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Teaching research methods to undergraduate dental students

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Abstract

The provision of undergraduate statistics teaching varies across UK dental schools, but some challenges are faced in all schools. These include the need to (i) demonstrate the relevance of statistics to dentistry, (ii) address the phenomenon of statistical anxiety likely to be experienced, and (iii) deliver the teaching with a limited number of statistically trained staff. Our objective was to design a research methods course that combined epidemiology and statistics teaching for undergraduates at Bristol Dental School (University of Bristol) that was clinically relevant, focused on concepts and interpretation rather than calculation, and was sustainable, using new technology to enhance learning. The research methods course was introduced in 2008, extensively developed over the next two years based on student and tutor feedback, and has run with only minor updates ever since. The aim of the course is to introduce year 2 dental students to the skills needed to practice evidence-based dentistry, i.e. understand and critically appraise published research. Basic epidemiological concepts, different types of study design, summarising and interpreting data, and choosing appropriate statistical analyses are covered. The course is introduced by a face-to-face lecture. This emphasises the relevance to future careers, and pre-empts the feelings of statistical anxiety by presenting evidence that exam results for this course are not associated with having achieved an A-level in mathematics. The rest of the course is delivered using the flipped classroom approach. Didactic teaching is in the form of nine e-lectures, each lasting 20-25 minutes. These are split into chapters to allow easy navigation, and include pop-up questions. Small group (up to 10 students) structured tutorials (one per e-lecture) are used to reinforce the material covered in the e-lectures, drawing on real clinical examples from research publications. They are interactive, and also include e-voting quizzes to allow the tutors and students to gauge the level of understanding that is being achieved. At the end of the course there is a revision session and written assessment, which must be passed before students can progress to year 3 of the dental degree. Approximately 70 students take the course each year, split into eight groups, and tutorials are based on pre-prepared materials. Tutoring on this course provides an attractive opportunity to gain teaching experience, with only a modest investment in time. Therefore, it has always been possible to recruit enough statisticians or epidemiologists in the Faculty of Health Sciences, University of Bristol to act as tutors. At least 89% of the students have passed the exam on first sitting each year, and all students have passed their re-sit exam. Marks ranged from 50-86% in 2019, and similar ranges were seen in previous years. Student feedback is consistently high, with virtually all students rating all components of the course at least satisfactory, and high percentages rating them good or excellent (e-lectures and tutorials were rated to be good or excellent by 72% and 95% of the students respectively in 2019). External examiners have been very complimentary, and only ever requested minor changes. Hence it has been possible to run a sustainable research methods course that engages students' interest and produces excellent learning outcomes.

Keywords

Research methods, undergraduate, dental

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The provision of undergraduate statistics teaching varies across UK dental schools, but some challenges are faced in all schools. These include the need to (i) demonstrate the relevance of statistics to dentistry, (ii) address the phenomenon of statistical anxiety likely to be experienced, and (iii) deliver the teaching with a limited number of statistically trained staff. Our objective was to design a research methods course that combined epidemiology and statistics teaching for undergraduates at Bristol Dental School (University of Bristol) that was clinically relevant, focused on concepts and interpretation rather than calculation, and was sustainable, using new technology to enhance learning. The research methods course was introduced in 2008, extensively developed over the next two years based on student and tutor feedback, and has run with only minor updates ever since. The aim of the course is to introduce year 2 dental students to the skills needed to practice evidence-based dentistry, i.e. understand and critically appraise published research. Basic epidemiological concepts, different types of study design, summarising and interpreting data, and choosing appropriate statistical analyses are covered. The course is introduced by a face-to-face lecture. This emphasises the relevance to future careers, and pre-empts the feelings of statistical anxiety by presenting evidence that exam results for this course are not associated with having achieved an A-level in mathematics. The rest of the course is delivered using the flipped classroom approach. Didactic teaching is in the form of nine e-lectures, each lasting 20-25 minutes. These are split into chapters to allow easy navigation, and include pop-up questions. Small group (up to 10 students) structured tutorials (one per e-lecture) are used to reinforce the material covered in the e-lectures, drawing on real clinical examples from research publications. They are interactive, and also include e-voting quizzes to allow the tutors and students to gauge the level of understanding that is being achieved. At the end of the course there is a revision session and written assessment, which must be passed before students can progress to year 3 of the dental degree. Approximately 70 students take the course each year, split into eight groups, and tutorials are based on pre-prepared materials. Tutoring on this course provides an attractive opportunity to gain teaching experience, with only a modest investment in time. Therefore, it has always been possible to recruit enough statisticians or epidemiologists in the Faculty of Health Sciences, University of Bristol to act as tutors. At least 89% of the students have passed the exam on first sitting each year, and all students have passed their re-sit exam. Marks ranged from 50-86% in 2019, and similar ranges were seen in previous years. Student feedback is consistently high, with virtually all students rating all components of the course at least satisfactory, and high percentages rating them good or excellent (e-lectures and tutorials were rated to be good or excellent by 72% and 95% of the students respectively in 2019). External examiners have been very complimentary, and only ever requested minor changes. Hence it has been possible to run a sustainable research methods course that engages students' interest and produces excellent learning outcomes.

Keywords

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Introduction

Up until 1990, teaching statistics to dental students was a relatively unexplored area (Smeeton, 1996). In 1990, the General Dental Council (GDC) published guidelines recommending that "teaching should introduce the student to the principles of scientific thought and argument including the evaluation of scientifically established facts, experimental design, statistics and the analysis of data, and place the clinical instruction in the scientific context". In 2002, an informal study of the methods of teaching statistics used in dental schools in Britain and Ireland was undertaken (Smeeton, 2002). Detailed information was received from all 14 dental schools. Courses were provided by dental departments in four schools, and statistics departments in the other nine, and in all but two schools, dental students were taught separately from medical students. There was variation in terms of the degree year in which the teaching was delivered, the method of delivery, the number of contact hours, the form of assessment used, and whether statistical packages were taught; no detail on the content of the courses was reported. However, the content of the course delivered at Barts and the London School of Dentistry (Queen Mary University of London) was the basis for "*Evidence-Based Dentistry: An Introduction"* published in 2006 (Hackshaw, Paul & Davenport). To our knowledge, there are no further publications detailing the provision of statistical teaching for dental students.

The current provision of statistics teaching varies across the 16 dental schools (two of which are graduate entry) and two postgraduate entry dental institutes in the UK, but is not well-documented. An overview of the undergraduate teaching of statistics within medicine and allied health sciences across UK universities, in particular detail on which statistical concepts are taught, it available online (Usher Institute, 2020). Although the focus of the overview did not include dentistry, information from Bristol and Cardiff Dental Schools are included, along with information from Newcastle on dental students that are intercalating.

Challenges in the provision of statistics teaching are likely to be faced in all dental schools. As pointed out by Race (2006), while it may be difficult to generate a strong wish to learn in the students, it should be possible to explain to them convincingly why they need to learn. Therefore, the relevance of statistics to dentistry must be demonstrated to the students. Another challenge is that dental students may lack confidence in their ability to understand statistics. Statistical anxiety is a recognised phenomenon, often experienced by students from non-statistics disciplines (Onweuegbuzie & Wilson, 2003), although to our knowledge, has not been formally assessed in dental students. However, statistical anxiety has been reported in medical students (Beurze et al., 2013), and dental students have been shown to suffer with anxiety in general more frequently than medical students (Prinz et al., 2012). Therefore, statistical anxiety should be addressed in dental students. A further challenge is that in most dental schools, there are only likely to be a few, if any, statistically trained staff. Dental statistics teaching may have to be provided by either statisticians or epidemiologists from other departments who are less likely to be able to illustrate concepts with relevant examples, or by numerate clinical academics. Williamson and Lancaster (2004) demonstrated that the consensus among medical statistics teachers is that teaching should be undertaken by a statistician.

Bristol Dental School (formally known as the School of Oral and Dental Sciences), UK introduced a new curriculum for the five-year Bachelor of Dental Surgery (BDS) degree in the academic year 2007-2008. Prior to this, undergraduate dental students were given a statistics and epidemiology course that comprised five lectures. The lectures were long and detailed, and included statistical theory that students would have been unlikely to require in their future careers. There were few examples of the application and interpretation of statistics, and those that were included tended to be more medical than dental so less relevant to the students. Each lecture was given by a different

lecturer (none of them statisticians), and as there was no overall coordinator, there were inconsistencies across the lectures. The new curriculum, based on the General Dental Council's *"The First Five Years – A Framework for Undergraduate Dental Education"* (2002) included a vertical theme of Oral Health Research, to be taught in years' 2 to 5 of the programme, beginning with the Element of Quantitative Research Methods (QRM). In 2007, Sam Leary (SL) and Andy Ness (AN) were appointed as a Lecturer in Statistics and Professor of Epidemiology respectively, and agreed to develop and deliver the QRM course, with SL as the lead.

Therefore, our objective was to design a quantitative research methods course that combined epidemiology and statistics teaching for undergraduate students at Bristol Dental School. It was to be clinically relevant, focused on concepts and interpretation rather than calculation, and sustainable, using new technology to enhance learning.

Methods

The QRM course was introduced for year 2 dental students in the 2007-2008 academic year. It was extensively developed over the next two years based on student and tutor feedback and has continued with only minor updates ever since.

Aim of the course

The GDC's *"The First Five Years – A Framework for Undergraduate Dental Education"* (2002) stated that undergraduate students should understand the importance of evidence-based dentistry and how this relates to clinical practice. The latest GDC guidelines "Preparing for Practice" (published 2011, updated 2015) state intended learning outcomes which focus on evidence-based dentistry, critical appraisal and epidemiology (§1.1.1, §1.1.2 and §1.1.12), rather than specifically mentioning statistics and data analysis. Therefore, the overall aim of the QRM course is to introduce year 2 dental students to the skills needed to practice evidence-based dentistry. The intended learning objectives are shown in Figure 1.

Figure 1

Intended Learning Objectives for the Quantitative Research Methods Course

- Appreciate the role of epidemiology in oral health research
- Recognise and describe different types of study design
- Understand and interpret results of statistical analyses
- Critically appraise research findings

The emphasis of the course is on the concepts, and the students are not expected to understand statistical theory, learn complicated formulae or perform calculations, as the majority will not require these skills in their future careers.

Introductory lecture

An introductory lecture was added for the QRM course for the 2008-2009 academic year, and improvements were made over the next two years. As well as providing an overview of the course, this lecture is used to explain the relevance of research methods for dental practice, and pre-empt the feelings of statistical anxiety that are expected to be experienced by some students.

Initially, many students had difficulty seeing the relevance of the course. Most staff who teach on the QRM course are non-clinical, so it is essential that an academic dentist gives the section of the lecture on the relevance of QRM. The students are presented with a clinical scenario, asked to

discuss how they would approach it, then the importance of evidence-based dentistry is illustrated to them, i.e. the need to keep up to date with the current literature and change their clinical practice accordingly in their future careers. In another section of the lecture, an overview of one of Bristol Dental School's research studies is described. This illustrates how some of the concepts covered in the course are applied to a specific research question, and how the results of research in Bristol Dental School are shaping policy and practice.

Another challenge was that some students lacked confidence in their ability to understand the material covered by this course. To address this statistical anxiety, students on the 2008-2009 course were asked whether they had mathematics A-level (school qualification obtained at age 18). Seventy-six percent of the 70 students had mathematics A-level, which is similar to the 69% (dental and medical students combined) stated in a 2013 Cambridge Assessment statistical report (Vidal Rodeiro & Sutch, 2013). The mean (standard deviation) QRM exam mark was 59.8 (7.0)% in those that had mathematics A-level, and 58.4 (9.7)% in those that had not, with a p value of 0.5, based on 70 students. These findings are included in the introductory lecture, to illustrate that students without mathematics A-level are not disadvantaged.

Content of the course

The content of the QRM course covers basic epidemiological concepts, different types of study design, summarising and interpreting data, and choosing appropriate statistical methods. It was originally based on the content of a clinical epidemiology course that had already been developed for medical students, but adapted based on statistical consultancy experience within Bristol Dental School. Also, all the material was put into context by using oral health examples rather than medical ones. These were taken from journal articles reporting on oral health studies, some of which were identified from Smeeton's *"Dental Statistics Made Easy"* (latest edition 2016) As stated by Yilmaz (1996), effective statistics education for non-specialists relies on developing a clear sense of the relevance of statistics in real situations i.e. applications specific to the students' field of study. In addition, Williams et al. (2016) suggest that more exposure to relevant examples based on quantitative methods increases students' appreciation of how these methods are used to inform their subject area.

The course comprises nine topics, as shown in Table 1; the main content is also listed.

The order of the topics aims to minimise statistical anxiety. Epidemiology is introduced before statistics, to engage students' interest, and then the remaining topics alternative between statistics and epidemiology for variety. There are some statistical concepts embedded in the epidemiology topics, for example risk ratios are introduced within cohort studies; this allows as much integration with epidemiology as possible. Everything that the students are expected to understand is included in the content of the e-lectures. However, if students would like to expand their knowledge of particular topics, the following texts are suggested: *"Essential Medical Statistics"* (Kirkwood and Sterne, 2003), *"Essential Epidemiology"* (Webb et al., 2016), *"Dental Statistics Made Easy"* (Smeeton, 2016), and *"Bad Science"* (Goldacre, 2009).

Table 1
Topics and Content Included in the Quantitative Research Methods Course

Topic	Content
Introduction to study design	Hypotheses, exposures and outcomes, hierarchy of evidence, chance, bias, confounding, reverse causality, genetic studies
Summarising data	Types of variables, graphical presentation, central tendency, variability, normal distribution, reference ranges, prevalence/incidence, correlation
Randomised controlled trials	Definition, planning, conducting, analysing (including intention to treat), numbers needed to treat, strengths and weaknesses
Interpreting data	Sampling/statistical inference, accuracy versus precision, standard errors and confidence intervals, p values
Cohort studies	Definition, prospective versus historical, risk ratios and differences, testing for trend, strengths and weaknesses
Choosing an analysis	Parametric and non-parametric methods for comparing outcomes between groups, assessing agreement (limits of agreement, kappa/weighted kappa)
Case-control studies	Definition, sources of controls, odds ratios, power, strengths and weaknesses
Regression analysis	Linear regression, other types of regression modelling, survival analysis, adjusting for confounders, interactions and subgroup analysis, meta-analysis
Other types of study design	Cross-sectional, ecological and descriptive studies; definition and strengths and weaknesses for all

Structure of the course

The main part of the QRM course is delivered using the flipped classroom approach, a teaching model that separates the didactic teaching from the interactive consolidation of the learning. This approach has become much more popular in recent years, and small improvements in student learning have been demonstrated (Låg & Sæle, 2019). For QRM, all material is initially introduced in the form of e-lectures (PowerPoint slides with synchronised narrative), then consolidated through small group structured tutorials. All course materials are available on the University of Bristol Blackboard virtual learning environment (Blackboard Learn, Washington, US).

The didactic teaching for QRM comprises nine e-lectures, one per topic, each lasting 20-25 minutes. They are split into chapters to allow easy navigation (e.g. students can re-watch any sections they may have struggled with), and include multiple choice and fill in the gap (where a word is missing from a statement) pop-up questions to engage students. Each e-lecture finishes with a slide summarising the take home messages, and a glossary of terms used in the course is also provided. The e-lectures were created using Camtasia (Camtasia 2019.0.0, TechSmith, Michigan, US). E-lecture viewing is timetabled, but students can choose to watch the e-lectures at the time of day that suits them best for studying, as long as it is before the associated tutorial; this has been shown to be associated with improved learning outcomes (Evans, Kelley & Kelley, 2017). They can also re-watch them for revision. The major drawback of using e-lectures is the considerable investment of time required for their development. However, this is outweighed by the sustainability that they create, as no staff time is needed for didactic teaching in future years, and they can always be used, even in unforeseen circumstances such as pandemics. Another drawback of using e-lectures is the lack of face-to-face contact with the students, so it is not possible to gauge their understanding of the concepts at the time of delivery. However, the pop-up questions give the students themselves

some idea of which concepts they are struggling with, and these can be raised during the associated tutorial.

Ramsden (1996) states that students need to be able to understand and use information they have learnt rather than just store it in their memories, therefore each e-lecture is followed by a small group structured tutorial. The students are split into eight groups of up to 10, the group size is determined by the requirement to keep students in their clinical groups which are already established by year 2. Each group of students is assigned a tutor for the whole course, to ensure as much consistency as possible. There are nine compulsory tutorials, one per e-lecture, each lasting 1.5 hours. Pre-prepared materials are provided for the tutors, to minimise the impact of different groups having different tutors, and also the workload for the tutors. The purpose of the tutorials is to reinforce the material introduced in the e-lectures, therefore no new material is included. They are intended to be as interactive as possible, with students being given the opportunity to ask any questions they have about the associated e-lecture. Each tutorial consists of an introductory exercise followed by a series of problems for the students to work through. Using a small number of different types of tasks within the nine tutorials allows a balance between some variety, but not so much as to confuse the students (Griffiths 2008). Introductory exercises are either e-voting quizzes or group work based on designing studies. E-voting quizzes are prepared using TurningPoint (Turning Technologies, Ohio, US), which allows creation of a PowerPoint presentation of multiple choice questions. Each student is required to have a handheld wireless device (Keepad Interactive, Sydney, Australia), which all year 2 students are provided with, which enables them to vote for the correct answer for each question. Although the voting is anonymous, students can identify which particular concepts they are finding more difficult so need to raise with the tutor, and tutors can judge whether as a group, the students are struggling with anything specific. The purpose of the group work based on designing studies is to help the students appreciate the challenges that would have been faced by researchers when they were designing the studies presented in published papers. The students are divided into groups of 3 or 4 and asked to design a study to address a given hypothesis, for example, a randomised controlled trial to compare the reduction of dental fluorosis in pre-school children who use a low fluoride versus standard toothpaste. Then they informally present their ideas to the others in their tutorial group. In the problem-based part of the tutorial students are provided with a brief summary of a published oral health example. They work through a series of short answer questions on the key concepts in pairs or small groups, then the answers are discussed as a whole group. The students are provided with the reference of the original article so they can refer to this if they wish, but it is not required or expected. Examples of the short answer questions include:

- What is the exposure and what type of variable is it?
- What is the outcome and what type of variable is it?
- What design has been used for this study?
- What are the main findings of this study, based on the effect estimate and confidence interval?
- Other than a true causal association, what other explanations are there for an observed association between the exposure and outcome?

Recruitment of tutors

Each year a tutor is required for each of the eight QRM groups. There would not be enough statisticians or epidemiologists employed by Bristol Dental School (University of Bristol) to cover this, even with some tutors taking two groups (two is the maximum that can be taken by one person, due to the way the course is timetabled). However, as the tutorials are based on pre-prepared materials, tutoring provides an attractive opportunity for statisticians or epidemiologists in the Faculty of Health Sciences to gain teaching experience with only a modest time investment, so enough tutors can be recruited. New tutors who have little previous teaching experience shadow an

experienced QRM tutor for their first year of teaching. New tutors with some previous teaching experience share a group if they feel more confident doing this. There is a continual cycle of tutor peer reviewing, so that everyone benefits from observing others and receiving feedback on their own tutorials. New tutors are peer reviewed the first time that they teach on the course, and all tutors are peer reviewed at least every couple of years.

Assessment of the course

At the end of the course there is 1.5-hour closed book written assessment, which must be passed before students can progress to year 3 of the dental degree. All questions are compulsory to ensure all students sit a comparable exam, and to encourage revision of all topics covered in the course. To encourage higher-order thinking (Bloom et al., 1956), and apply to what the students will be faced with in the real world when they are practicing evidence-based dentistry, multiple-choice questions are avoided. Instead, open answer questions are used, with a very detailed marking scheme to minimise subjectivity; they are marked by those who have tutored on the course. The exam paper has three sections (i) paper interpretation (50 marks) – a summary of a published research paper and table of results are provided, with a series of questions relating to interpretation and implication of findings (similar format as the problem-based exercises completed in the tutorials), (ii) conceptual understanding (25 marks) – a series of unrelated questions relating to various concepts introduced in the course, and (iii) designing a study (25 marks) – the students are required to design a study to address a specific hypothesis. The first part in particular follows the constructive alignment model, whereby teaching and assessment methods support the explicit aims and intended outcomes of the course (Biggs & Tang, 2011).

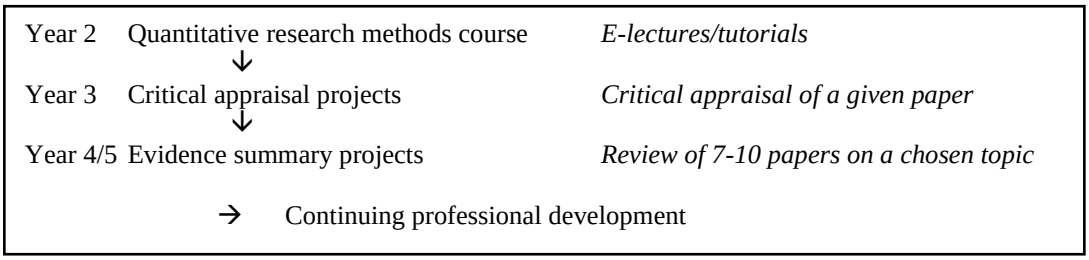
The students are provided with a two-hour revision session in their tutor groups; this is held between one and two weeks prior to the exam, depending on availability of sessions in the timetable. This is the only time that the students are required to prepare work before an interactive session, as they should have attempted a mock exam paper. The main part of the revision session is spent discussing the model answers to the mock paper, which also includes informal peer marking of some sections, to ensure the students are aware of precisely what is required of them in the exam (Jordan, 1999).

Overview of the theme of Oral Health Research

Figure 2 illustrates how the QRM course is built upon in future years of the BDS degree, within the theme of Oral Health Research. A model of scaffolding learning is used, whereby a variety of instructional techniques are used to increase students' independence in the learning process (www.edglossary.org/scaffolding).

Figure 2

Theme of Oral Health Research: Year 2 to Year 5 of BDS



Following on from QRM, the students do a Critical Appraisal Project in year 3. Firstly, students critically appraise a published paper on a specific oral health topic in a small group, led by a tutor. Following this they individually critically appraise another paper, and assessment is based on a written report and oral presentation. The final component of the Oral Health Research theme is an Evidence Summary Project, where students work in pairs to produce a comprehensive review of 7-10 published papers on a topic of their choice. The students aren't assigned a supervisor, but advice from the Evidence Summary Team (which includes SL) is available via email if required. Assessment is based on a written report. Development of critical appraisal skills should then continue in future careers.

Up until the end of the 2017-2018 academic year, students could elect to undertake one of a range of different project types in year 4 and 5. This included primary research (data collection and analysis), an audit, production of an e-learning resource, or an evidence summary. SPSS (Statistical Package for the Social Sciences) was introduced to students who needed to analyse data for their projects at the end of year 4. However, to ensure that all students have as similar a learning experience as possible, everyone is now required to undertake an evidence summary project, so SPSS skills are no longer necessary. As the overall aim of the QRM course (and theme of Oral Health Research) is to introduce students to the skills needed to practice evidence-based dentistry, statistics packages are not taught at any stage of the BDS degree. Struggling to get software working may detract from improving understanding of the underlying concepts, and as suggested by Yilmaz (1996) the development of technical expertise is unlikely to be an attainable goal in introductory courses for non-specialists. If analysis is required in future careers, it would be more beneficial to learn a statistics package at that time, to minimise the gap between learning and applying the knowledge (Hajian, 2019).

The only other part of the BDS curriculum that includes any statistics is the Sample Statistics course in the year 1 Unit of Physiology. Liaison with the basic scientists that run this course has been essential to minimise inconsistencies with QRM, such interpreting p values in terms of strength of evidence, rather than using an arbitrary cut point to indicate significance (Sterne & Davey Smith, 2001).

Results

Approximately 70 students take the QRM course each year, split into eight groups. Students are timetabled nine hours for e-lecture viewing (note that one hour is given for each 20-25 minute e-lecture to allow time for making notes/re-watching sections), 13.5 hours for attending tutorials, and 2 hours for attending the revision session i.e. 24.5 hours in total. The only task set for students to complete in their own time is attempting the mock exam paper.

Attendance at tutorials

Very few students missed more than two out of the nine compulsory tutorials each year, up until the 2018-2019 cohort,. Non-compulsory lectures were introduced to the curriculum in September 2018, and although QRM remained compulsory, 10 of the 73 students (14%) missed more than two tutorials without explanation during this academic year.

Assessment results

At least 89% of the students have passed the QRM exam on first sitting each year, and the percentage is usually much higher than that. All students have passed their re-sit exam; re-sits are capped at 50%. For the 2018-2019 cohort of 73 students, marks ranged from 50-86%, mean 67% and standard

deviation 10%. In previous years, very similar ranges, means and standard deviations were achieved, as seen in Table 2.

Table 2
Summary of exam results 2015-2019

Year	Number of students	Number of fails	Mean*	Standard deviation*	Range*
2014-2015	74	2	68%	10%	50-87%
2015-2016	65	2	70%	9%	53-89%
2016-2017	66	2	69%	9%	52-89%
2017-2018	67	1	70%	9%	50-88%
2018-2019	73	8	67%	10%	50-86%

*of those that passed

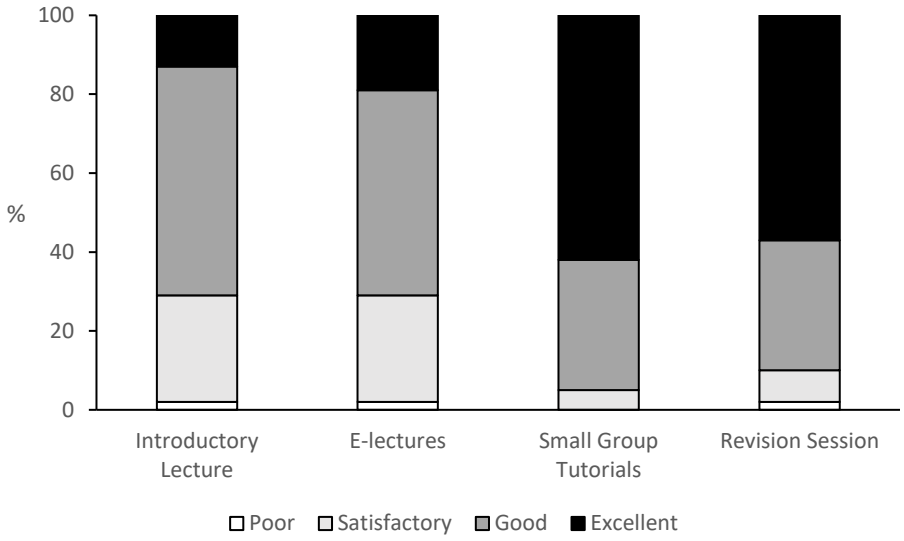
Students are provided with a summary of the main strengths and weaknesses, based on all exam scripts. They are also given the opportunity to discuss their own exam paper with the course lead; this opportunity is generally only taken by those required to re-sit.

Internal course evaluation

Each year, students complete a feedback questionnaire at the QRM revision session. In addition, a focus group comprising one student from each of the eight tutor groups was held during the 2008-2009 course. Tutors are emailed after each tutorial for feedback on the appropriateness of the length of the session, any concepts that the students struggled with, and any suggestions for improvements. There is also a face-to-face end of year review meeting for all tutors. The course is also evaluated during the Annual BDS Programme Review. All changes made to the course are based on feedback from all these sources. The main substantial changes made over the first two years of running the course were (i) the addition of the introductory lecture, primarily to address the issues of relevance of the course and statistical anxiety, and (ii) restructuring of the e-lectures and adding slots for them in them in student timetables.

Since 2010, the student feedback has been consistently high, with virtually all students rating all components of the course at least satisfactory, and high percentages rating them good or excellent (the choice of categories was very poor, poor, satisfactory, good, or excellent). For the 2018-2019 cohort, the student ratings for specific components are shown in Figure 3, based on responses from 64 of the 73 students (one tutor unfortunately forgot to hand out the feedback forms in the revision session):

Figure 3
Student Feedback for the 2018-2019 Quantitative Research Methods Course (N=64, no components were rated very poor)*



*The frequencies for poor/satisfactory/good/excellent were as follows:
Introductory lecture – 1/17/37/9
E-lectures – 1/17/33/13
Small Group Tutorials – 0/3/21/40
Revision Session – 1/5/21/37

In addition, 95% of the students felt fairly or very confident (versus not very confident) with understanding and judging the quality of published research by the end of the course. All student feedback can be viewed by students on Blackboard, and the most recent is included as part of the introductory lecture.

External course evaluation

There have been three external examiners over the duration of the QRM course who have tended to focus their comments on assessment, and only requested very minor changes such as small improvements to the wording of questions and avoiding awarding half marks. Their feedback has been consistently positive, for example, the current examiner reported that the exam paper was broad ranging and challenging and that he envisaged that it would thoroughly assess the full range of abilities on the course. The previous examiner reported that the assessment process was extremely thorough, with an appropriate spread of student marks, and the high performance of several students indicated that all the necessary resources were provided.

The course was reviewed by the Faculty Quality Team in 2009. Points for commendation included the introduction of significant teaching innovations (e-lectures, e-voting), the retention of the same tutor for all tutorials (allows any specific weaknesses within the student group to be identified), and also the opportunity for educational training through pairing new tutors with more experienced tutors. The main suggestions for improvement were to make the introductory lecture less research-focused, add an interactive element to the e-lectures, and reduce the number of calculations required in the tutorials; all these issues were addressed for the 2009-2010 course. There was a further Faculty

Quality Team review in 2017, and no further changes were requested. These reviewers felt that the course was very well-structured, covered a wide and relevant range of statistical and methodological information, and was valued by the students. They also felt that the assessments were well planned, fair and robust.

New curriculum

A new dental curriculum was introduced for the 2019-2020 academic year, based on a rigorous review of the previous curriculum by senior staff in Bristol Dental School. The QRM course for year 2s ran for the last time, and the theme of Oral Health Research was replaced by the theme of Evidence-Based Practice (EBP) for the new curriculum. The research methods teaching is in year 1 of the new curriculum (to allow reduction of content in the previously overcrowded year 2), and is based on the year 2 QRM course with some modifications, outlined in Table 3. The format of the introductory lecture remains similar, but with information on dental research opportunities added; this information had not previously been formally included in the curriculum, and the EBP theme is the most suitable home for it. The flipped classroom format remains, but with six instead of eight tutorial groups, as there is no longer a constraint to have eight groups due to clinical commitments as the course is in year 1. There are now eight rather than nine topics to fit the timetable, the content has been simplified slightly, and e-lectures re-recorded using different software as recommended by the Technology Enhanced Learning Developer for Dentistry. An engagement task is now used to maximise attendance at the tutorials. Individual course assessments are no longer allowed to be used, so EBP questions are included in the end of year programme-based assessment. Six questions are included in the 120-question single best answer section (7% - topic weightings range from 1 to 26%) of the assessment, and two 10-mark questions are included in the 140-mark multiple short answer section (14% - topic weightings range from 4 to 21%).

A series of critical appraisal workshops in year 2 and 3 will be used (to replace the Critical Appraisal Projects), to further consolidate the material learnt in year 1, based around application of Critical Appraisal Skills Programme (CASP) tools (CASP, 2020). A key feature of the new curriculum is full integration between clinical and non-clinical subjects, so clinicians will be introducing their own clinical examples to be used in the workshops. The final part of the EBP theme will be the Evidence Summary Projects, but these will be in year 4 rather than primarily year 5.

Streamlining teaching and moving research methods teaching to year 1 allows the removal of the Physiology Sample Statistics course. Instead, the statistical knowledge required for physiology tasks is covered within the EBP sessions. This has the benefit of ensuring complete consistency, but does present timetabling challenges, as the relevant EBP session must have been completed before the Physiology task is introduced.

Table 3

Changes to the Quantitative Research Methods course for the New Curriculum

Change	Details
Introductory lecture	Awareness of dental research opportunities, for example through INSPIRE, a programme coordinated by the Academy of Medical Sciences (2020) designed to engage dental students with research, is now highlighted in the introductory lecture
Number of topics	There are eight rather than nine topics: Introduction to study design, Introduction to summarising data, Randomised controlled trials, Understanding statistical inference, Cohort studies, Investigating hypotheses, Case-control studies, Assessing associations
Content	Some concepts have been expanded/simplified and examples have been updated One new concept has been added (PICO** framework) Some concepts have moved to year 2/3 (number needed to treat to benefit, sensitivity and specificity, meta-analysis) Some concepts have been removed completely (genetic studies, survival analysis, descriptive studies)
E-lecture creation	New e-lectures have been created using Windows Mediasite Recorder (Sonic Foundry Inc, Wisconsin, US), and incorporating quiz questions within Blackboard
Number of tutorial groups	The number of tutorial groups has reduced from eight to six
Engagement task	An engagement task is included in the tutorials, whereby pairs of students present a brief recap of the previous topic at the start of each tutorial, with every student presenting one recap during the course
Assessment	EBP questions are included in the end of year written exam, due to a move to programme-based assessment.

** P – Patient, Problem or Population. I – Intervention. C – Comparison, control or comparator

Discussion

It has been possible to run a research methods course for undergraduate dental students that is well regarded by students and external examiners. It regularly produces excellent learning outcomes; few students have needed to re-sit the final exam, and some have achieved marks in excess of 80% in an exam which has been described as challenging by one of the external examiners. Clinically relevant examples are used to engage students' interest, and the focus is on statistical concepts and interpretation, rather than calculation. Pop-up questions within e-lectures and e-voting quizzes within tutorials are used to enhance learning. The provision of pre-prepared tutorial materials minimises workload, so it is easier to recruit enough tutors. The existence of e-lectures ensures that the course is sustainable; no staff time is needed for didactic teaching, and they can always be used, even in unforeseen circumstances such as pandemics. A further advantage is that postgraduate students and staff within Bristol Dental School are also able to use these resources, as either an introduction or revision of statistical and epidemiological concepts.

However, there are still some challenges with running this research methods course. Students need to have watched the e-lecture before the tutorial, and tutorial attendance is compulsory, but it is difficult to enforce these. Tutors can see the last date that students accessed the QRM course material on Blackboard, but they cannot tell whether specific e-lectures have been viewed fully. However,

as tutor groups are small and interactive, it is usually obvious if a student has not watched the associated e-lecture, so this has rarely been an issue. Up until the 2018-2019 academic year, missing tutorials had only been a minor issue, and not specifically related to the QRM course. But after that, some lectures changed to become non-compulsory, which appeared to have an impact on attendance at all sessions, whether they were compulsory or not. However, all the students who missed several tutorials failed the QRM exam in 2019, and this is now mentioned in the introductory lecture to highlight the importance of attendance. Students are encouraged to catch up on the content of any missed tutorials. This is particularly important due to the cumulative nature of the course, although they will not have had the opportunity to ask questions unless they contact their tutor directly. Another challenge is that not all students remember their e-voting devices for all the tutorials, but it is now possible to set up quizzes which allow voting via smartphones which should overcome this problem.

The implementation of a similar model in other dental schools in the UK would be possible if desired. The main requirements are a senior statistician who can invest a substantial amount of time developing the course materials, enough statisticians or epidemiologists to be tutors, IT support, and adequate time in the curriculum. In Bristol Dental School we have been extremely fortunate in having excellent e-learning support, and have always been provided with as many contact hours in the timetable as required. It is difficult to know whether it would be feasible to use the Bristol model in non-UK dental schools. A biostatistics course at the University of Otago, Dunedin, New Zealand designed for health science students before they embark on professional programmes including dentistry is described in Harraway and Sharples (2001). To our knowledge, it is still the case that very little is known about dental statistics teaching in other parts of the world, as reported by Smeeton in 2002 (Smeeton, 2002).

A priority for the future should be to comprehensively review the provision of undergraduate dental statistics teaching in the UK. An overview of course content, number of contact hours, use of statistical packages and assessment methods would be possible if all dental schools contributed to the overview of teaching statistics within medicine and allied health sciences across UK universities (www.ed.ac.uk/usher/annual-meeting-teachers-of-medical-statistics-2018/overview-of-teaching-of-statistics-within-medicine). It is currently only possible to compare the Bristol research methods course with the dental statistics teaching at Cardiff Dental School (their contribution to the overview was last updated in September 2019). Bristol and Cardiff have a similar number of undergraduate dental students each year, cover most of the same statistical concepts (although methods of assessing agreement are only included in the Bristol course), encourage students to interpret p values in terms of strength of evidence, and base assessment around critical appraisal. The main differences are that at Cardiff, the statistics sessions begin later in the curriculum (year 3), use a statistics package, and include some history of statistical methods. As statistics and critical appraisal are taught separately at Cardiff, it is not possible to compare total teaching time between institutions.

As noted above, a comprehensive review of undergraduate dental statistics provision would allow sharing of ideas between dental statistics teachers in different institutions. Williamson and Lancaster (2004) ran a workshop at the 2003 annual meeting of teachers of medical statistics (*"Burwalls"*) to discuss the provision of statistical education for PhD students in UK medical schools; a similar approach could be used for undergraduate dental statistical education which could be a focus for a future Burwalls meeting. A recent survey of medical graduate views on statistical learning needs for clinical practice identified some disparities between what is taught and what is needed (MacDougall, Cameron & Maxwell, 2020). A further essential exercise would be to undertake a similar survey for dental graduates to assess whether the GDC guidelines and their translation into undergraduate dental statistics courses match what is required in their dental careers.

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