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Inquiry based assessment of statistical methods in psychology

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1. Overview

Statistical methods are a critical component of undergraduate psychology, but students often find statistics the most challenging and least enjoyable aspect of their degree. This chapter reports an inquiry-based learning (IBL) approach to teaching and assessing statistical methods on a Level One course with approximately 100 students. The project involved the students designing an experiment and analysing the results and is reported as a case study. IBL encompasses activities where the learner explores open-ended problems and chooses their own solutions. In a tutorial setting, students worked as a team to design an experiment to address a research question set by their postgraduate tutor. Following the tutorial a dataset was simulated that might have been gathered from the experiment. The next tutorial functioned as a collaborative, open-book statistical analysis examination. The tutorial group worked as a team to analyse the simulated dataset using SPSS software, and wrote up a collaborative report of the results during the session. Formal examination of the material covered in the activity improved in the year that the IBL teaching was added although a number of other factors may explain this effect. In evaluation of the course students reported that they appreciated that the activity gave them experience of designing experiments. The teamwork was largely experienced positively although a few students complained that colleagues had not contributed sufficiently to the project to justify a share of the mark. Advantages of this approach include close alignment of assessment with course objectives and real-world research practice.

2. Background

2.1 Statistics in Psychology

Psychology is a young science and there is great potential for researchers to advance the frontiers of knowledge through quantitative research. Nevertheless, psychology students are often surprised by the centrality of research methods and statistics in their undergraduate training. Their backgrounds are heterogeneous; although a few have previously studied advanced mathematics and many have previously studied psychology, a substantial proportion come from an arts background. It is common for students to have difficulty in engaging with statistics lectures. Typical comments from student evaluations include

"The module was understandably tedious in places…"

"Although very boring, this module has helped me grasp statistical tests."

Although, lecture courses are often titled "Research Methods" or "Experimental Design and Analysis", it is not uncommon for their focus to be on statistical analysis rather than experimental design. Traditional didactic lectures are often used to explain statistical tests and computer classes are often attached to the lectures to allow application of techniques covered using computer software. Assessment is often via examination, with questions commonly presenting a fictional experiment with some computer output that might have been generated. Students are graded on how well they can interpret the output. Despite a lack of enthusiasm for statistics, students often have sufficient study skills to perform well in examinations. Their knowledge may not generalise well to new problems, however, for example in managing the design and analysis components of their self-directed empirical work.

This situation provided an opportunity to revise the teaching and assessment of statistics. In particular the aim was to engage students in the research process, demonstrate its value in advancing knowledge and produce graduates who are more independent researchers. This endeavour was guided by the framework of inquiry-based learning (IBL).

2.2 Inquiry Based Learning and statistics in psychology

IBL may be defined as learning involving a process of self-directed exploration. Rather than passively receiving information through didactic methods, students are provided with open-ended scenarios where different approaches may lead to equally valid solutions and students have the freedom to choose the methods employed (Kahn & O'Rourke, 2005). Fisher and Moore (2005) report that IBL has been used at the University of Plymouth to apply psychological theory to practice. In the study concerned, as well as linking theory and practice effectively, the IBL process facilitated the development of a range of graduate skills, for example improved problem-solving skills and confidence. In a greater number of cases, problem-based learning (PBL), which is closely linked to IBL, has been usefully employed as a method of engaging students with disciplinary content, skills and methodologies on

psychology courses (Willis, 2002; Pond III, 2004). Particular emphasis has been placed on the use of authentic PBL scenarios and tasks for the development of practitioner and professional competencies, including student ability to direct their own learning, especially in the field of clinical psychology (Huey, 2001; Albrandt Dahlgren and Dahlgren, 2002; Reynolds, 1997).

In some senses IBL may be thought unsuitable to teaching elementary experimental analysis, as almost all statistical questions will have a single correct answer in terms of test choice, method of application and interpretation. However, the broader research process is inherently inquiry-based. Choice of research question and method of approach are both open-ended activities that determine the appropriate analysis. It is as a component of the entire research process that academic psychologists apply statistics. Through employing IBL, Level One students were provided with a flavour of this context in their research methods training.

In order to develop independent research skills this project aimed to provide the students with tasks similar to those that academics would need to undertake in order to conduct research. The principles of aligned teaching emphasise that deep learning is more likely to occur in situations where the curriculum, teaching methods, assessment procedures, context of tutor-student interactions and the institutional climate are aligned with each other (Biggs 2003). Brew & Boud (1995, page 70) argue that "Doing research demands a deep approach to learning. Researchers therefore model, in their own work, learning approaches which it is desirable for students to emulate." Linking teaching and research is discussed at length in Jenkins et al. (2003) and it is concluded that engaging undergraduate students in the research culture of the department is beneficial on multiple levels.

Psychological research is almost never conducted in isolation. Single author papers are very rare in the quantitative psychological literature. Therefore the IBL activity was designed to be strongly collaborative at all stages, including assessment. Sander et al. (2000) have shown that students expect to be taught via formal lectures at university but prefer to learn via group-based activities. Collaborative inquiry involves students working together to approach a task or question, generate discussion based on their experiences and reading, and negotiating through the created shared

knowledge towards a joint approach to the problem. Constructivist theories of education propose that an environment that fosters deep approaches to learning can be created through the use of peer collaboration as the dialogue it entails can 'shape, elaborate and deepen understanding' (Biggs, 2003). Collaborative techniques have been widely used for statistics teaching and this has been found to reduce students' anxiety and improve abilities to build statistical skills and knowledge (Delucchi, 2007). Beyond improving statistical and research methods skills, collaborative inquiry also helps students develop cooperative team working skills that are required for most careers (Race, 1999; Biggs, 2003).

2.2 Aims of the project

This project formed one strand of a larger departmental project to build on existing excellence in IBL entitled PEBBLE (Psychological Enquiry-Based Learning: see www.shef.ac.uk/cilass/projects/psychol.html for details). The project was funded by CILASS (Centre for Inquiry-based learning in the Arts and Social Sciences), a Higher Education Funding Council for England supported Centre for Excellence in Teaching and Learning (CETL) based at the University of Sheffield. Project funds were used to buy staff time for the curriculum design activities, and capital funds were used to purchase 10 laptop computers to be used in delivering the project.

The project introduced an experimental design and statistical analysis activity to the Level One tutorial programme. This was integrated with the Level One research methods lecture course. Lectures addressed descriptive statistics, experimental design, t-tests, Pearson correlation and simple contingency table analysis. The project was designed to introduce students to the whole research process, including selecting a research question to address, formulating a hypothesis, designing an experiment, choosing a statistical analysis, running the analysis, and reporting and interpreting the results. The rationale was that when students could see statistics embedded in the whole process then they would be more able to generalise their statistical skills to novel research situations in the future.

3. Methods

3.1 Initial tutorial

There are approximately 100 students enrolled on the course who are divided into tutorial groups of 4-5. Postgraduate tutors host these tutorials under the supervision of the Level One research methods lecturer. More than 20 postgraduate tutors (some running 2 groups) studying for both taught and research based higher degrees in psychology are employed to lead these tutorials. Some tutors were taking an MSc Research Methods in Psychology course that included a Postgraduate Tutor Training module. These tutors keep a reflective diary regarding their experiences of small group teaching as a course requirement. All tutors attended a 1 hour training session with the research methods lecturer to introduce them to the tutorial activities and ensure a standard approach.

The design of the IBL tutorial programme for the statistical methods module gave postgraduate tutors an opportunity to link their teaching with their research, a feature of IBL that, it has been argued, has positive benefits for both tutors and students (Brew, 2006). Prior to the tutorial, the tutors were asked to prepare three questions from an area of research with which they were familiar. These were submitted to the research methods lecturer for screening and either accepted or returned for revision. The questions were presented to the students at the start of the tutorial and they were asked to choose to focus on one of the questions. The tutor led a group discussion of the issues involved in designing an experiment to address the chosen research question. Topics covered included hypothesis formation, the advantages and disadvantages of within- and between- participant designs, choice of dependent variable and potential levels of the independent variable. As the discussion progressed the group filled out a generic research proposal form that contained all the information necessary for data to be simulated for their design.

3.2 Data simulation

On the basis of the submitted design form a dataset was generated for each tutorial group. The drawnorm command of Stata (StataCorp, 2003) was used for data simulation. Data were generated to have means and standard deviations that were appropriate for the measures chosen. These were based on the knowledge of the tutors and the research methods lecturer. In many cases more variables were created than specified in the original design sheet, to allow the full range of statistical tests covered

in the Level One lecture programme to be applied to different aspects of the dataset. A mix of significant and non-significant relationships was specified in each dataset.

3.3 Assessment materials

The assignment instruction sheet gave a description of the variables in the simulated dataset. Following this were five questions that the students needed to answer using the dataset. The first four required one each of a correlation, related t-test, unrelated t-test and contingency table analysis to be answered correctly. The fifth question asked the group to "Choose one further analysis to run based on your dataset and write up the results." This would involve repeating one of the tests already used in the assignment as all the tests the students had been taught had already been covered. Students were told to write up the answers to all five questions using Microsoft Word and include graphs and tables of descriptive statistics as appropriate. They were also instructed to quote statistical test results in the format of the American Psychological Association and provide brief interpretation.

The students had been informed that notes and textbooks could be consulted and this was confirmed on the guidance sheet. It was also stated that the tutor would provide assistance with running analyses.

3.4 Example assessment

In an example tutorial group the students designed a study to examine the relationship between driving aggression and age using a correlation design. In order to allow questions requiring the full range of statistical methods covered in the course the dataset was expanded. The variables included driving aggression score before and after a driver attitudes training programme, a binary variable indexing whether the driver had ever had a crash, driver gender and age. The four specific questions and associated analyses are shown in Table 1. This data set offered a range of possible questions that students could address for the analysis of their choice. These included comparison of crash involved and non-crash involved drivers in driving aggression and sex differences in post-intervention driving aggression. The group chose to test whether age differed between crash involved and non-involved drivers using a between participants t-test.

(Insert Table 1 about here)

3.5 Second tutorial

Each tutorial group was provided with 2 laptop computers running SPSS statistical software and Microsoft Word. Memory sticks were available to facilitate data transfer between computers. The simulated dataset was preloaded onto both computers. Tutors were instructed to ensure students had 50 minutes to work on the project, allowing 10 minutes per question. Room bookings were for 1 hour so 10 minutes was allowed for change over. Tutors instructed their groups that they could use their resources how they chose; they could all work on each question together or they could split into two groups and apportion different questions to each group. At the end of the session the students saved their completed Microsoft Word document and this formed their submission for the assignment. There was only one submission from each group and all students received the same mark.

3.6 Marking

The first four questions were marked on whether the correct test had been chosen to answer the question, whether it had been conduct properly, reported correctly, supported with appropriate graphs/tables/descriptive statistics, and interpreted accurately. The question asking the students to choose their own test was additionally assessed on whether their choice of question was appropriate.

The collaborative aspect of the assessment had implications for the marking strategy. The students worked in groups of 4-5 so there were fewer scripts to mark than in a traditional examination. Individual comments are not usually provided on examination performance but they were given for this assessment as it was also being treated as a teaching opportunity. The lower volume of scripts reduced the time commitment required to provide detailed comments. Marking was conducted using a Microsoft Excel spreadsheet where various criteria for each question were identified as fulfilled or not. The spreadsheet combined these scores and translated them into an assignment mark. Each cell was also linked to a cell containing a comment regarding that criterion, with the returned comment differing depending on whether the criterion was fulfilled or not. A free text comment on each question was provided by the marker to augment these automatically generated comments. The automatically

generated and free text evaluation was then mail-merged into a Microsoft Word document that also contained some generic comments on the assignment. Each student received these three types of feedback (Excel generated comments, marker comments and generic assessment comments) on a single sheet in time for it to be helpful to them in preparation for their traditional statistics examination

4. Evaluation

4.1 Examination Performance

In order to examine whether the inquiry based teaching and assessment improved statistical skills, examination performance was compared before and after the IBL project was introduced. The relevant examination component presented four questions to be completed in approximately one hour and twenty minutes. Typically the questions gave a brief explanation of an experiment, some SPSS output providing descriptive and inferential statistics, and asked a number of sub-questions about analysis and interpretation. The examination section was scored on the usual UK universities marking scale where a mark of 70 or above corresponds to a first class degree, a mark between 60 and 69 corresponds to an upper second class mark and a mark of 59 or less is in the lower second degree class or below. In the year before the IBL activity was introduced the mean examination mark from 125 students was 64 (standard deviation 8.8). In the year that the IBL task was included the mean was 71.2 (standard deviation 9.5) from 102 students. An independent samples t-test shows this was a significant improvement ($t(225)=5.9$ $p<.001$). This result is compatible with the hypothesis that the IBL activity improved students' statistical skills. However, it must be noted that the IBL activity was introduced within a major course overhaul in which set text books and lecture materials were revised and presented by a new member of staff. The examination was also set and marked by different lecturers in the two years. Therefore, it is possible that differences in examination marks may reflect other factors than the introduction of the IBL activity.

4.2 Lecturer reflection

This activity and assessment has a number of features that were novel locally to teaching and assessing statistics. Previously statistics had been assessed via traditional examination at Level One. Assessment in the small group examination provided a number of advantages. One advantage was that competence in using computer

statistical packages was included in the assessment. Examinations offer a more effective means of assessing such competence compared to coursework as there is no opportunity for students to use unfair strategies of collusion or plagiarism, although the collaborative nature of this examination diluted the possibility for direct assessment of individuals' ability. For this reason collaborative assessments may be best used in combination with more traditional assessments. The activity reported here contributed only 10% of course mark, leaving room for such a combined approach. There seem to be a number of additional advantages to a collaborative assessment.

Collaborative assessment was introduced to the assignment as research is usually a collaborative process in academic psychology. This is consistent with the standard conceptualisation of IBL as a form of student-led active learning that positively models disciplinary research practices (Kahn and O'Rourke, 2005; Prosser and Trigwell, 1999). The postgraduate tutor was included in the collaboration to provide an expert resource, as methodological experts will often be available for consultation in real-world psychology research. It is speculated that this had a number of benefits for the students. First, the collaboration gave a sense of shared responsibility that served to reduce anxiety. The expertise of the tutor also helped to ensure that all groups produced a reasonable solution to most questions, which may increase student confidence with statistics. As noted in the background section, anxiety about statistics is a major problem in undergraduate psychology courses.

A further advantage of the tutorial programme was that the analysis session provided an opportunity for the students to learn about statistical analysis during the assessed session. The students were able to learn by observing their colleagues' approach to the session, from the guidance provided by their tutor and from comments provided on their scripts which were returned after marking. Therefore, all aspects of the tutorial task and its assessment were integrated, ensuring that student learning was both relevant and constructively aligned with the objectives of the tutor and the module as a whole. This is an approach that Biggs (1996; 2003), among others, has argued facilitates more effective student learning. Further reinforcing the holistic nature of the approach, non-assessed activities of a similar sort were included earlier in the course. Students may have engaged in the non-assessed sessions to a greater extent,

given that they knew a similar assessed activity would follow. It is also believed that the course mark contribution provided increased motivation for students to engage with the analysis during the assessed session itself.

4.3 Student evaluation

A number of questions about this activity were included in the department's usual round of feedback collection. This showed that 89% of respondents agreed or strongly agreed that the activity had improved their skills in formulating research questions. A small number of students complained that they felt their team mates had not contributed equitably to the task and felt it was unfair that the whole group received the same mark. In future it may be possible to ask students to rate the contribution of their team mates and use these to weight the individual's mark within the group. This approach is commonly used (Biggs, 2003), however it still does not necessarily eliminate the problems of inequitable contribution. Often, while students are happy to complain informally about 'carrying' their colleagues through group work, they are reluctant to actually mark them down when given the opportunity (Race, 2001). The current approach was adopted as the assessment was designed to mimic academic research collaboration as closely as possible. Inequitable contribution to group projects is likely to feature in many such research collaborations. Answers to the students who raised this query highlighted that inequitable contribution may be involved in professional activities they undertake in future. Therefore, any opportunity they had to develop coping strategies in this relatively benign environment would be to their advantage. The quantitative student evaluation indicated that 71% agreed or strongly agreed that their collaborative skills had been improved by the activity and 63% agreed or strongly agreed that their negotiation skills had improved. The students were also reassured them that the assignment contributed 10% of a Level One module and that group marking would not be employed in assessments that contributed to their final degree classification. Despite some isolated complaints, therefore, the majority of students were positive about the collaborative aspects of the project.

4.4 Tutor feedback

The tutors informally reported a number of problems with the analysis session. Most importantly, they noted that 10 minutes was not sufficient for each question so the

students were put under too much time pressure. In future presentations only 3 questions will be included in the assessment, two specifying which variables to analyse and one asking the students to generate their own question. The tutors also reported several logistical problems in room set-up and equipment availability. While it should be possible to overcome these issues with good administration, the practical burden of organising a large student cohort into groups of 4-5 students in separate rooms with two laptop computers in each should not be underestimated.

A more substantive problem that the tutors noted was that they were unsure how much help to give the students with the analysis. Allowing the tutor to act as facilitator rather than examiner was desirable for a number of reasons. As noted above, it closely mimics the situation of a professional researcher, where expert statistical advice is often available. Second, it allowed some control over the students' work, to ensure they did not go too far wrong. It also provided the students with some reassurance that the task could be completed successfully and meant that the session could serve as a learning opportunity as well as an assessment. For future presentation the following tutor guidelines have been prepared.

- Make sure the students run the analyses for the two explicit questions asked. If they can't generate a solution themselves then ask students questions to try to help them decide on an answer. You should try to give less input in the write-up but make sure they don't get entirely stuck.
- Let students formulate their own question for the free question, with only very minimal help if they look like they have reached an impasse. Once they have agreed on a question, you can facilitate their selection of a test to provide an answer, but again give them little help in writing it up.

The tutors were generally positive about the experience of running the tutorials. The activities were designed to benefit the tutors by giving them an opportunity to use their own research expertise in their teaching and prepare parts of the material themselves.

4.5 Progression at Level Two

This project aimed to improve students' research skills for their Level Three project and beyond. As such it formed part of an integrated programme of IBL research methods activities at Levels One and Two. At Level Two the design and analysis activity is expanded into a full piece of coursework with less input from tutors. During a lab class students work in groups of four and choose their own topic of research. They then search the literature using on-line bibliographic databases to learn about current developments in that area. Within the lab class they work as a team to develop a research design based on the existing literature. After the lab class, students work individually to write up their design as a research proposal. Datasets are generated for each group and each member receives a different sample from this population. The students analyse and write up their results individually as a piece of coursework. This Level Two activity is designed to build on the Level One project, allowing students greater independence to develop their research skills, while still offering more structure and support than is involved in their Level Three empirical dissertation.

4.6 Utility of inquiry-based assessment

This project suggests that IBL has particular usefulness in a number of areas for teaching and assessing statistics learning and developing research design skills in undergraduate psychology students. The integration of a degree of student independence to the inquiry activities, the close collaboration with postgraduate tutors and fellow students in small groups and the increased sense of relevance given by allowing students to choose their own questions all positively impacted upon student engagement, even enjoyment. As was noted above, the innovations in this module form part of a broader project to embed inquiry - specifically research skills development - across all three levels of the psychology curriculum. Again, this aligns with current thinking on IBL at a curriculum design level and with the approaches taken in a number of other subject areas with which CILASS has engaged. In such projects there has been an emphasis upon supporting students through the independent and collaborative learning process and the development of baseline skills (for example, in research), from which students can then move on to more independent and advanced work at higher levels (Wood and Levy, 2009, forthcoming).

The initial tutorial at which the inquiry task and process were established and the students were given the opportunity to choose their topic from the list established by

the postgraduate teacher were relatively tutor-led. This is wholly appropriate given the level of the students, the difficult nature of the material and the strong possibility that they would establish unworkable research designs without well structured support. The Level Two development of the activity is designed to give the students greater leeway in their choice of research question and the process by which they follow them. This greater independence is appropriate at Level Two, when students are more familiar with the subject.

The issue of facilitation, that is, the degree of support and direction to give to students, figures highly in the literature on IBL and problem-based learning (Hutchings, 2006; Savin-Baden, 2003). As with the degree of open-endedness of the inquiry task and process, the extent to which individual tutors direct, support and monitor those processes is dependent upon student level, intended learning outcomes and disciplinary approaches. The reported reactions of tutors on this module to this learning approach is entirely in line with the literature: tutor anxiety over the issue of facilitation is also commonplace and it is important to consider this when offering support and advice to those teaching in this manner, especially those who are inexperienced in inquiry approaches (Kahn and O'Rourke 2005, Goldring and Wood 2007).

The activity also served to strengthen links between teaching and research. As the tutorials were structured around topics of interest to the postgraduate researcher, the students were introduced to topics that are being actively researched in the department. By encouraging the tutors to engage explicitly with IBL pedagogy in the context of their personal research interests, the approach taken on this module would seem to offer an opportunity for strengthening research-teaching linkages. Such links may have important benefits for student learning and staff teaching and research (Brew, 2006; Jenkins and Healey, 2005).

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Table 1. Questions set in an example assessment.

Question	Statistical test
Is age related to pre-intervention driving aggression?	Pearson Correlation
Are male drivers more aggressive than female drivers at pre-intervention?	Between-participants t-test
Are male drivers more likely to have been involved in an accident?	Contingency table analysis
Did the anger management programme reduce driver aggression?	Within-participants t-test