AN OVERVIEW OF TECHNIQUES USED IN THE TEACHING AND ASSESSING OF KNOWLEDGE AND APPLICATION OF STATISTICAL SKILLS ACROSS UNDERGRADUATE LEVELS

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Teaching statistical methodology and application of such methodologies requires a varied approach depending on the abilities and level of expertise of students. This paper outlines some of the varying methods used in teaching and assessing statistics at different levels of an undergraduate degree program in Statistics. The discussion includes teaching methods used to instil a thorough understanding of the basic concepts that underpin statistical analysis to a student body with varied academic backgrounds and assessment strategies that are designed to provide frequent monitoring of students progress, for both students and instructors. Different approaches to delivery and assessment of more advanced methodologies and concepts, including approach to data analysis, problem solving skills and practical applications incorporating statistical IT literacy are also reviewed.

INTRODUCTION

During the last two decades the UK Higher Education (HE) system has undergone much change with many more students now participating in Higher Education. Students entering university now have a much more diverse range of academic backgrounds and skills than would have been seen twenty years ago. At the same time there has also been great change in the needs of industry and the attributes and skills they expect graduates to possess. Hence it has been necessary for many aspects of the HE system to change accordingly.

Programs of study have had to be adapted in response to both the changing student body and to address the changing needs of industry. These programs must provide instruction in the material required to achieve degree level knowledge in a way that will engage all students, from those with little traditional educational background through to those who have entered HE via more traditional routes. Teaching and assessment are two key areas where such change has taken effect. For example, traditional lectures have been widely replaced by a more blended learning approach which combines teaching styles including lectures, interactive tutorial sessions, practical based work and online learning systems. Similarly there has been a general move away from assessment wholly by end of year examinations towards a more combinatory approach which typically mixes examinations and in-course assessment, often with several separate contributing components. In designing programs we need to consider both teaching and assessment strategies that will benefit all students and disadvantage none. The overall aim is to do this effectively in order to engage students of all types and backgrounds without leaving some behind or others disinterested. Hence program design must be undertaken carefully and with a logical approach, addressing the needs of students from all backgrounds. In this paper some of the different teaching and assessment approaches that are used in an undergraduate half field in Statistics are discussed.

BACKGROUND

In the teaching of statistics at undergraduate level, instruction in technical ability is vital but instruction in the wider role of a statistician is equally important. As teachers of statistics we have an obligation to provide students with knowledge and understanding of theoretical and methodological concepts, practical applications of such concepts and an appreciation of the many stages of conducting a statistical investigation from problem formulation through to communication of results As Gal and Garfield (1997) summarise there are several goals that should be achieved in teaching statistics. In undertaking statistical analyses, choosing and applying the appropriate methodology is essential but equally important is communication of the results (Strasak, Zaman, Pfeiffer, Gobel & Ulmer, 2007). Hence in teaching students how to conduct statistical investigations we should also teach them about the different stages in conducting an

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investigation and make them aware of all the steps involved in producing reliable, accurate and comprehensible information as and when required. We need to teach not only statistical methods but also about the many aspects of the wider subject area. Our aim should be to produce competent statisticians who are prepared for the workplace. These persons should understand the different phases of a statistical inquiry and be confident in choosing correct methods to analyse data effectively. Crucially they should also be able to present their findings within the context of the study at hand and in a manner that is comprehensible to the receiving audience regardless of their level of statistical expertise.

The program discussed here is a half field in Statistics which would be combined with another discipline including Business, Economics, Mathematics or Computing. The statistics component of the program has been carefully designed to provide students with all the basic skills that would be expected in a graduate statistician. In order to provide students with a thorough knowledge of the fundamental concepts and theorems that underlie statistical applications, it was decided that the first half of the program should be composed of compulsory or 'core' statistics modules along with mathematics and IT based modules that underpin and complement these. During the first three semesters students take three core statistics modules which cover all of the basics ranging from introductory probability and statistical inference through to multiple linear regression techniques. The rationale behind the design is that this knowledge is the minimum standard that an employer would expect of a graduate statistician. Students must achieve passes in these modules in order to progress on the program and achieve their degree.

The second half of the Statistics program (semesters four, five and six) is fully constructed of statistics option modules. Students can choose modules from a list of options which individually focus on specific branches or applications of statistical theory. Several of the modules are available at both levels two and three of the UG program so as not to limit choices and provide greater flexibility for students to design their own program of study as their knowledge and expertise in the area increases. During the final year students also have the option to undertake a project rather than one or two taught modules. This is a self learning based exercise which allows them to investigate and develop expertise in a new area or application of statistics and also to develop their independent learning skills.

The rationale behind the program design is to provide students with a thorough grounding in basic statistical testing and modelling along with a general awareness and knowledge of the many applications of statistics to real life problems. The idea is that by the time students are mid-way in their degree program they will have accumulated a thorough knowledge and understanding of the basic concepts of statistical inference and the testing procedures therein; they will have completed an introductory course in statistical modelling which covers both theoretical and practical application of the construction and validation of a general multiple linear regression model and have expertise in using statistical software. They will also have been introduced to the concepts of interpretation and presentation of results and report writing.

Teaching and assessment strategies

In designing a teaching and assessment strategy for the program we took account of the different background knowledge and diversity of skills of the students involved. Students will not all respond to the same teaching and assessment methods, what works for one will not necessarily work for another. To encompass this we tried to adopt an approach that will both benefit those with little background in the subject area while keeping the more academically prepared students engaged. Further, as students progress through the different levels of the undergraduate program their knowledge, judgement, competence and ability to work independently increases. Hence different teaching and assessment strategies are suitable at the different stages of the undergraduate program. It is obvious that a one size fits all approach is not the best option and so a combination of teaching and assessment methods is employed as discussed below.

Core Statistics modules

When students first join the program it is assumed that they have little or no statistical background and so in semester one, an introductory statistics module covers basic probability and introductory statistical inference. The material is delivered during weekly three hour lecture blocks

which will typically include theoretical material reinforced by several worked examples. This is followed by a two hour tutorial session during which students have the opportunity to complete practice exercises and ask questions on the lecture material, allowing problems and queries to be addressed while the material is still fresh in their minds.

Both formative and summative assessment is used at this stage. Students can gauge their own progress by completing the weekly practice exercises. Summative assessment consists of three in class tests which take place at equal intervals, approximately four weeks apart, throughout the teaching schedule. Each test covers the material from the previous four weeks only. The aim is to provide feedback rapidly so both students and teacher can assess progress regularly and more importantly can identify problems sooner rather than later. This is important so that any problems can be dealt with before they impact on learning for the rest of the module. In line with university policy, there is no end of module examination for this module. It is felt that the more progressive assessment strategy helps in keeping students turned on at this crucial transitional period of settling into a new learning environment. In addition students are given the opportunity to retake failed in-class tests during the inter semester break, allowing them to recoup any lost ground.

The secondary statistics module, delivered during semester two, expands on the theme of statistical inference building on the knowledge gained in the introductory module. The teaching strategy is similar to that of the previous module with lectures and tutorials scheduled on the same day. Lecture material is again delivered as a combination of theory and worked examples completed during the lecture. In this module students are introduced to a statistical software package, currently Minitab (Eales & Stander, 2009), during scheduled laboratory based practical sessions.

Summative assessment for this module is a combination of in-course assessment and end of module examination. In course assessment consists of two in-class tests timetabled at approximately equally spaced intervals in the teaching schedule. Students are also required to build a full portfolio of the weekly practice exercises completed using Minitab. These exercises should be completed in the practical sessions and provide a vehicle for formative assessment. As the portfolio is submitted at the end of the teaching schedule, the exercise also introduces some self discipline in management of workload while reinforcing learning. The final piece of assessment is an end of module examination which contributes 50% to the final module mark. At this stage students should be prepared for examinations and be well settled into the university procedures and environment.

The third and final core statistics module is delivered in the second year during the third semester of the program. At this point students are first introduced to the concept of statistical modelling; again this is a progressive learning development of the knowledge gained so far. The teaching strategy is similar to that used in the first year, all the necessary material is provided during lectures, underpinned by worked examples in the lecture and additional example exercises for completion during the lab based practical sessions. The amount of contact time is reduced to two hours of lectures and two hours of practical and/or tutorial sessions, as students are gently eased into the concept of additional self study to complement the taught material. Students are also introduced to an industry standard statistical software package, currently SAS, and emphasis is placed on application of correct methodology and on interpretation of results.

Again, assessment is both formative and summative. Students are given practice datasets on a weekly basis and they use these to practice the theoretical concepts from the lecture and develop their modelling skills. Throughout the teaching schedule the guided instructions become progressively less detailed requiring students to think through the problem statement, choose and apply the correct modelling procedure and then interpret their results. Summative assessment consists of in-course assessment and end of module examination. The in-course component comprises of an individual test designed to test basic modelling skills. This is followed by a group assignment during which three or four students work together on a project which requires them to carry out a full regression analysis on a given dataset. They have to present their findings in a written report and also in an oral presentation. Marks are awarded for the modelling procedure and the correct solution but also for setting the problem in context, evidence of background research, evidence of effective team working and communication of the problem and solution in a non-technical way.

On completion of the core statistics modules which form the first half of the program it is hoped that students will have gained a thorough grounding in the theory and application of statistical inference and introductory statistical modelling. They will know how to assess a statistical problem, choose the correct test and apply it. They should also have gained an understanding of the need for reliable interpretation and good communication of results and have developed softer skills in communication, independence, time management and team work.

Option Modules

The latter half of the program allows students much more flexibility as they can choose which statistics modules they want to study. The aim of providing this freedom of choice in the second and third years of the program is to broaden student's knowledge and experience in statistical methodology and the range of applications of statistical theory. Students can choose modules which include those on experimental design, stochastic processes, medical statistics, financial mathematics, time series and forecasting, operational research, inference and Bayesian methods, multivariate data analysis and an individual project.

Teaching strategies for the option modules are similar to that for the core modules with the curriculum material being delivered in lectures supported by worked examples and practice exercises. The contact time is four hours per week per module and typically this will be a combination of lectures, tutorials and practicals which provide a forum for asking questions and solving problems. There is an increased expectation for students to reinforce the lecture material through self study.

The main difference between core and option modules is in the assessment strategies. All of the option modules are assessed by a combination of examination and in course assessment but typically the end of module examinations will contribute a higher proportion to the final mark, usually 60%. The assessment tasks for option modules are designed to test not only theoretical knowledge but also statistical judgement and understanding (McNiece, 2010). Different types of in course assessment are used depending on the module, including individual in-class tests, individual small project type assessments and group assignments. Components of assessment might include multiple choice or short answer questions, longer structured questions, practical exercises, written reports (individual or group) , oral presentations and research based exercises.

In-course tests and formal examinations allow us to test a student's ability to identify study types and the appropriate methods of analysing data, manipulation of data, calculations of appropriate statistical measures and basic interpretation of the results of such applications, for example from the output of a software package. Individual and group assignments are usually aimed at testing deeper understanding and judgement of statistical problems as well as communication skills which cannot readily be examined in a time constrained assessment. For example students may be given a dataset and asked to use appropriate methods for analysing the data. They might then be asked to write a report summarising their work and presenting their findings clearly and comprehensively. Another assessment might require the student to undertake some research, for example in Medical Statistics students are asked to find real life examples of the types of studies encountered during the course of the module and to then critically review various aspects of their chosen studies. They are asked to write a report to compare the different study types, to include discussion of why the different study designs are appropriate in each case and to discuss how the study results were achieved and presented. They are also asked to comment on any issues that might have arisen in the planning stages, including ethical considerations, and to discuss any limitations of the studies and thus by implication limitations of the study findings. Often such assignment descriptions are purposely left open to allow students some freedom and independence in producing reports. Students are encouraged to think beyond the guidelines of the assignment and to consider aspects such as data collection and data analysis methods or any other information which they think relevant and that might further demonstrate their understanding of the use of epidemiological studies in practice.

The project option allows students to undertake a long term self based learning exercise which can be equivalent to one or two third year taught modules. The project requires good self-discipline and independent learning skills. Typically it will involve intensive background research as well as the design, analysis and solving of a problem. While students are supervised and guided

throughout the project it remains very much an individual learning experience which is only appropriate for the experienced and mature student. At the end of the project students take part in an assessed viva during which they are required to explain and defend their work.

The pedagogic aim of such assessments is to broaden students' understanding of the processes involved in conducting statistical analyses. All are aimed at deepening students' understanding of the processes involved in conducting analyses of data, and at developing skills in communicating statistical information in a clear and comprehensive manner. Many of the tasks are also designed to promote independent study and research skills. Such assessments are usually produced in a period of three to four weeks which allows sufficient time to conduct the research, contemplate the study protocol and to submit a well planned and structured report. This form of assessment allows teachers to assess students' understanding of the wider implications of an analysis of data, which requires knowledge and perception that cannot be assessed in a traditional examination.

CONCLUSION

Overall the mixed approach to teaching and assessment seems to be working well and in general students have responded well to the varied teaching and assessment strategies. It is hoped that students enjoy the exercises and that they help them to appreciate the role of statistics in real life applications, making what they have learned in lectures seem valuable and relevant to daily life. In group assignments most have delivered at least fair attempts at presenting their work and can provide good justifications as to why the study designs used are appropriate for the investigations being undertaken. There is evidence that students have collaborated and given due thought to the processes that underpin their analysis. Students demonstrate that they can use software and interpret outputs showing that they have developed team working and communication skills.

There are several stages to the data analysis process and the statistician undertaking such analyses must have a comprehensive understanding of the various steps involved. The rationale behind focused and practical assessments is to give students an understanding of the wider role of a statistician and to promote the communication skills and thinking processes essential to the role of statistician (O' Fallon, 2000) which are often lacking in graduates.

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