life and education beyond school. Before the intervention had been implemented, the means, close to and greater than 4, suggest that the students were clearly aware and convinced of the importance of mathematics in the Pilot and CAVC groups (Table 4). However, the St David's groups scores were lower, ranging from 2.89–3.77 (Table 4).

Table 4
ATMI Results Pre-Intervention.

Label from ATMI	Domain	Pilot Pre-Test		CAVC Pre-Test		StD Pre-Test	
		Mean	SD	Mean	SD	Mean	SD
	Value						
1	Val 1	4.48	0.64	4.25	1.09	3.77	0.93
2	Val 2	4.32	0.93	3.85	0.85	2.98	1.24
4	Val 3	3.92	1.13	4.00	0.89	3.39	1.02
5	Val 4	3.96	1.18	4.00	0.89	3.25	1.05
6	Val 5	3.60	1.13	3.75	0.89	3.16	1.02
7	Val 6	3.80	0.98	3.90	1.18	3.11	1.00
8	Val 7	3.44	1.13	3.70	0.90	2.89	1.32
		3.93		3.92		3.22	
	Self-confidence						
9	SlfCon 1R	3.16	1.38	3.25	1.22	2.19	1.48
10	SlfCon 2R	3.76	1.11	3.60	1.11	2.66	1.29
11	SlfCon 3R	3.36	1.23	3.70	0.95	2.94	1.46
12	SlfCon 4R	3.56	1.30	3.75	0.99	2.95	1.34
14	SlfCon 5R	3.64	1.05	3.60	1.11	2.39	1.38
20	SlfCon 6R	3.52	0.98	3.60	0.66	2.92	1.07
16	SlfCon 7	3.08	0.98	3.40	1.11	2.64	1.40
17	SlfCon 8	2.80	0.94	2.90	0.94	2.11	1.25
18	SlfCon 9	3.08	0.98	3.40	0.84	2.61	1.07
19	SlfCon 10	3.52	1.06	3.25	0.99	2.58	1.16
22	SlfCon 11	3.00	0.94	3.50	1.02	2.34	0.96
40	SlfCon 12	3.08	1.09	3.10	1.14	2.61	1.10
		3.30		3.42		2.58	
	Motivation						
28	Mot 1R	3.72	1.25	3.45	1.16	2.83	1.43
23	Mot 2	3.44	1.06	2.80	1.08	2.14	1.42
32	Mot 3	3.40	1.17	2.80	1.17	1.88	1.15
33	Mot 4	2.88	1.37	2.55	1.02	1.61	1.06
		3.36		2.90		2.11	
	Enjoyment						
25	Enj 1R	2.80	1.20	3.55	1.36	2.58	1.31
24	Enj 2	2.72	1.36	3.50	1.32	2.55	1.45
26	Enj 3	3.52	1.02	3.25	1.22	2.55	1.33
27	Enj 4	2.88	1.39	3.05	1.53	2.80	1.54
29	Enj 5	3.32	1.12	3.00	1.14	1.91	1.16
30	Enj 6	2.60	1.39	2.30	1.10	1.70	1.13
31	Enj 7	3.64	1.20	3.20	1.21	2.09	1.17
37	Enj 8	3.32	1.05	3.10	1.14	2.52	1.32
38	Enj 9	3.16	1.19	3.30	1.19	2.45	1.24
		3.11		3.14		2.35	
	ATMI	3.39	1.12	3.39	1.08	2.60	1.23

Note: Mean values are unweighted for each subscale and for the overall ATMI inventory

There were six negative items in the Self-confidence subscale (with the letter R next to them in Table 4), and they referred to mathematics causing nervousness, confusion, feeling of dread, dislike of the word mathematics, and being uncomfortable. The positive items relate to student expectation of doing well in mathematics, being able to learn mathematics easily, and being good at solving problems. The means of the 12 items suggest that students' Self-confidence in mathematics were lower than the Value scores, being closer to a mean score of 3, ranging from 2.8 to 3.75 for the Pilot and CAVC groups. Again, the St David's group had lower scores in this domain, ranging from 2.11–2.95 (Table 4).

The Motivation subscale covered willingness to pursue mathematics beyond the compulsory level. The mean scores for the Pilot group in this domain were higher than the other two groups, with the St David's group having the lowest motivation scores to pursue mathematics.

The nine items in the Enjoyment subscale referred to enjoying mathematics, the challenge of solving new problems, the comfort level in participating in discussion in mathematics, and feeling of happiness in the mathematics classroom. Again, the Pilot and CAVC groups had comparable Enjoyment scores, with the St David's group having lower scores for this domain. Overall, all groups showed medium to low enjoyment levels for mathematics.

Post intervention, the Pilot group saw increased scores for the domains of Value, Self-confidence, Motivation, and Enjoyment (Table 5). These differences are also statistically significant results at the 5% level, except for the Motivation subscale (Table 6). The confidence intervals associated with the statistically significant results (i.e., all except the Motivation subscale) are negative, which suggest that these scores are likely to have increased after the intervention (Table 6).

The scores for the CAVC group were roughly comparable, pre and post intervention (Tables 4 and 5). However, there were statistically significant differences in the Self-confidence and Enjoyment subscale scores, when comparing pre and post values, at the 5% level (Table 6). The confidence intervals for these results suggest that the Self-confidence scores are likely to have decreased (i.e. associated with a positive confidence interval) whereas their Enjoyment scores are likely to have increased (associated with a negative confidence interval) after the intervention (Table 6).

A similar story is found in the St David's group; mean scores were roughly comparable, pre and post intervention (Tables 4 and 5). In addition, there was no statistical significant difference in their subscale scores, when comparing pre and post values, at the 5% level (Table 6).

Table 5
ATMI Results Post-Intervention.

Label from ATMI	Domain	Pilot Post-Test		CAVC Post-Test		StD Post-Test	
		Mean	SD	Mean	SD	Mean	SD
	Value						
1	Val 1	4.56	0.60	4.42	0.76	3.69	0.98
2	Val 2	4.56	0.60	3.92	0.86	2.82	1.15
4	Val 3	4.28	0.65	4.33	0.62	3.35	1.20
5	Val 4	4.17	0.76	4.00	0.82	3.14	1.24
6	Val 5	3.61	1.01	4.17	0.69	3.18	1.18
7	Val 6	4.06	0.97	3.75	0.92	3.41	0.97
8	Val 7	3.56	0.96	3.42	1.26	2.82	1.13
		4.11		4.00		3.20	
	Self-Confidence						
9	SlfCon 1R	3.28	1.45	3.17	1.07	2.37	1.37
10	SlfCon 2R	3.72	1.24	3.25	0.92	2.63	1.30
11	SlfCon 3R	3.72	1.24	3.25	1.01	2.92	1.41
12	SlfCon 4R	3.89	1.29	3.58	1.11	2.88	1.42
14	SlfCon 5R	3.67	1.41	3.67	1.25	2.43	1.35
20	SlfCon 6R	3.61	1.21	3.17	1.07	2.71	1.19
16	SlfCon 7	3.83	1.12	3.08	1.04	2.45	1.26
17	SlfCon 8	3.44	1.30	2.67	0.75	2.22	1.14
18	SlfCon 9	3.67	0.82	3.17	0.80	2.57	1.03
19	SlfCon 10	3.56	0.90	3.08	0.86	2.45	1.09
22	SlfCon 11	3.50	1.12	3.25	1.01	2.33	0.96
40	SlfCon 12	3.67	1.11	3.33	0.85	2.59	0.97
		3.63		3.22		2.55	
	Motivation						
28	Mot 1R	3.56	1.17	3.33	1.11	2.55	1.23
23	Mot 2	3.61	1.38	3.25	1.16	2.02	1.21
32	Mot 3	3.89	0.81	3.00	1.22	2.08	1.06
33	Mot 4	3.44	1.01	2.75	1.16	1.75	0.97
		3.63		3.08		2.10	
	Enjoyment						
25	Enj 1R	3.89	1.10	3.50	1.19	2.59	1.30
24	Enj 2	3.67	1.33	3.83	0.90	2.43	1.27
26	Enj 3	3.72	1.10	3.67	0.75	2.57	1.05
27	Enj 4	3.78	1.47	2.92	1.32	2.35	1.36
29	Enj 5	3.56	1.17	3.08	0.86	2.31	1.16
30	Enj 6	3.22	1.36	2.67	1.19	1.75	0.98
31	Enj 7	3.89	1.05	3.58	0.86	2.33	0.96
37	Enj 8	3.83	0.90	3.50	0.96	2.82	1.02
38	Enj 9	3.67	0.94	3.33	0.94	2.53	0.98
		3.69		3.34		2.41	
	ATMI	3.75	1.08	3.41	0.98	2.59	1.15

Note: Mean values are unweighted for each subscale and for the overall ATMI inventory.

Table 6
Paired *t*-test, Comparison of ATMI Subscale Scores Pre- and Post-Intervention

Pre/Post Comparison: Group, Subscale		Paired Differences							Sig. (2- tailed)
		Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference		<i>t</i>	<i>df</i>	
					Lower	Upper			
Pair 1	Pilot, Value	-0.18	0.12	0.05	-0.29	-0.07	-4.05	6	0.01
Pair 2	CAVC, Value	-0.08	0.25	0.09	-0.31	0.15	-0.85	6	0.43
Pair 3	StD, Value	0.02	0.15	0.06	-0.12	0.16	0.35	6	0.74
Pair 4	Pilot, Self-Confidence	-0.33	0.28	0.08	-0.51	-0.16	-4.15	11	0.00
Pair 5	CAVC, Self-Confidence	0.20	0.20	0.06	0.07	0.32	3.47	11	0.01
Pair 6	StD, Self-Confidence	0.03	0.11	0.03	-0.04	0.10	1.00	11	0.34
Pair 7	Pilot, Motivation	-0.26	0.33	0.17	-0.79	0.26	-1.60	3	0.21
Pair 8	CAVC, Motivation	-0.18	0.23	0.12	-0.55	0.19	-1.56	3	0.22
Pair 9	StD, Motivation	0.02	0.22	0.11	-0.34	0.37	0.13	3	0.90
Pair 10	Pilot, Enjoyment	-0.59	0.33	0.11	-0.84	-0.33	-5.30	8	0.00
Pair 11	CAVC, Enjoyment	-0.20	0.22	0.07	-0.37	-0.04	-2.79	8	0.02
Pair 12	StD, Enjoyment	-0.06	0.25	0.08	-0.25	0.13	-0.70	8	0.50

To get a sense of the overall size of impact of the Pilot Scheme in SA course on student attitudes, we measure Cohen's *d* using student responses to the full ATMI (i.e., combining the four subscales). Cohen's *d* is a measure that changes in terms of standard deviations to enable direct comparison between groups. Cohen's *d* values between groups were calculated using the means and standard deviations of each group (UCCS 2017). Cohen suggests that $d = 0.2$ be considered a "small" effect size, 0.5 represents a "medium" effect size, and 0.8 a "large" effect size. This range means that if two groups' means don't differ by 0.2 standard deviations or more, the difference is trivial, even if it is statistically significant. The results of the Cohen *d* value between the CAVC and Pilot group, pre-intervention, show that there was complete overlap in scores (Table 7). However, the Cohen *d* value between the St David's and Pilot group show a large effect size with a score of 0.67 (Table 7). This value increased slightly between the CAVC and Pilot group post-intervention, revealing a Cohen *d* value of 0.33 (Table 7). The value increased to 1.04 between the St David's and Pilot group, post intervention, indicating an increasing amount of non-overlap in scores (Table 7). The change in effect size between the Pilot Scheme, pre-post, and the two control groups is almost identical, which may suggest this result could be due to the intervention.

Table 7
Cohen's *d* Comparisons between Groups for the ATMI Questionnaire

	CAVC	StD
Pilot Pre-Test	0	0.67
Pilot Post-Test	0.33	1.04

Critical Thinking Results

Overall, all three groups had medium to high level attitudes in relation to the usefulness of critical thinking, pre-intervention (Table 8). The Pilot and CAVC groups had similar overall scores, with the St David's group having the lowest overall mean score for this questionnaire (Table 8).

Table 8
Critical Thinking Results Pre-Intervention

Label from Critical-Thinking Questionnaire	Pilot Pre-Test		CAVC Pre-Test		StD Pre-Test	
	Mean	SD	Mean	SD	Mean	SD
1	3.92	0.74	3.80	0.75	3.91	0.86
2	3.48	0.70	3.45	0.86	3.38	0.65
3	4.20	0.57	3.95	0.67	3.34	0.81
4	4.36	0.62	4.05	0.74	3.94	0.73
5	3.76	0.86	3.55	0.74	3.59	1.01
6	4.28	0.78	4.05	0.86	3.97	0.88
7	4.40	0.63	3.80	0.87	3.56	0.83
8	3.88	0.95	3.75	0.99	3.20	0.89
9	3.20	0.89	2.75	0.89	2.77	0.93
10	3.32	0.73	3.05	0.86	2.86	0.95
11	3.48	1.06	3.50	0.97	2.88	1.08
12	4.16	0.88	3.85	0.85	3.61	0.78
13	4.16	0.83	4.20	0.93	4.11	0.89
14	4.32	0.68	3.85	0.85	3.69	0.79
15	3.80	1.10	3.75	0.62	3.88	0.74
16	3.92	1.06	3.85	1.01	3.91	1.03
17	3.40	1.13	2.75	1.37	2.17	1.27
18	3.48	0.75	4.00	0.89	3.67	1.03
19	3.52	0.85	3.50	0.67	3.34	0.75
20	4.28	0.83	3.85	0.79	3.72	0.78
Overall	3.87	0.83	3.67	0.86	3.47	0.88

In terms of comparing the groups' initial scores, it appears that all three groups had similar attitudes to critical thinking pre-intervention, demonstrated by their similar mean scores for the critical thinking questionnaire, and also similar standard deviation values (Table 8).

Post-intervention, there were some changes in the attitude scores for all groups (Table 9). The Pilot group saw an increase from 3.87 to 4, in relation to the mean score. This increase was also a statistically significant result, at the 5% level (Table 10). However, the CAVC group saw a decrease in critical thinking attitudes post-intervention, dropping from 3.67 to 3.43. This difference was also a statistically significant result, at the 5% level (Table 10). The St David's group had the same mean scores pre- and post-intervention (Table 10).

Table 9
Critical Thinking Results Post-Intervention

Group Label from Critical-Thinking Questionnaire	Pilot Post-Test		CAVC Post-Test		StD Post-Test	
	Mean	SD	Mean	SD	Mean	SD
1	4.17	0.90	3.50	1.32	3.80	0.74
2	3.83	0.90	4.08	0.76	3.31	0.73
3	4.00	0.75	3.50	1.04	3.65	0.86
4	4.33	0.47	3.42	1.19	3.92	0.79
5	3.94	0.70	3.25	1.01	3.63	0.99
6	4.28	0.65	3.58	1.26	3.96	0.77
7	4.28	0.65	3.58	1.19	3.86	0.91
8	4.11	0.66	3.25	0.60	3.35	0.84
9	3.28	0.93	2.92	1.11	2.88	0.96
10	3.39	1.01	3.25	1.23	2.88	1.02
11	3.50	1.21	3.50	1.26	2.90	1.14
12	4.06	1.03	3.58	0.86	3.65	0.84
13	4.33	0.82	4.08	0.64	3.96	0.97
14	4.17	0.76	3.67	1.03	3.73	0.84
15	4.28	0.65	3.67	1.11	3.65	0.76
16	3.94	0.85	3.25	1.42	3.57	1.00
17	3.72	1.04	2.50	1.32	2.63	1.30
18	4.06	0.85	3.58	1.11	3.25	0.84
19	4.06	0.97	2.92	1.04	3.29	1.02
20	4.28	0.80	3.50	1.19	3.57	1.05
Overall	4.00	0.83	3.43	1.08	3.47	0.92

Table 10
Paired *t*-test, Comparison of Critical Thinking Scores Pre- and Post-Intervention

		Paired Differences							
				95% Confidence Interval of the Difference					Sig. (2-tailed)
		Std.	Std. Error						
Group		Mean	Deviation	Mean	Lower	Upper	<i>t</i>	<i>df</i>	
Pair 1	Pilot	-0.13	0.23	0.05	-0.24	-0.03	-2.62	19	0.02
Pair 2	CVAC	0.24	0.31	0.07	0.09	0.38	3.39	19	0.00
Pair 3	STD	0.00	0.21	0.05	-0.10	0.10	0.04	19	0.97

Cohen *d* values between the CAVC and Pilot group, pre intervention, show that there was a large amount of overlap in scores, with a value of 0.24 (Table 11). However, the pre-intervention Cohen *d* value between the St David's and Pilot group shows a medium effect size with a score of 0.47 (Table 11). This value increased between the CAVC and Pilot group post-intervention, resulting in a Cohen *d* value of 0.59 (Table 11). The value also increased to 0.60 between the St

David's and Pilot group, post-intervention, indicating an increasing amount of non-overlap in scores (Table 11).

Table 11

Cohen's d Comparisons Between Groups for the Critical-Thinking Questionnaire

	CAVC	StD
Pilot Pre-Test	0.24	0.47
Pilot Post-Test	0.59	0.60

Discussion

These results are interesting, especially considering that the four subscale scores in mathematics for the control groups mostly decreased after the experiment. As stated earlier, all students in this experiment 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 mathematics for 14–16 year old students in the UK) enabled them to realise the importance of developing these skills, although this is only speculation. Other explanations could be linked to the Hawthorne effect, 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). However, McCambridge et al. state that accurately measuring the impact of this effect on the results can be difficult to achieve due to the complexity of the experimental design adopted.

The Pilot group 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 (see student evaluation questionnaires in Jones 2018b), results from the attitudes to mathematics suggest it could have enabled them to see the value in and enjoyment of what they were doing. The results also suggest that their self-confidence with mathematics improved. In contrast, traditional methods of teaching mathematics are characterised by a didactic approach, which lacks debate, giving mathematics an uninteresting identity (Noyes 2007, 69; Porkess 2013; Donaldson 2015). Coupled with this, mathematics has a socially accepted negative identity; it's OK 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 their attitudes towards the value, motivation, and their self-confidence with reference to the mathematical encounters they have received in secondary school education.

The critical thinking attitudes of participants in the Pilot group revealed increases in their perceived abilities. In contrast, students from both control groups revealed mostly decreases or no change. Participants in the Pilot group 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) who argues that students should develop a relational understanding (knowing what to do and why). Intentionally constructing a curriculum that embeds statistical concepts and critical thinking has had the intended effect of increasing perceived abilities in critical thinking.

Limitations

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, this was not within the scope of this research (Trautwein 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 negative mathematical attitudes onto statistics. This would be an area for potential future research.

The questionnaires selected for this study 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. 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 et al. 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 and critical thinking, pre- and post-intervention. However, the level of negative mathematical attitudes imprinted onto statistics goes beyond the scope of this paper, and would require additional data with modified questionnaires to investigate if this phenomenon exists in the types of populations investigated during this study.

Other external factors that could have had an impact on these 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, and the gender of the participants, 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 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).

Recommendations

The positive outcomes identified in this study support an expansion of the course (increasing student numbers), to enable other students to increase their attitudes mathematics, statistics and critical thinking. Over time, this should contribute towards an increase in participation, engagement and achievement in mathematics, statistics and critical thinking (Gal and Ginsberg 1994; Khoo and Ainley, 2005), which are skills that 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; pp.160-181; Schleppegrell 2007; Walshaw and Anthony 2008; Durrand-Guerrier 2015, pp.453-457). Statistical education in its current form (in schools in the U.K.) underprepares students for HE, as outlined by the recent ACME recommendations to the Department for Education (ACME 2011). Even with the changes to statistics curricula within the new A Level mathematics, which began 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; 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 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.

Future runs of the course should also consider being reduced in length, perhaps into a 10-week block. This alteration would reduce the amount of commitment year-12 and -13 students would need to allot to engage with this course.

Significant elements of the Pilot Scheme in SA are currently available as a series of units, via the awarding body Agored Cymru (Agored 2017). 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 (CAVC) delivering the units includes lecturers on the TPS, who played an active role in creating the Pilot Scheme course in SA. This development places that particular centre in an advantageous position by being able to deliver elements of a course they created.

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).

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References

- Advisory Committee on Mathematics Education (ACME). 2011. *Mathematical Needs: Mathematics in the Workplace and in Higher Education*.
 Agored. 2017. "Social Analytics Unit Documents."
<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.](#)
- Arnold, P., Pfannkuch, M., Wild, C., Regan, M., Budgett, S. 2011. “Enhancing students’ inferential reasoning: From hands-on to “movies.” *Journal of Statistics Education* 19(2): 1-32. <https://doi.org/10.1080/10691898.2011.11889609>.
- Bennet, T. 1988. “An Assessment of the Design, Implementation and Effectiveness of Neighbourhood Watch in London.” *Howard Journal of Criminal Justice* 27(4): 241–255. <https://doi.org/10.1111/j.1468-2311.1988.tb00623.x>.
- Boynton, P.M., Greenhalgh, T. 2004. “Selecting, Designing and Developing Your Questionnaire.” *BMJ* 328:1312. <https://doi.org/10.1136/bmj.328.7451.1312>.
- Bryden-Miller, M., Greenwood, D., Maguire, P. 2003. “Why Action Research?” *Action Research* 1(1): 9–28. <https://doi.org/10.1177/14767503030011002>.
- Boyle, E.A., Duffy, T., Dunleavy, K. 2003. “Learning styles and academic outcome: The validity and utility of Vermunt’s Inventory of Learning Styles in a British higher education setting.” *British Journal of Educational Psychology* 73(2): 267- 290. <https://doi.org/10.1348/00070990360626976>.
- Budgett, S., Pfannkuch, M., Regan, M., Wild, C. 2013. Dynamic visualizations and the randomization test. *Technology Innovations in Statistics Education* 7(2).
- Cartwright, N. 2007. “Are RCT’s the Gold Standard?” *Biosocieties* 2(1): 11–20. <https://doi.org/10.1017/S1745855207005029>.
- Carver, R., Everson, M., Gabrosek, J., Horton, N., . . . , Wood, B. 2016. *Guidelines and Assessment for Instruction in Statistics Education (GAISE) College Report*. Alexandria, VA: American Statistical Association.
- Cardiff and Vale College (CAVC) 2017. “Welcome page.” Available from: <http://www.cavc.ac.uk/en/about-us/welcome-cardiff-and-vale-college/>.
- Cook, T.D., and Campbell, D.T. 1979. *Quasi-Experimentation: Design and Analysis for Field Settings*. Chicago: Rand McNally.
- Critical Thinking Community, The. 2016. “Higher Education Workshop in Critical Thinking.” <http://www.criticalthinking.org/pages/higher-education/431>.
- Croasmun, J.T., and Ostrom, L. 2011. “Using Likert-Type Scales in the Social Sciences.” *Journal of Adult Education* 40(1): 19–22.
- Daniels, M.J., Hogan, J.W., Chapman, H. 2011. “Missing Data in Longitudinal Studies: Strategies for Bayesian Modeling and Sensitivity Analysis.” *Statistics in Medicine* 30(11): 1327–1328. <https://doi.org/10.1002/sim.4162>.
- Donaldson, G. 2015. “Successful Futures: Independent Review of Curriculum and Assessments Arrangements in Wales.”

- <https://gweddill.gov.wales/docs/dcells/publications/150225-successful-futures-en.pdf>.
- Durrand-Gurrier, V. 2015. "Reasoning, Proof and Proving in Mathematics Education. The Proceedings of the 12th International Congress on Mathematical Education, part 7." Springer International Publishing. https://doi.org/10.1007/978-3-319-12688-3_39.
- Fitzmaurice, O., Leavy, A., Hannigan, A. 2014. "Why Is Statistics Perceived as Difficult and Can Practice during Training Change Perceptions? Insights from a Prospective Mathematics Teacher." *Teaching Mathematics Applications* 33(4): 230–248. <https://doi.org/10.1093/teamat/hru010>.
- Fonow, M., and Cook, J. 1991. *Beyond methodology: Feminist Scholarship and Lived Research*. Indiana University Press.
- Forbes, S. 2014. "The Coming of Age of Statistics Education in New Zealand, and Its Influence Internationally." *Journal of Statistics Education* 22(2): 1–19. <https://doi.org/10.1080/10691898.2014.11889699>.
- Forman, E. 1996. "Learning Mathematics as Participation in Classroom Practice: Implications of Sociocultural Theory for Educational Reform." In Steffe, L. (ed), *Theories of Mathematical Learning*. Lawrence Erlbaum Associates.
- Franklin, C. 2013. "Common Core State Standards and the Future of Teacher Preparation in Statistics." *The Mathematics Educator* 22(2): 2–10.
- Gal, I. (2002). "Adults' Statistical Literacy: Meanings, Components, Responsibilities." *International Statistical Review* 70(1): 1–25. <https://doi.org/10.1111/j.1751-5823.2002.tb00336.x>.
- Gal, I., and Ginsberg, L. 1994. "The Role of Beliefs and Attitudes in Learning Statistics: Towards an Assessment Framework." *Journal of Statistical Education* 2(2). <https://doi.org/10.1080/10691898.1994.11910471>.
- Gardner, H. 1983. *Frames of mind: The Theory of Multiple Intelligences*. Chapter 9: *Bodily-Kinesthetic Intelligence*. USA: Basic Books.
- Gersten, R., Baker, S., Lloyd, J.W. (2000). "Designing High-Quality Research in Special Education: Group Experimental Design." *The Journal of Special Education* 34(1): 2–18. <https://doi.org/10.1177/002246690003400101>.
- Gibbons, R.D., Hedeker, D., Elkin, I., Waternaux, C., Kraemer, H.C., Greenhouse, J.B., Shea, T., Imber, S.D., Sotsky, S.M., Watkins, J.T. 1993. "Some Conceptual and Statistical Issues in Analysis of Longitudinal Psychiatric Data. Application to the NIMH Treatment of Depression Collaborative Research Program Dataset." *Arch GenPsychiatry* 50(9): 739–750. <https://doi.org/10.1001/archpsyc.1993.01820210073009>.
- Gibbison, B. 2017. "Statistically Speaking: Fifty Percent of Anaesthetists Are Worse than Average at Understanding Statistics and Risk." *Anaesthesia* 72: 118–121. <https://doi.org/10.1111/anae.13690>.

- Hey, W., Lovett, M., Church, T., Hey, D. 2016. "Understanding the Intentions of Teaching Styles to Improve Student Learning in Physical Education." *KAHPERD Journal* 54(1): 53-64.
- Jones, R. C. 2019. "Statistical Investigation Measuring Intelligence and Creativity." *Teaching Statistics* 41(1): 36-40.
<https://doi.org/10.1111/test.12169>.
- Jones, R. C. 2018a. "Igniting the Statistical Spark in the Social Sciences." *Journal of Mathematical and System Science* 8: 153-174.
- Jones, R. C. 2018b. "Igniting the Statistical Spark in the Social Sciences—Abilities, Student Feedback and Teacher Observations." *Journal of Mathematical and Statistical Science* 10: 397-403.
- Harrison, S. 2014. "History of Numeracy Education and Training for Print Journalists in England." *Numeracy* 7(2): 1-13. <https://doi.org/10.5038/1936-4660.7.2.2>.
- Hine, G.S.C. 2013. "The Importance of Action Research in Teacher Education Programs." *Issues in Educational Research* 23(2): 151-163.
- Khoo, S. T., and Ainley, J. 2005. "Attitudes, Intentions and Participation: Longitudinal Survey of Australian Youth." Victoria: Australian Council for Educational Research.
- Landers, M. 1999. "Is Socrates Dead (in Mathematics)? The Role of the Mathematics Teacher in Higher Education Now and for the Next Ten Years. Bollinger-Rosado Teaching & Learning Effectiveness Symposium Proceedings." Seventh Annual Symposium on Teaching Effectiveness.
- Linacre, J.M. 2002. "Optimizing Rating Scale Category Effectiveness." *Journal of Applied Measurement* 3(1): 85-106.
- Lincoln, Y., and Guba, E. 1985. *Naturalistic Inquiry*. Newbury Park, CA: Sage.
- Lincoln, Y., and Guba, E. 1988. "Do Inquiry Paradigms Imply Inquiry Methodologies?" In D. Fetterman (ed.), *Qualitative Approaches to Evaluation in Educational Research* (89-115). Newbury Park, CA: Sage.
- Lui, M. 1994. "The relationship between the learning strategies and learning styles in a hypermedia environment." *Computers in Human Behavior* 10(4): 419- 434. [https://doi.org/10.1016/0747-5632\(94\)90038-8](https://doi.org/10.1016/0747-5632(94)90038-8).
- MacInnes, J. 2009. "Proposals to Support and Improve the Teaching of Quantitative Methods to Undergraduate Students in the UK." Swindon: Economic and Social Research Council.
- Mainemelis, C., Boyatzis, R.E., Kolb, A. 2002. "Learning styles and Adaptive Flexibility. Testing Experiential Learning Theory." *Management Learning* 33(1): 5- 33. <https://doi.org/10.1177/1350507602331001>.
- Majeed, A.A., Darmawan, I.G.N., Lynch, P.2013. "A Confirmatory Factor Analysis of Attitudes Toward Mathematics Inventory (ATMI)." *The Mathematics Educator* 15(1): 121-135.

- Maxwell, J. 2004. "Causal Explanation, Qualitative Research, and Scientific Inquiry in Education." *Educational Researcher* 33(2): 3–11.
<https://doi.org/10.3102/0013189X033002003>.
- McCambridge, J., Witton, J., Elbourne, D.R. 2014. "Systematic Review of the Hawthorne Effect: New Concepts Are Needed to Study Research Participation Effects." *J Clin Epidemiol* 67(3): 267–277.
<https://doi.org/10.1016/j.jclinepi.2013.08.015>.
- Miller, R., Acton, C., Fullerton, D., Maltby, J. 2002. *SPSS for Social Scientists*.
<https://doi.org/10.1007/978-0-230-62968-4>.
- Mincemoyer, C.C., and Perkins, D.F. 2005. "Measuring the Impact of Youth Development Programs: A National Online Youth Life Skills Evaluation System." *The Forum for Family and Consumer Issues Journal* 10(2).
- Morgan, L. 2007. "Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods." *Journal of Mixed Methods* 1: 48–76. <https://doi.org/10.1177/2345678906292462>.
- National Numeracy 2017. "A New Approach to Making the UK Numerate." https://www.nationalnumeracy.org.uk/sites/default/files/nn124_essentials_numeracyreport_for_web.pdf.
- Noyes, A. 2007. *Rethinking School Mathematics*. Sage Publications Company, London.
- Nunez, R. 2006. *Unconventional Essays on Nature of Mathematics, chapter 18: Do Real Numbers Really Move? Language, Thought, and Gesture: The embodied Cognitive Foundations of Mathematics*. 160–181. Springer New York. https://doi.org/10.1007/0-387-29831-2_9.
- Payne, G. 2014. "Surveys, Statisticians and Sociology: A History of (a Lack of) Quantitative Methods." *ELiSS* 6(2): 74–89.
<https://doi.org/10.11120/elss.2014.00028>.
- Payne, G., Williams, M., Chamberlain, S. 2004. "Methodological Pluralism in British Sociology." *Sociology* 38(1): 153–163.
<https://doi.org/10.1177/0038038504039372>.
- Petticrew, M., Cummins, S., Ferrell, C., et al. 2005. "Natural Experiments: An Underused Tool for Public Health?" *Public Health* 119: 751–757.
<https://doi.org/10.1016/j.puhe.2004.11.008>.
- Platt, J. 2012. "Making Them Count: How Effective Has Official Encouragement of Quantitative Methods Been in British Sociology?" *Current Sociology* 60(5): 690–704. <https://doi.org/10.1177/0011392112440438>.
- Porkess, R. 2013. "A World Full of Data: Statistics Opportunities across A Level Subjects." <http://www.rss.org.uk/Images/PDF/influencing-change/A-world-full-of-data.pdf>.

- Roth, M-W. 2014. "Interdisciplinary Approaches in Mathematics Education." *Encyclopedia of Mathematics Education*, 317–320.
https://doi.org/10.1007/978-94-007-4978-8_82.
- Royal Statistical Society and Advisory Committee on Mathematics Education (RSS and ACME) 2015. "Embedding Statistics at A Level."
<http://www.rss.org.uk/Images/PDF/publications/embedding-statistics-at-a-level.pdf>.
- Saba, F. 2000. "Research in Distance Education." *International Review of Research in Open and Distance Learning* 1(1): 1–9.
<https://doi.org/10.19173/irrodl.v1i1.4>.
- Schleppegrell, M.J. 2007. "The Linguistic Challenges of Mathematics Teaching and Learning: A Research Review." *Reading and Writing Quarterly: Overcoming Learning Difficulties*; 23(2): 139–159.
<https://doi.org/10.1080/10573560601158461>.
- Schau, C., & Emmioglou, E. 2012. "Do Introductory Statistics Courses in the United States Improve Students' Attitudes?" *Statistics Education Research Journal* 11(2), 86–94.
- Schilling, K., and Applegate, R. 2012. "Best Methods for Evaluating Educational Impact: A Comparison of the Efficacy of Commonly Used Measures of Library Instruction." *J Med Libr Assoc* 100(4): 258–269.
<https://doi.org/10.3163/1536-5050.100.4.007>.
- Skemp, R.R. 1976. "Relational Understanding and Instrumental Understanding." *Mathematics Teaching* 77, 20–26.
- Slavin, R.E. 2008. "Perspectives on Evidence-Based Research in Education: What works?" *Issues in Synthesizing Educational Program Evaluations. Educational Researcher* 37(1): 5–14.
<https://doi.org/10.3102/0013189X08314117>.
- Smith, A. 2004. "Making Mathematics Count."
<http://www.mathsinquiry.org.uk/report/MathsInquiryFinalReport.pdf>.
- Smith, A. 2017. "Report of Professor Sir Adrian Smith's Review of Post-16 Mathematics."
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/630488/AS_review_report.pdf.
- St David's College (St David's) 2017. "Welcome Page." Available from:
<https://www.stdavidscollege.ac.uk/the-college/>.
- Swan, M. 2005. "Improving Learning in Mathematics: Challenges and Strategies." Sheffield: Teaching and Learning division, Department for Education and Skills Standards Unit.
- Tapia, M. and Marsh, G. E. 2004. "An Instrument to Measure Mathematics Attitudes." *Academic Exchange Quarterly* 8(2): 16–21.

- Trautwein, U., Luke, O., Marsh, H. W., Koller, O., Baumert, J. 2006. "Tracking, Grading, and Student Motivation: Using Group Composition Status to Predict Self-Concept and Interest in Ninth-Grade Mathematics." *Journal of Educational Psychology* 98(4): 788–806. <https://doi.org/10.1037/0022-0663.98.4.788>.
- University of Colorado—Colorado Springs (UCCS) 2017. "Cohen *d* Effect Size Calculator." <http://www.uccs.edu/~lbecker/>.
- Walshaw, M., and Anthony, G. 2008. "The Teacher's Role in Classroom Discourse: A Review of Recent Research Into Mathematics Classrooms." *Review of Educational Research* 78(3): 516–551. <https://doi.org/10.3102/0034654308320292>.
- Welsh Joint Education Committee (WJEC) 2016. "Sociology A Level Specification." <https://www.wjec.co.uk/qualifications/sociology/r-sociology-gce-as-a/wjec-gce-sociology-spec-from-2015.pdf>.
- Welsh Joint Education Committee (WJEC) 2017. "Psychology A Level Specification." [http://www.wjec.co.uk/GCE%20Psychology%20Spec%202009%20onwards%20\(31-03-14\).pdf?language_id=1](http://www.wjec.co.uk/GCE%20Psychology%20Spec%202009%20onwards%20(31-03-14).pdf?language_id=1).
- Welsh Joint Education Committee (WJEC) 2017a. Government and Politics A Level Specification.: [http://www.wjec.co.uk/qualifications/government-and-politics/government-and-politics-gce-from-2010/GCE%20Government%20Politics%20Spec%202010%20onwards%20\(31-03-14\).pdf?language_id=1](http://www.wjec.co.uk/qualifications/government-and-politics/government-and-politics-gce-from-2010/GCE%20Government%20Politics%20Spec%202010%20onwards%20(31-03-14).pdf?language_id=1).
- Williams, M., Payne, G., Hodgkinson, L. 2008 "Does Sociology Count? Student Attitudes to the Teaching of Quantitative Methods." *Sociology* 42 (5): 1003–1022. <https://doi.org/10.1177/0038038508094576>.
- Williams, M., Sloane, L., Cheung, S.Y., Sutton, C., Stevens, S., Runham, L. 2015. "Can't Count or Won't Count? Embedding Quantitative Methods in Substantive Sociology Curricula: A Quasi-Experiment." *Sociology* 1–18. <https://doi.org/10.1177%2F0038038515587652>.
- Yee, L.S., and Chapman, E. 2013. "Development of a Short Form of the Attitudes toward Mathematics Inventory." *Educational Studies in Mathematics* 82: 145–164. <https://doi.org/10.1007/s10649-012-9414-x>.

Appendix 1

Level 3 Pilot in Social Analytics Learning Outcomes (Units 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 21st 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 square 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 2

Scheme of Work: Level 3 Pilot Scheme in Social Analytics

Course:

Unit 1—Social Science in Practice (SSP)

Unit 2—Applied Statistics (AP)

SoW 2015/16 (4–6 p.m.)

Date (Week commencing)	Topic		Statistics covered	Notes
	Unit 1 SSP (4-5pm)	Unit 2 AP (5-6pm)		
12/10	Introduction to the course		Designing research questions	
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			
28/12	Christmas & New Year Break			
04/01	Data collection and analysis Coursework and presentation guidance		Reliability and Validity	
11/01				
18/01	Major breakthroughs of the 21 st century	Information presentation	Reliability and Validity	
25/01	Technology and the environment	Can you trust what the newspapers say?	Chi-square	
01/02	Gender and science	Power of the media	Chi-square	
08/02	Data collection and analysis Group presentations		Perceptions and reasoning	
15/02	Half Term Break			
22/02	Data collection and analysis Group presentations		Regression and validity	
29/02				
07/03	The future	The future of the media	Regression	
14/03	Crime and deviance introduction	Becoming an effective researcher - plenary	Regression	
21/03	The role of crime in society	Group work	Review	End of course evaluation
28/03	Easter break			
04/04	Easter break			

Appendix 3

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	$mgft$
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—

1. Which region resulted in the highest final gang numbers?
2. What other factors could influence the amount of time needed to train gang members?
3. Do you think it would be fair to pay gang members different rates—depending on the region they are located? Explain your answer.

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.

Appendix 4

Attitudes towards Mathematics Inventory



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



Cardiff School
of Social Sciences



Name _____	School _____
Teacher _____	
<p>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.</p>	
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

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.					
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).