PROJECTS FOR ADVANCED UNDERGRADUATES ®

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This paper presents some issues arising in the use of unscripted consulting projects for final year undergraduate students. The issues relate to the context and difficulty of the projects, the supervisor's role, the technical and interpersonal skills required to be developed by the student, the randomness of consulting projects, with their concomitant frustrations and messiness; and the role of such projects in the transition to work as a statistician. It is argued that such a course provides valuable experience that cannot be achieved by simulated, scripted or more closely managed programs.

INTRODUCTION

A full-year consulting course is a compulsory part of the final year of a four-year degree majoring in statistics at the University of Technology, Sydney, Australia (UTS). In Australia a typical fourth (honours) year will include a student research project on some relatively theoretical topic, leading to a written dissertation and a seminar presentation. This type of project has a long history and the issues associated with it are well understood, although not all are completely resolved. However, consulting projects are less common, and raise different issues. (The terms *student* and *supervisor* are used in this paper to refer to the statistics undergraduate and his/her supervisor, and *client* refers to the person(s) owning the consulting problem. In the special case of university clients, these are frequently graduate students in other fields, who may have supervisors of their own to complicate the matter.)

This paper is not about how to teach consulting, a topic with its own considerable literature already – from "classics" such as Chatfield (1995), Boen and Zahn (1982), Hand and Everitt (1987), to conference papers including Smyth (1991) and others presented at the International Conference on Teaching Statistics, and more modern books such as Spurrier (2000) and Derr (2000). We present a small selection of the issues that have challenged us in incorporating consulting projects into the undergraduate experience. They are not by any means exhaustive, nor mutually exclusive, and most of them are to some extent unresolved. However this does not reduce our enthusiasm for the use of such projects!

The first group of issues relate to the nature of consulting projects and the demands they place on the student: the need to master a client's subject material in some detail; the need to have knowledge of a range of methodology so that suitable techniques can be chosen and to have the skill to apply them; possibly the need to engage with the client's software; and the interpersonal skills needed to achieve a successful consulting outcome. The second group of issues relate to the role of the supervisor, including the level of engagement with the projects, managing stakeholders, setting limits, modelling the behaviours the student is to learn, and enhancing student knowledge.

The final set of issues relate to the project as learning task: the fact that the level of difficulty is unknown in advance; the projects may be messy and unpredictable in size and demands on students; the fact that (unlike the classic research project) performance on the project has consequences outside the student's course context (that is, for the client); the requirement for some form of (objective) assessment of student performance; and the function of the project as a transition to the work environment.

PROJECT CONTEXT ISSUES

"Numbers do not speak to strangers." In order to successfully advise a client it is almost invariably essential to master the context of the client's project in some detail. In-depth client interviews may be sufficient to obtain the necessary information, or there may be background literature to be read. Final year students tend to be fully committed with classwork at a high level of difficulty and it may be difficult for a student to appreciate the importance of learning about issues in a different field when there seems to be an unbounded amount of statistical methodology

to be learnt. It is easy to feel that if one knows about enough methodology it will be clear what to do with any given project.

In recent projects, students have had to become familiar with individual terms, ideas that are used in various fields, and even whole branches of knowledge. Without knowledge of the term "post-prandial", students were unable to carry out the required analysis in a nutritional project since they did not know at what time the measurements were taken. Another project used the Munsell colour scheme in classifying silvereyes (a type of bird) into sub-species. Students carried out a principal components analysis that reduced the variables 'hue', 'value' and 'chroma' to a single dimension, 'hue+chroma', but it proved to be harder to convince the researcher that this was a useful reduction. Yet another study, involved with the use of water by trees, required understanding of the biological and mechanical processes involved before any statistical models could be suggested and any analysis of data carried out. What some students might see as a distraction from the main task – the statistical work – can also be seen by others as a bonus. Statistics is a passport to vast areas of knowledge, and its applications are to be found almost anywhere.

We try to show the importance of context in statistical consulting work by example, and students seem to appreciate this variety. Understanding the importance of context can be developed in earlier years in the course of learning about data analysis. One student at the end of their third-year, in thinking about the possibility of doing an honours year, reflected on their previous classes:

> *Our lecturer really treated us as if we were working, like, giving us real life problems. Because our lecturer is a consultant, and he also gives us problems that he gets from clients, as assignments, so that helps. That's very critical, I think, in regression analysis, because I've learned just how useful it actually can be, and how the results it comes up with are fairly important in terms of trying to find the effects of variables or situations.*

The context of a statistical consulting job is not just background or colour – it is an essential part of the statistical work.

METHODOLOGY, COMPUTING AND RESOURCE ISSUES

An undergraduate course typically exposes students to a limited range of methodology, depending to some extent on the expertise of local faculty, on historical accident and other environmental factors. It is unlikely that a student will have previously learnt enough about any significant methodology apart, perhaps, from linear modelling, to be able to usefully address client problems. This is particularly the case when a client's field of research uses some form of methodology as standard (correspondence analysis, complex sample designs, graphical models, etc). It is also likely that a client will use as standard some software other than that used by the student in previous studies. In a year of consulting projects a student may need to engage with several new pieces of software.

Like the context-learning issue this requires scope management by the supervisor. There is potential for the student to acquire only 'cookbook' knowledge without understanding, but also potential to broaden awareness of techniques beyond standard coursework and also to introduce students to a wide range of information retrieval resources (statistical encyclopaedias, web resources, journal data bases, etc). On the other hand, learning about the technical detail of some methodology is one of the classic types of honours research project, and there is also potential for the consulting project to deteriorate into another theoretical study and lose the client engagement that is critical to consulting.

Preparation in earlier subjects can give students this type of experience. We have often set problems, even in first-year subjects, which require students to investigate something beyond their 'syllabus' (for instance, a sample-size problem). It is also becoming more important to give students the opportunity to carry out statistical work with a variety of packages. In our third-year undergraduate regression analysis course earlier this year we set as an assignment an investigation of a set of data concerned with the uptake of copper by fish in polluted water. Our question asked for an analysis using a particular package (new to most students) "since that is what the client

uses". We also suggested that students carry out a parallel analysis in the package with which they were familiar.

As consulting projects of this type come up, they can be shared amongst students in such a way that each of them engages in some of the research that experienced consultants often have to carry out. If the students have differing backgrounds, these can be used to advantage. A project investigating the use of Cox's proportional hazards model in a study of companies' foreign investment patterns was given to two students in the class who had a strong financial background in their degree, whereas the study of trees' use of water was allocated to a team that included one student with some background in biology.

INTERPERSONAL SKILLS

Over the past ten years there has been an increasing emphasis on the importance of "communication skills" in undergraduate studies in mathematical and information sciences. Writing reports and making verbal presentations about projects are now often components of applied subjects, and even of the classic honours research project. It is relatively straightforward to set and to grade assessment tasks of this type. However, listening skills and client interviews, "desk-side manner", while a standard component of professional activity in many health sciences, are not usually developed in undergraduate courses in statistics. It is more difficult to set and to assess tasks of this type, which tend to be relatively unstructured and open.

In a consulting course, the supervisor can demonstrate the interview, students can be given guidelines and carry out interviews under supervision. The student can then be assessed on how successfully (s)he clarifies the client's research question(s) and elicits the important details of context. The text by Derr (2000) has examples of good and bad interviews on the accompanying CD-ROM, although our students found these rather simplistic.

There are also the communication skills involved in letting clients know the results of a statistical investigation, whether written or verbal. These are more traditional skills that students tend to have practice with throughout their degree. However, they sometimes misjudge the level of the client audience. A few years ago, a couple of our honours students made a presentation of the results of their loglinear analysis of a questionnaire to the headmaster of an evening college. Having listened to a five-minute long and fairly technical summary of their conclusions, he leaned back and told them quite plainly: "*Could you start again from the beginning, because I didn't understand a word of that."*

SUPERVISOR ROLE

The supervisor will typically find projects for the consulting student, manage the demands of stakeholders, provide feedback and input to the student, demonstrate important behaviours, and possibly engage actively with the client's problem. Stakeholders may include the client's supervisors if the client is a graduate student.

Finding projects can be as easy as calling on established collaborators or as difficult as starting any other new consulting venture. For our students, a well-established course attracts a reasonably steady stream of enquiries. A potential client phones the course supervisor, gives a brief outline of the type of advice likely to be needed, and unless deemed obviously unsuitable, is allocated the next available slot in the weekly two-hour meeting time. Timing, scale and difficulty of projects need to be assessed if possible at this screening stage. At the beginning of the year more difficult projects may be rejected which would have been suitable for the students further into their year's training.

Issues of timing may be critical to manage. Clients may require results to be produced when the student is engaged with examinations, or after the end of the academic year when the student's involvement with the course is finished. Issues of scope are also important; a student cannot be expected to become a partner in a long-term project or to learn an unreasonably large amount of new material for a single client.

The student's level of responsibility for the overall project outcome should also be made explicit. While the supervisor as gatekeeper can try to eliminate unsuitable projects, (s)he should probably be prepared to take over, or direct the client to other resources, if a project proves to be

unfeasible in the course context. It is important that the course not attain a reputation for providing unsatisfactory client outcomes because of poor gatekeeping in this way.

One indicator for possibly unmanageable projects is a client who has a poor understanding of his or her research aims, and of how statistical advice is going to contribute to their achievement. "*My supervisor told me I have to do t-tests"*, or even more concerning "*My supervisor said I should use XXXX methodology…(s)he doesn't know anything about it but (s)he thinks it would be a good idea if I tried it out"*, indicate situations where more than a student level of consulting skill is likely to be required.

As well as the management function, the supervisor has a role as expert, providing guidance to the student about suitable approaches to take to problems, demonstrating the consulting process and providing feedback about the student's performance in the various parts of the consulting process. It can be useful to start the course with the supervisor demonstrating the consulting process with the first client and the student carrying out limited tasks (taking notes of an interview; showing a client how to design a data entry proforma, etc), and to gradually extend the roles that the student performs until a complete consultation from initial interview to final report is carried out by the student under general (but not close) supervision.

RANDOMNESS

Consulting projects arrive in a very random stream, and it can be difficult to manage a steady flow of work for students in a course of this type. The level of difficulty of projects can be hard to assess in advance, and again is not predictable. A whole year may produce only work whose statistical content, in methodological terms, is quite trivial. Students may become bored with creating simple cross-tabulations or carrying out chi-squared tests. Simulated problems may be used to broaden the range of demands on the student, but this loses the critical element of the unscripted live consulting project in which the student performance has consequences for stakeholders beyond the consulting classroom.

The messiness of real data, the degree of confusion often experienced by real clients about their research aims, combined with student uncertainty about their ability to deal with unknown problems have the potential to make the consulting course a source of anxiety. Unless assessment is based simply on participation it can be difficult to develop suitable assessment instruments, and impossible to make assessment consistent from year to year when projects of very different levels of difficulty may have been undertaken.

Using a client project, rather than a theoretical investigation, for the major honours project is particularly problematic for this reason. One student, committed from the beginning to carry out an analysis of a large body of data for an organisation, spent a great deal of time mastering background information, and waited many months for data to appear. Unfortunately, she had to write a dissertation before the data arrived, placing her at a considerable disadvantage compared with her colleagues who carried out self-contained projects. At least if all students in a year have the same experience of uncontrollable consulting projects, this form of inequity can be minimised.

On the other hand, this randomness and messiness is a realistic part of statistical work in a large variety of situations, and it seems that we do our students a service to introduce them to this while they are still with us as "apprentices". Bowden and Marton (1998) write:

> Graduates are going to face a great variety of situations in their professional life. We cannot grasp this variation in advance, nor do we have to. What is effective action varies from situation to situation. We cannot specify competence just in terms of what a person can do. … So what the student should learn, above all, is to focus on critical aspects of professional situations (p.11).

An honours course in statistical consulting represents a shift in the focus from teaching to learning, and the fact that the situation is less predictable and controlled does not detract from the learning environment. In fact, Bowden and Marton suggest that this is a direction in which quality universities should be moving: "Academics would necessarily work more collaboratively; teaching and learning would be undertaken in a less ordered way than now; assessment of student

learning outcomes would be more complex, but more valid; …" (p.250). Does this not sound familiar from statistical consulting classes?

Another consequence of the "Poisson arrival process" of jobs is that sometimes (not often) there are none available. These are the times when critical professional aspects of statistical work, such as the ethical dimension, or the interplay between qualitative and quantitative methods, can be investigated and discussed.

TRANSITION TO WORK

Barnett (1999) argues that learning and working are separate, but rapidly converging activities. "Each profession has its own mix of factual knowledge, theoretical principles, action understanding, process knowledge, tacit knowledge and communicative competence" (p.30), and it is in courses such as statistical consulting that we can prepare our students for the world of professional statistics.

The strong motivation for students to involve themselves with a course in consulting is that it is direct preparation for the world of work. No matter where they end up employed, if their colleagues know that they have a degree in statistics someone will come along and ask about required sample size for some project. If they take the place of someone who has resigned or retired, they will be expected to rapidly replace their expertise with whatever software they were using. If they move into a pharmaceutical company, or a mineral exploration company, or an insurance company, they will be expected to rapidly learn about whatever methodologies they are using, and about the details of the context within which they operate. Moreover, many students in an honours year know this already from their friends who have finished pass degrees and are already out in the workforce.

That this is an important concern for students, even in their undergraduate courses, is shown by their comments on real statistical examples and case studies. For example:

> *The first statistics subjects we did were really theoretical and this one was really practical. And the examples we got, compared with … like, he said, he said sometimes students he has taught call me up and they have problem and they want me to work through it. And he works through it with honours students sometimes, and so yeah, sometimes he takes practical questions. Like, he did really good ones, like times when the data just doesn't work and your graphs just don't work. And that seems like something that could happen all the time with things at work. And he took questions where nothing was working well and you just have to do the best you can, and it was pretty good.*

Consulting projects give an opportunity to practice work-relevant skills in a work-like context. That is, one where one's actions have real context, and real consequences beyond the classroom. Role plays, case studies and simulations can provide almost all the other experiences of the consulting course, but the real-life messiness of projects, and the motivation of knowing that there is more than just a grade at stake, cannot be simulated. In fact, statistical consulting courses are an entry into the notion of work-based learning in the field of statistics, widely used in other areas of education. Trigwell and Reid (1998) write:

> Curriculum devices such as learning contracts, personal reviews of learning and "real-time" work-based projects provide structures within which learner development can be negotiated, made explicit, monitored and accredited. The specific learning outcomes, which accrue from such open-ended programs, often extend beyond those that were predictable at the outset. The learners gain additional benefits in the form of greater confidence in their ability to manage their own learning and development, benefits that will also be important in their personal lives (p.144).

If we can accomplish this in our statistical consulting courses, we will have achieved significant benefits for our students' learning and preparation for work.

CONCLUSION

Research projects and other forms of major, relatively well-scripted and defined projects have been a feature of final, particularly honours, undergraduate study for many years. These projects usually require the student to master and report on some material that is quite new to them, under relatively loose supervision. Such projects extend able students, give them a taste of the research process, often feature importantly in honours grading, and are usually of comparable difficulty both between and within student years. They typically focus student attention into the field of statistics, to its theoretical or computational aspects, and will be supervised by a faculty member for whom the project topic concerns a research or consulting interest. The projects within a consulting course have very different features and require a different type of supervisor management. They provide a complementary learning experience, directing students' attention outward from the field of statistics to its engagement with the broader realms of numerical investigations where, for most of them, the future will lie.

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