

REFEREED PAPER
REFLECTIONS ON DESIGNING A STATISTICAL CONSULTING CAPSTONE UNIT

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ABSTRACT

Statistical analysis is required in many different projects throughout most work areas, which makes statistical consulting both exciting and challenging. Most students majoring in statistics do not have real-life experience of statistical consulting, and so it is very important that we as educators prepare our students for the statistical consulting needs of the workforce by offering training in this important area of statistics. We have recently set out to design a final-year undergraduate capstone statistical consulting unit (course) for our students majoring in statistics at Macquarie University, Sydney, Australia. This unit brings together the various technical aspects of students' studies via a problem-based approach to learning about statistical consulting. In this paper, we document our planning of a statistical consulting unit: we discuss the challenges that we faced and indicate our solutions to these challenges during the planning stages of this capstone unit.

BACKGROUND

Macquarie University is a large institution in Sydney, Australia. It has about 24,000 undergraduate students, 12,000 postgraduate students, 1,120 academic and 1,245 non-academic staff. The academic year is divided into two 13-week semesters, each followed by a 2-week formal examination period, plus a 6-week summer session for selected units.

In 2008 the University introduced a process of curriculum change for undergraduate units (which is how the university refers to individual semester-long courses), aiming to broaden students' experiences and expertise by adding several 'breadth' units (referred to as 'people' and 'planet' units) as well as mandating a capstone unit for each program and/or major, with the aim of better preparing students for the workforce. 'People' units are designed to help students to understand the world through learning about the challenges of modern society, while 'planet' units provide opportunities for students to understand the physical environment and differentiate between scientific and anecdotal evidence. Capstone units are intended as a bridge between university studies and professional work (see the Annual Report, Macquarie University, 2009).

During the curriculum change process, the authors' department, the Department of Statistics, created two majors, a Decision Science major and a Statistics major – this latter can be completed by students in the Science or Art faculty. The capstone unit for the Statistics major is Statistical Consulting: it was created on paper in 2009; concepts for the unit were developed during 2010; and the first offering of the unit is taking place presently – in second semester 2011 (August–November).

Four academics from the department (the authors of this paper) set out to design the unit in 2010. During a number of meetings, the unit was planned by taking into account the experiences and expectations of these academics, supported by relevant literature. In the following sections we will summarise what we have planned for our students to learn, how we will provide opportunities for community engagement as part of their learning and what we considered while we were designing the assessment options for the unit. Finally, we will summarise our recommendations for designing such a unit.

The topic of teaching consulting already has a substantial literature, including 'classics' such as Kimball (1957), Zahn and Isenberg (1983), Kirk (1991) and Chatfield (1995, 2007), as well as more recent contributions by Derr (2000), Russell (2001), Taplin (2007), and Smith and Walker (2010). Wild and Pfannkuch (1999) present a schema for statistical thinking in general, a useful starting point for discussion about the process of solving statistical consulting problems. Finney (1991) discusses the ethical aspects of statistical practice, and hence statistical consulting in particular. Skovsmose (2009) points out the importance of including ethics – "structures for analyzing and reflecting on action" (p. 342) – in all aspects of scientific education, including of

course statistical education. He points out that taking a view of science (and statistics) as neutral and representing the true progress of humanity leads to the notion that ethics is irrelevant in science (and statistics). Jersky (2002) has documented the positive outcomes of using statistical consulting as a learning opportunity for undergraduate students who may have only taken an elementary statistics class previously. Mackisack and Petocz (2002) identify the problems and successes of a statistical consulting class with statistics honours students, who have three or four years of statistical education behind them. Our focus here is on an intermediate situation, where our students are in the final semester of a three-year degree majoring in statistics.

There is also considerable recent research on better ways of fostering learning – including collaborative and active learning, student-centred classrooms, constructive learning, context-driven activities with appropriate technological support – all of which encourage student engagement in learning (see Chance *et al.*, 2007 and Zieffler *et al.*, 2008 for summaries). The authentic nature of working with real statistical problems encourages students to make clear connections between their university studies and their future (or sometimes current) professional lives, a feature that enhances their engagement with their studies (Petocz & Reid, 2010).

WHAT STUDENTS CAN LEARN IN A CONSULTING UNIT

The required statistical units for our students at Macquarie include an introductory statistics unit, second-level units in probability, applied statistics and computer simulation or operations research, and third-level units in linear models and at least two more statistics units from various areas of statistics, as well as Statistical Consulting. Therefore it is possible to tailor the lectures in the Statistical Consulting course to cover (summarise) techniques that are not part of required units, and use practicals and/or tutorials for client consultation. However, this would undermine the main aim of the unit, which is equipping students with the skills that are essential to be able to work as a successful statistician after they graduate. Instead of teaching the students additional methods as part of this unit, we decided to create opportunities for them to learn these themselves or from each other. This way, they will also be practising their lifelong learner abilities while they still have opportunities to be supervised by us.

During their studies, students would have already substantially improved their problem formulation and problem solving skills. However, since these skills are usually practised in practicals and/or tutorials tied to lectures, they might not be very realistic. It is this realism that the statistical consulting unit, in which students will be required to identify the client's problem, put the problem into statistical terminology, identify suitable statistical technique(s), solve the problem and report back to the client(s) in day-to-day terminology, not in statistical jargon, will provide.

Most statistics majors or programs include group activities requiring team work. Since these groups are composed of students within the statistics program, these students do not learn to work with non-statisticians or in general with people without statistical knowledge. Working with such people requires higher-level communication skills, such as the ability to elicit sufficient information from clients to formulate their problems within a statistically satisfactory framework. It also requires writing coherent reports and presenting results so that they are understood by non-statisticians.

The preparation of students for the workforce needs to include not just knowledge of statistical techniques and how to apply them, but also opportunities to develop and improve 'soft skills' such as working in a team, conflict resolution, and highly developed oral and written communication skills. These are particularly important for statisticians, since they most often work as part of a team. These skills thus become very important for successful work as a statistician. In addition, ethical considerations of statistical work are an important issue that is sometimes overlooked and often not included in any required units of a statistics major. Therefore these so-called soft skills and ethics will be amongst the most important learning outcomes of the Statistical Consulting unit.

COMMUNITY ENGAGEMENT

An authentic real-life experience of statistical consulting is not possible without having a real client and a real (unsolved) problem. Documented case studies may be useful starting

examples, but they will not be as exciting (and authentic) as working with a real client. Therefore, we have started collecting a number of real statistical problems from the staff and students (possibly higher degree students in other departments) at Macquarie University. We have designed various forms to facilitate the journey from problem collection to the grading of the students on their consulting (by the clients).

Firstly, an e-mail was sent to the people who showed interest in our Statistical Consulting unit at faculty-level learning and teaching meetings and/or seminars, as well as people who attended the university's Learning and Teaching Week Capstone Workshop last year, which outlined the possibilities of offering statistical help. These people have been asked to contact one of the teaching staff to declare their interest to be our students' clients.

Secondly, we are asking possible clients to complete a form regarding their statistical problem(s) early in the first semester (March) and are holding initial meeting(s) with them to decide the suitability of their project(s) for our students. Due to the time constraints, we will only accept projects which are clearly defined and ready to be acted on (either by analysing the collected data or by designing a study for data collection). Any harder problems will be passed onto our postgraduate coordinator to be considered as one- or two- semester long Master's projects. There is of course a problem with the time delay: in planning our collection of problems in advance we are asking potential clients to wait for statistical attention, and some may not be happy about this. However, the statistical help does not require any payment, so that may balance the delay for some people (particularly doctoral students).

Thirdly, when the semester starts our students will be put into groups of three and briefed on the possible projects by the lecturer(s). We are hoping to collect more projects than our students need so that they will have an opportunity to choose a project they are interested in from the available projects: we will have to address the question of what to do with projects that have not been selected – we may need to look at these ourselves, and could possibly use them as early examples in the unit. It is also possible that students could bring problems from their workplace to work on during the semester – some of them are studying and working at the same time. If this happens, the students concerned might prefer to work alone instead of working in a group (though our previous experience in such situations is that many of them will welcome a colleague to help with the problem). This option will also be provided to accommodate this kind of project.

After allocating students to the projects, we will organise our student groups to meet with the clients to discuss and better understand the project. The students will be helped to convert the clients' problem into a statistical problem and identify the required methods for the solution. If necessary, the students will study and learn new (to them) statistical techniques either from each other or themselves under the supervision of the lecturer(s). During the stage of data analysis and/or design of a study we expect that further meetings with the client will be necessary to clarify some aspects of the study.

When the project is completed, the students in the team will prepare a professional written report for their clients. In addition, they will make a conference-style presentation to communicate the findings to the clients as well as to their peers in the class.

DESIGN OF SUCH A UNIT INCLUDING ASSESSMENT OPTIONS

At a previous IASE Satellite meeting, Petocz and Reid (2007) pointed out that the main role of assessment is to support learning and prepare students for their future professional role; further, any particular view of assessment implies a corresponding view of learning. In the development of the assessment plans for this unit, we have been guided by the principles (and examples) given in that paper.

Of course, there is "growing demand for verification that students are, indeed, learning what they need to learn ... driving institutions and programs to develop tools for assessing the level of knowledge and skills of their graduating students" (Beard, Schwieger & Surendran, 2008). In this paper, the authors "suggest additional means of addressing and measuring requisite soft skills for Information Technology (IT), accounting, and other business students." We agree that such means of assessment are important as well for statistics students.

Interestingly, in a secondary analysis of the National Child Development Study in the UK, Machin and his co-authors find that "[m]ost of the attitudinal variables and soft skill

measures do not individually have a significant impact on individuals' outcomes." However, there were certainly additional marginal gains found for subjects who had more highly-developed soft skills (Machin et al., 2001). Kumar and Hsiao (2007) address the issue of teaching these soft skills to engineering students, and claim that it is better to do this in class, rather than allowing students to acquire such skills only after graduating. We agree.

Initially, we considered concentrating on statistical thinking skills and improving such skills by the end of this unit. We also considered the use of role plays instead of real clients to allow students to practice their skills and to reduce any risk. However, concentrating on statistical thinking skills would have limited the time required to practise, learn and improve the statistical communication skills (both oral and written) that will be amongst the most important skills acquired in this course. Therefore, after a number of meetings and discussions, we decided to design this unit to provide an authentic experience of statistical consulting by including as many real clients as possible instead of role plays, and to address soft skills as well as statistical thinking skills in this context.

Students will be given a low-risk assessment task at the beginning of the semester (this is a requirement at Macquarie University) without a real client, in which each student will be required to prepare a project report alone. This will allow us to assess individual students' abilities and knowledge. We will then form student groups (with a maximum of three students in a group) in which there will be a mixture of abilities and knowledge for the authentic projects with real clients. As part of these projects, students will be asked to write reflections on their learning during client interviews and throughout the project of working as a team member and for the whole process of statistical consulting. These self-reflections will form one of the assessable artefacts of the unit.

A formative or summative assessment could also be integrated into this process by including peer assessment. Such peer assessment could be considered in two different ways. Firstly, students in the same group could assess team members to help one another improve at each step of the project. This could either be formative or summative. Secondly, the interviews with the clients could be assessed by other students in the class, as long as clients are happy to have student observers for the interviews (they will have already agreed to lecturer observers). This form of peer assessment is more suitable as a formative (where feedback is provided to improve students' current performance) than a summative assessment (where both feedback and the marks provided that counts towards the final grade).

With the agreement of the clients, we would like the project report and the process of statistical consulting to be assessed by the client, in either a formative or a summative form, perhaps depending on the expertise of the client in pedagogy. The lecturers will also assess the project report summatively. All the assessment criteria and expected standards will of course be provided to students with the project introduction, so that students are aware of what is expected. For this first offering, we will not have example reports. For subsequent offerings of the unit, we will use prior semesters' reports as examples on which the students can build.

Ethics is an important component of professional statistical work. In a capstone unit such as this one, we would expect students to discuss possible ethical problems and their solutions with clients who have asked for statistical consultation – this would form part of the project report and also their reflections. In this way, they would build on their earlier awareness of the ethical dimension of statistics (a first unit) and their discussion of ethical aspects of a particular project that they were undertaking (a second unit). Students' notions of ethics were reported by Reid, Taylor and Petocz (2011): they ranged from subjective ideas about right and wrong, maybe based on rules (from church, university, the law, etc.), through to a consideration of the effects of one's behaviour on other people. In our experience, an early discussion of these ideas is a good way to introduce the notion of ethics. Students' awareness of their own and others' views is an important first step towards ethical professional behaviour.

There are various options for assessing oral presentations, including lecturers, clients or peers as assessors. In our experience, it helps to have the criteria presented in the form of a check list, with opportunities to amplify the assessments with written comments. A final sit-down examination in which knowledge is assessed does not seem to be suitable for this unit. However, it is still possible to construct and use a final examination based on presentation of a number of

hypothetical case studies to students (perhaps given out a week before the final exam), asking them to answer questions on these case studies. For example, we might use the following questions in an examination:

“If you were the statistical consulting for XYZ company, which three questions would you ask to clarify the problem?”

“After the communication breakdown between client and the statistical consultant in case study two, what would you advise the statistical consultant to do to re-built trust and bring the project back on track? List three points and explain why these would be useful.”

Our current preference would be to assess the students’ work in this unit using the same authentic approach as the actual statistical consultations, and so eschewing the use of a final examination. However, university and/or departmental policy may end up constraining us on this point. Shreeve, Baldwin & Farraday (2004) delineated students’ notions of assessment. The students’ narrowest view was ‘correction’, tutors checking that they have done the right things and the right amount of work. A broader view was ‘developmental’, tutors giving them advice to help their progress. The broadest view was ‘partnership’, in which they see themselves as equal partners with their teachers in the process of evaluating their work. Although this model was developed in the context of design and creative arts, it seems likely to apply in other disciplines, including statistics. In a capstone statistical consulting unit, we should aim to utilise the partnership view of assessment as much as possible – after all, such final year students are likely to be our professional colleagues in the very near future.

CONCLUSION

An undergraduate unit in statistical consulting is our opportunity to involve our students in authentic statistical work while they are still studying. Such opportunities are not so frequent in the standard approach to statistical education, which traditionally focuses on the technical aspects of various branches of statistics. Using the consulting format gives students an opportunity to see the whole landscape of statistics as a coherent field of study and as an approach to solving problems in a wide variety of contexts. This encourages them to develop the broadest conceptions of statistics as “an inclusive tool used to make sense of the world and develop personal meanings” (Petocz & Reid, 2010, p.277). Further, it allows them to develop more generic skills such as communication and teamwork, and dispositions such as an appreciation of the ethical aspects of statistical work, that are so crucial in their path from student to professional. Such a consulting unit gives students the opportunity to actually become statisticians, while still preserving the safety net of support by their lecturers and peers.

In this paper we have described the background of and preparations for our new ‘capstone’ Statistical Consulting unit for our undergraduate Statistics major. The unit is running in the second semester 2011 (which in the southern hemisphere means that it starts in August), so our discussion documents our planning and preparation, but not our actual experience with the students and clients. As such, it is unusual – papers often describe innovations that have actually occurred rather than those which are yet to happen – but the documentation will be a useful way to compare our expectations with the actual outcomes of the unit. Further, we will welcome comment and discussion at the presentation of the paper, and will have the opportunity to use this to improve the first presentation of the unit, which will have only recently started.

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