Helping Undergraduates to Contribute to an Evidence Based World

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Abstract

In recent times many authors have advocated change to the way statistics is taught to specialist and non-specialist undergraduates. One argument has been that adopting an approach that reflects real world experiences would better equip them for joining an evidence-based world after graduating. Even though some progress has been made, steps to change things have not been taken by curriculum designers or the vast majority of teachers of undergraduate statistics courses. More recently, in 2006 in the UK there were urgent calls from the Higher Education Funding Councils and the Economics and Social Science Research Council for proposals to develop undergraduate curricula to address the needs of today's evidence based world. We describe an approach to teaching statistics to students in the key discipline area of the social sciences using an evidence-based problem-solving approach. Examples of materials that can be used to support this approach are also presented.

1 INTRODUCTION

Over the years several authors have been advocating change to the way statistics is taught to specialist and non-specialist undergraduates. Stuart (1995 and 2003) discusses the dominance of mathematical thinking in statistics education and suggests a statistical problem solving approach (PSA) as being a good counter-measure to this. Other authors have presented the views of educational researchers on statistical learning which support this approach, see for example Garfield (1995), Garfield and Ben-Zvi (2007), Cobb (1992) and Cobb and Moore (1997). More recent publications have supported this view and provided illustrations of the incorporation of active learning and the PSA being written into curricula for pre-university courses, see Franklin and Mewborn (2006), Rossman et al (2006), Groth (2006) and Marriott et al (2009).

One argument in support of using the PSA with university undergraduates has been that adopting an approach that reflects real world experiences would better equip them for joining an evidence-based world after graduating. While some progress has been made, it has typically been by individual enthusiasts and steps to change things have not been taken by most curriculum designers or by the vast majority of teachers of undergraduate statistics courses.

In 2006, in the UK, such was the concern for the apparent lack of suitable statistical education in the social sciences that there were urgent calls from the Higher Education Funding Councils and the Economics and Social Science Research Council for proposals to develop undergraduate curricula. These calls stipulated that the curricula should be designed to build on the students' existing skills and include the use of real data that is collected by the students themselves. These proposals support the original advocates of change in recommending a move away from undergraduate curricula that concentrate on techniques and methods of statistics to ones that are broader and reflect reality. Indeed, improving undergraduates' education for the workplace must include teaching about what is done in the workplace. For specialist and non-specialist undergraduates this should involve demonstrating what statisticians do, that is, to use evidence to solve problems.

We describe material for teaching statistics to undergraduates in the key discipline area of the social sciences using an evidence-based PSA consisting of the four activities: specify the problem and plan; collect data from a variety of suitable sources; process and represent the data; and interpret and discuss the results. This is particularly suitable for level-one undergraduates as it attempts to link knowledge and experience prior to arrival at university with what is initially taught in a typical introductory social science course in statistics.

Setting the scene at an early stage involves demonstrating what statistics is for and that it can provide the engine for evidence based decisions in other subject contexts. This will help

students and teachers in other disciplines. We believe that all graduates need to be able to at least understand how evidence-based decisions are made and be able to undertake the activities necessary to make informed decisions themselves. In Section 2 we describe two examples of problems that can be used to engage undergraduates in problem solving, the process of identifying questions that need to be answered and the collection of data to provide the evidence needed to answer these questions. In Section 3 we provide illustrations of the materials that have been developed to exploit this approach in the classroom.

2 TWO EXAMPLES

The last eight or nine years have seen a growing concern within the UK social science community about the lack of quantitative literacy in the undergraduate student population. In 2001, Rice et al. (2001) reported the results of an enquiry into the use of numeric datasets in learning and teaching within UK higher education. The research was sponsored by the Joint Information Systems Committee (JISC) and looked into barriers faced by undergraduate teachers (among others) who wanted to use empirical datasets in the classroom. Among the recommendations emerging from this report were the following:

1. a broad initiative is recommended to promote subject-based statistical literacy for students, coupled with tangible support for academic teaching staff who wish to incorporate empirical data into substantive courses;
2. the development of high-quality teaching materials for major UK datasets must be funded adequately, in order to provide salience to subject matter and demonstrate relevant methods for coursework.

In reporting their research into the problems faced by education and sociology students Murtonen and Lehtinen (2003) concluded that many of these students view statistics with some trepidation and found quantitative methods more difficult than qualitative methods. Williams et al. (2004) came to the conclusion that there is a crisis in the production of quantitative academic output in Sociology in the UK and relate this, through problems faced by students, to a “societal problem of numeracy”.

In 2006 the Economic and Social Research Council (ESRC) in the UK, in collaboration with the funding councils for higher education, issued a number of calls for proposals to address the perceived need for the development of undergraduate curricula in quantitative methods. The ESRC indicated that they would consider a broad range of ideas and included the following among the examples they cited:

- the development of undergraduate curricula which takes account of contemporary and topical examples to show the value of quantitative research - these should draw on students’ own interests;
- a need to develop curricula in order to demonstrate to students that they already have the skills needed to understand the foundations of quantitative research, by building upon their GCSE experience and their computer skills;
- curricula which encourage students to conduct their own surveys and to analyse the results as part of their course work;
- curricula which encourage applicants to carry out their own research projects through the use of secondary data.

We provide here two examples that should engage the interest of students from all undergraduate disciplines in the UK, and possibly elsewhere. The first involves the students in a discussion of the quality, or otherwise, of their accommodation and this can be used to provide student-centred data that could feed the development of an entire first year introductory course. The second example is based around a discussion of crime in and around the neighbourhood in which the students live. This can provide a background and source of real data both for a general introductory course for all undergraduates and also a platform from which to launch a more detailed examination of social data collected by Government agencies.

2.1 STUDENT ACCOMMODATION

Our first example is based on the authors' experience of tutoring first year quantitative methods seminars in a business school. While the students were working on problems they had been set in their lectures they were all actively engaged in talking about the accommodation they had found themselves allocated at the start of the first semester. They eagerly compared data about their accommodation and its location that they had observed, or had obtained 'second hand' from their friends, rather than continue working on the dry examples from the textbook.

Figure 1 shows two introductory slides that can be used to stimulate a discussion of student accommodation for the cohort in question. The tutor leads the class through a series of prompts that motivate a discussion of questions that are of interest and how best to collect the data. The result of this is the design of a student accommodation survey with the aim of collecting data from students that they could use themselves in class. In practice this questionnaire would be made available in the first class/workshop during which the students are asked to complete the questionnaire. Each class then has the opportunity of looking at their own responses as part of the 'process' stage of the PSA. In subsequent classes data for the whole cohort, as well as samples from a database containing responses from students at other universities, will be available for the students to examine.

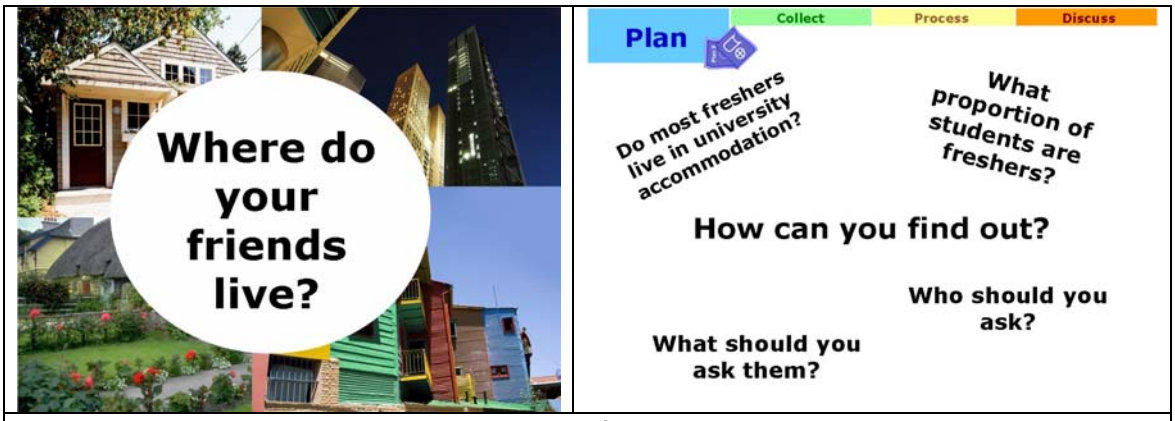


Figure 1: Two introductory slides for the accommodation example

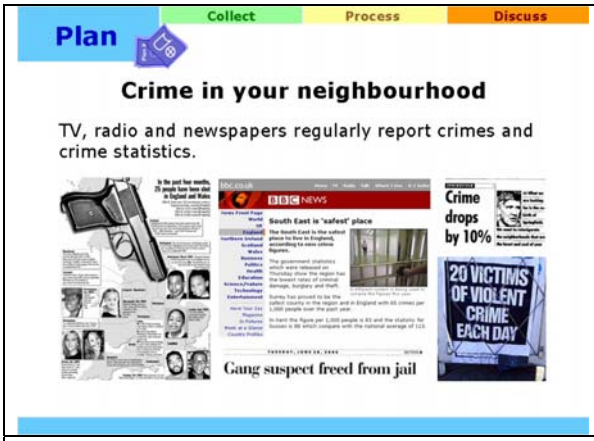
A survey arising from these considerations was run by statistics tutors in three UK universities and the results collected in a database. During the first lecture the students are also reminded of the PSA and aspects of data presentation that they are already familiar with from their pre-university studies. The survey itself included questions on type and quality of accommodation, amount of rent paid, mode of transport and time taken to travel to university which provided a rich source of data for developing a wide range of statistical techniques. Samples from this database are used for the illustrations in Section 3

2.2 CRIME IN THE NEIGHBOURHOOD

The second example utilises an idea first developed for a secondary school PSA project which is one of eight that can be viewed at www.rsscse.org.uk/qca/resources0.htm. Figure 2 shows two example slides used at the start of a class that would lead to a discussion of crime in the neighbourhood of the university. As the discussion develops, questions the students feel should be addressed emerge and, as in the first example in Section 2.1, this is followed by revision of the PSA and a discussion of the collection of suitable information and data. This particular problem can be used to approach either an investigation of peoples' perception of crime or the actual occurrence of crime that is recorded by the authorities. For the former, at the 'collect' stage of the PSA, possibly in their first seminar, the students could complete a questionnaire comprising three demographic questions, with date of birth, and three or four other questions taken from the British Crime Survey (BCS, www.statistics.gov.uk/ssd/surveys/british_crime_survey.asp). For the latter, which might be of particular interest for undergraduate social science degree programmes, data collected by Government agencies, for example

www.homeoffice.gov.uk/rds/soti.html, can be utilised. Of course there is no reason why both sources of data cannot be used as the introductory statistics course develops.

Figures 1 and 2 both illustrate colour coding that can be used to reinforce the place within the four-stage PSA.



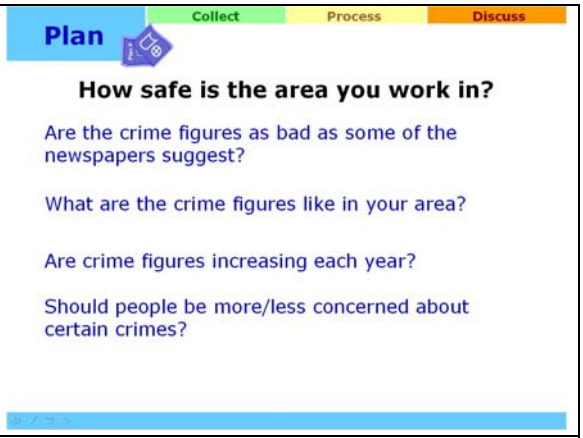


Figure 2 Introductory slides for the neighbourhood crime example

3 TEACHING MATERIALS

For both of the scenarios described in Section 2, the results could be entered into a spreadsheet and the students could use this opportunity to revise the data presentation aspects of the statistics they studied at school. This is of particular importance since many introductory courses devote several classes to laboriously repeat what the students have been studying at least from the age of 10. A much better approach is to prompt them to draw on their earlier experiences to summarise the evidence from their own seminar group and draw tentative conclusions. In the following week they could return to look at the data for the entire cohort.

In what follows we illustrate the use of the data collected by the students to teach the use of a chi-squared test of association and one-way analysis of variance. We stress that these commonly used methods in statistics are techniques appropriate to the 'process' stage of the PSA. As such they should be considered as *part* of a problem solver's toolkit.

3.1 CHI SQUARED TEST

During the 'plan' stage for this example questions of whether students from different universities would have different perceptions of crime in their location would be raised. In particular a model for the population that specified the appropriate null and alternative hypotheses for a chi squared test of association would be developed.

The data from a crime survey question is used to provide the evidence for the PSA. Random samples of students from three universities, A, B and C, are taken. Responses to a question asking how concerned students are at the prospect of being mugged, measured on the Likert scale shown in table 1, are assembled into a two way table that shows which university was attended as the rows (see in Figure 3).

Table 1: Likert scale for crime example

Description	Very worried	Fairly worried	Worried	Not very worried	Not at all worried
Worry scale	1	2	3	4	5

The 'process' stage of the PSA draws on earlier work on probability and a preliminary examination of the tabulated data leads to discussion of two ways of estimating a joint probability

of interest. This is then followed by a development of the test statistic and discussion of its sampling distribution. Finally at this stage the calculation of the test statistic (using available software) takes place. Figure 3 shows two slides that are used during this stage of the PSA. On the left hand slide part of the early development of the test statistic is shown, while on the right, the slide explains how computer output, that the students will see when using Minitab, naturally fits into the 'process' stage of the PSA.

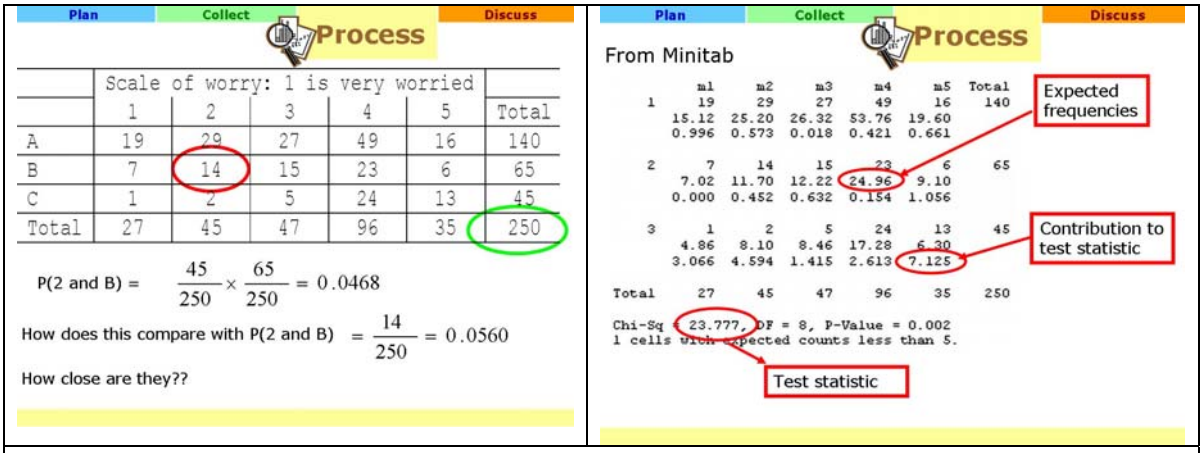


Figure 3: Two slides from the 'process' stage of the chi square test example

At the 'discuss' stage of the PSA for this example the discussion begins when all the evidence from the processing of the data is complete. The use of a decision rule to inform the conclusion that must be drawn is clearly identified with this stage of the process. This is then followed by a return visit to the original questions raised at the 'plan' stage to discuss whether or not they have been satisfactorily addressed. Figure 4 shows two slides used at the end of the example: the left hand slide shows how the beginning of the discussion stems from the interpretation of the test results; and on the right hand side, the final slide poses the important question of whether what has been achieved so far necessitates another visit to the first stage of the PSA.

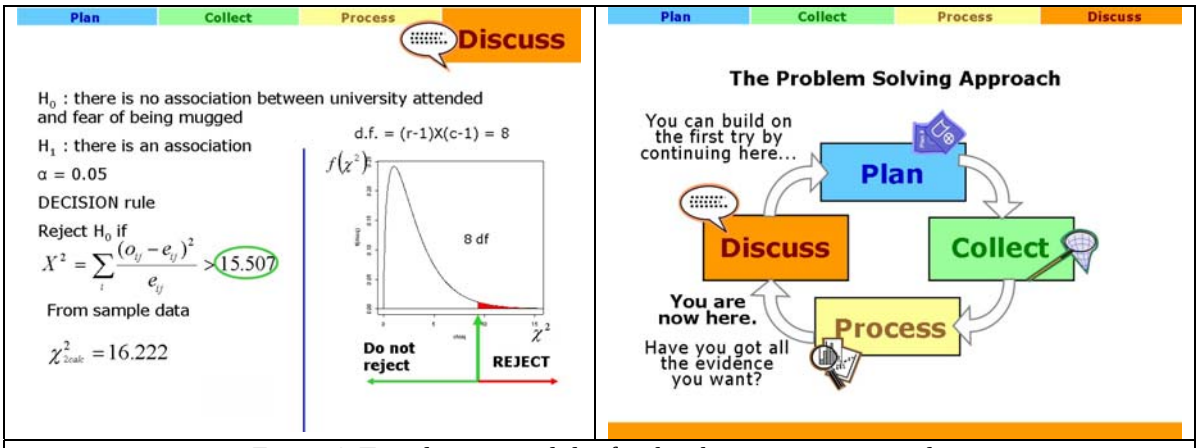


Figure 4: Two discussion slides for the chi square test example

3.2 ONE WAY ANOVA

At the 'plan' stage of the PSA for this example, students would be prompted to discuss their term time accommodation: what type of accommodation is was; how far it was from their classes; how much they paid in rent. One of the specific questions they would be encouraged to ask is whether the average rental would be the same for the different types of accommodation.

The data for this example come from random samples of students from the same three universities as in Section 3.1. In this case they were asked to indicate the type of term-time accommodation they lived in, either Home, university-provided accommodation or private sector accommodation, and also how much rent they paid per calendar month in £ sterling.

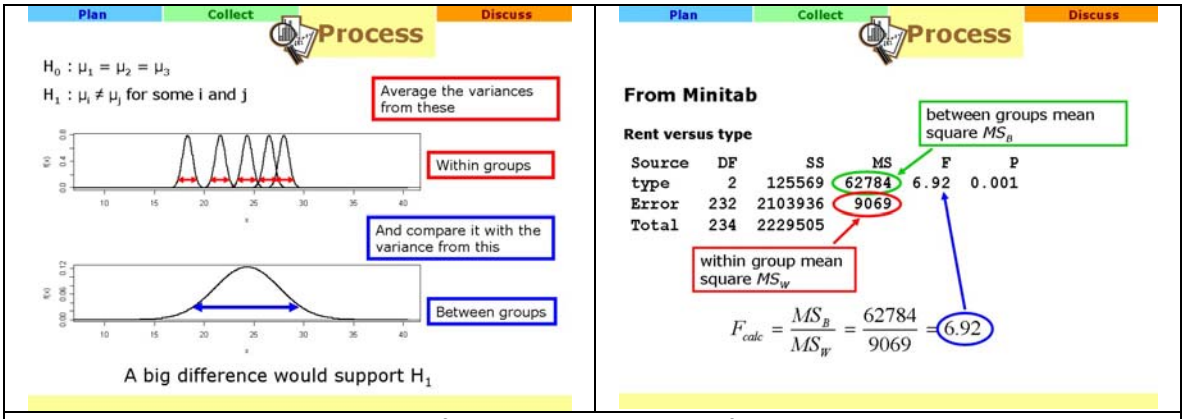


Figure 4: Two slides from the 'process' stage of the ANOVA example

The 'process' stage for this example would begin with a consideration of what sample statistics could help the investigator to compare more than two means. The left hand slide in Figure 4 illustrates part of these deliberations. This then leads to the development of the test statistic and consideration of its sampling distribution. Finally, the use of appropriate software to compute the test statistic is explained, Minitab is used in the right hand slide of Figure 4.

As for the previous example, the 'discuss' stage begins with application of the decision rule, see the left hand slide in Figure 4. This then naturally leads to a discussion of the possible source(s) of observed differences and, on the right hand slide of Figure 5, further consideration of interesting results that had, perhaps, not been anticipated during the original 'plan' stage for the problem.

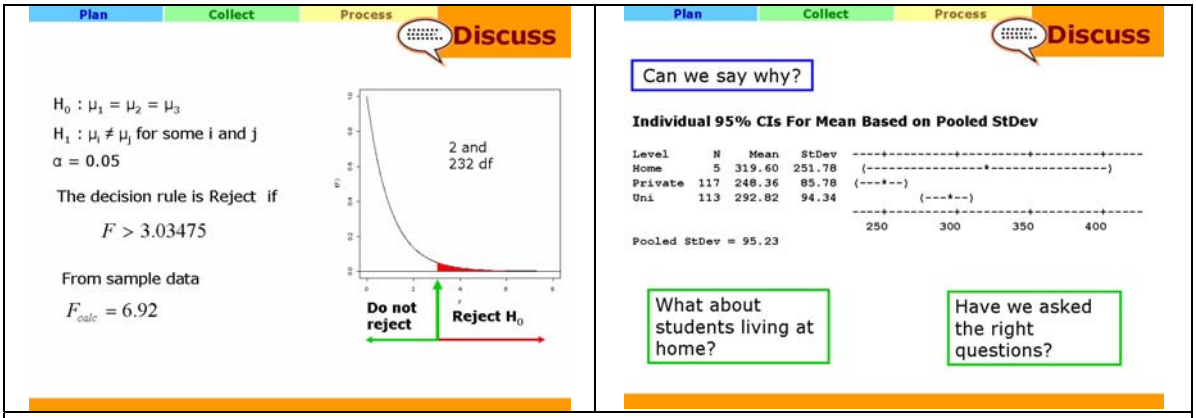


Figure 5: Two slides from the 'discuss' stage of the ANOVA example

4 CONCLUDING REMARKS

In this paper we have described the pressing need for more use of the PSA in undergraduate statistics teaching. To illustrate this we discuss two problems that should stimulate an interest in undergraduates from a wide range of backgrounds and in a wide variety of disciplines. One problem in particular lends itself to a more in depth treatment for many social science students. We have also presented teaching and learning material that integrates the development of two widely used statistical test procedures within the PSA.

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