A Thousand Projects

Behind the scenes with student projects in statistics and statistical modelling

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Some *MSOR Connections* readers may have seen a paper or references (for example, MacGillivray 1998a, 1998b, or MacGillivray and Hayes, 1997) to the own-choice group project strategies I started in introductory statistics mainstream and "service" courses about nine years ago. Colleagues in statistics and the "serviced" disciplines, particularly engineering, often ask about aspects such as the types of contexts students choose, how do I "guide" their choices, analysis and reporting, and how to assess such individual projects in large classes. These types of questions are not easy to answer in a formal paper in the way colleagues want, so it was suggested that MSOR Connections could be a suitable medium for more anecdotal and informal comments.

The original objectives were to provide hands-on data investigations for mainstream students, in contexts of their choice, from the conception, planning, collecting to exploring phases, and to integrate development of communication skills within mathematics degrees from the moment the students came to us. We had made a deliberate decision to integrate such skills within mathematics and statistics subjects rather than be vulnerable to separate "communication" subjects. At the time, Margaret Mackisack's excellent work with the second year mathematics students (Mackisack, 1994) involved asking them to apply given experimental specifications to designing and analysing an experiment of their choice. My emphasis with the first year students was intended to be an extension of the real datasets and their associated "stories" that I was providing for them. There was also increasing interest in Australia in training "for consulting", in the statistics consulting centres of, for example, the universities of Melbourne and Adelaide, and in cooperative honours and postgraduate student projects with industry (see, for example, Diamond and Hallett, 1998).

The idea worked so well with the first year students that, with great trepidation, I tried it in 1994 with the engineering statistics (introductory data analysis) subject of almost 400 students in their second or third year. These students were not satisfied with leaving "their" data at the exploration stage, wanting to use data analysis techniques as, or even before, they met them. The trepidation never completely disappeared but was mostly replaced with delight at the success in helping the students own and improve their learning. In expanding to include analysis, other unforeseen benefits began to emerge, and the own-choice projects strategy evolved to become an integral part of my and my colleagues' teaching at the introductory level. For a number of reasons, including student desire to use web-based datasets, it may be time to evolve further, but the lessons learnt by both staff and students have been invaluable. A smaller version in the introductory probability/distributions modelling subject, requires student groups to choose two stochastic variables (one discrete, one continuous), whose processes could be Poisson (such as queueing processes), collect data, check assumptions, and write a report.

Students' choices

In a quick estimation for writing this article, I was amazed to realise that in the last seven years I have overseen/assessed more than a thousand different projects. Adding those overseen/assessed by my colleagues gives quite a total. So what types of projects do students choose? One beneficial aspect of the strategy is that, even though we advise on their ideas, there is no way I could come up with one-tenth of the ideas that more than a thousand groups of students have.

The principles are that they suggest and we respond. We help them to articulate their ideas, to identify their variables and units of observation, to obtain a dataset that is suitable for their timeframe and level, but has "enough" in it – enough to enable them to explore and to demonstrate judgement in choosing, using and interpreting appropriate statistical techniques from their basic armoury. The last-mentioned may seem to the students to have an element of crystal ball-gazing or crossing fingers, but five variables with at least one continuous usually provide sufficient opportunity. If all their variables are categorical, more than five is preferable. How many observations? It is an excellent learning experience for the students to realise that we cannot advise on this without their input. I have found we need to (a) counter their training (from where?) in the single experiment/single hypothesis "scientific method" – we emphasize explore, investigate, use your data; (b) emphasize that the project is about choosing and using appropriate techniques appropriately – do NOT approach it with mindset of throwing as many techniques at the data as you can; (c) allay fears that they'll "find nothing" – "finding nothing" can be just as important as "finding something".

The range of interests is enormous. I have the titles of the projects from my engineering students from 1995-2001 if anyone would like them, but some titles are more informative than others. It may seem from the titles that there is repetition of ideas, but although there are perennial favourites such as petrol and alcohol prices, even projects on the same topics are always different, reflecting the students' lives or interests. Another interesting aspect is that each year, there are occurrences of different groups independently choosing similar contexts, reflecting how similar stimulii can arise in the ordinary everyday happenings for a class. For example, in 2001, in a class of 200 electrical engineering students, there were two projects on different aspects of elevator performance and one on escalator behaviour; four on observing various behaviours of their fellow students in class – two on arrival/departure patterns, one on mobile phones and reactions, one on apparel and weather relationships; and two on weather predictions and connections. In the probability modelling class of 80 students in 2001, there was great preoccupation with arrival and service processes at the library and fast food outlets; in a previous year, the fashion tended to processes associated with the internet and traffic.

There are amusing but fairly informative titles such as *Golf: better played than analysed* and *Sleeping patterns of international students* and *Murphy's Law and its ramifications for Toast*. But some reader-puzzlers are *Newton's Fourth Law - Do Singles Seek Comfort Through Trees? Do Unfriendly People Walk Upstairs? Get Popped. The Very Irresponsible William Tell. Do Bimbos Exist? To press or not to press. Chicks in red cars. Crashing for dummies. Behind the covers. Time to boredom. I can't believe it's not dominoes. Joy with Jelly.*

Students are neither encouraged nor discouraged towards any type of project. The only criteria are that there be no ethical or data privacy problems, and that the data be collectable and useful for the students without too much time/expense. Sometimes student enthusiasm gets them into problems. A recent development is the apparent ease of collecting computer data, but automated collection without careful planning can give much data on few variables, with unrecorded or unknown "happenings" and significant missing data. Some students try to collect data on too many variables, or in too much detail, and having to ignore carefully recorded information is very dampening to student spirits. One group set up an automated ping-time experiment, with 50 pings every 15 minutes. But they used only two machines and could neither control nor monitor other users interfering with their experiment, so had an enormous but not very useful dataset. In contrast the ping time experiment written up in the project manual (MacGillivray and Hayes, 1997) was a smaller but better planned experiment. Another group, in trying to emulate the wonderful bikeway dataset, with variables speed, gender, type of transport, time of day, and direction of travel, tried to spend a day recording details of every vehicle along Surfers Paradise Esplanade. Unfortunately they chose Easter, and by 11am were exhausted; after suitable refreshment at the nearest "watering hole", they then sampled in time frames.

Course-related projects

In describing projects to staff in other disciplines, particularly engineering, I have to be prepared for their reaction to many of the students' choices of "but what has this to do with the students' course?" Although the answer is "everything" if the students choose their own context for the learning they then transfer into their engineering contexts, I confess that awareness of the attitude behind this question tends to make me conscious of encouraging students who wish to use course contexts.

Successful projects in such contexts - with successful defined as contributing successfully to the students' learning and confidence - tend to occur when the student is familiar and interested in the context. Thus there are few contexts taken directly from engineering courses that tend to produce successful projects. There

have been successful projects on resistors, capacitors, and file compression, a successful but challenging one on *Words, Relevances & Number of Sites: Internet Searching*, and in medical engineering on *Weights of students' bags*, and *Visual Acuity*. I now discourage resistor analyses as they tend to sameness and tediousness. There have been moderately successful ones in traffic analysis using engineering data *(Do Cars Travel Faster in the Right Lane?*), in medical engineering on *Pain and Lecture Posture*, in some mechanical engineering experiments (for example, a glass cutting machine, rolling friction, and pulley roller analysis), a couple of civil engineering experiments (on wood creep, and on flow tank data), a surveying one called *A Statistical Analysis of Distance Measurement by Modern Electronic Distance Measurement (EDM) Equipment*, and random number generation, but the last really requires more sophisticated statistical tools and thought.

Projects that I would not describe as successful for the students include *Statistical analysis of K-type and T-type thermocouples, Secondary Thickener 8 classifier, Soil laboratory tests and laboratory comparisons, Our communities knowledge of Engineering, Cyrix and Pentium p6 benchmarking on various mother boards*, and, most recently, attempts to illustrate the central limit theorem and modelling noise in signal processing. In each case, either the engineering context was too new for the students, or the statistics too advanced, or the combination had too many new aspects to handle simultaneously.

More successful projects associated with engineering contexts are those that are peripheral to, or linked with, aspects of engineering, but not necessarily with the students' own engineering area! Computer and internet usage (for example, *Computer helpdesk, Use of the CBE facility at QUT from 14 April to 25 May 1998.*), computer and telecommunications prices and services, computer games, and computer programs to assess reaction times, including assessing the effects of alcohol, have all provided successful projects. However, computer game contexts can share the complications that occur in competitive sport data. Traffic and transport studies are rich sources: various speed studies (e.g. *Car speeds in residential streets, Speeds in speed zones*); behaviour (e.g. *Indicate, why don't you!*); bus, train and ferry schedules and performance (e.g. *Is my bus here yet? Bus implementation project, Citycat travel*); air transport (e.g. *Brisbane Domestic Airport Terminal, Airplane accidents*). For double degrees in business and engineering, currency and stock market analyses are of interest.

Work-related contexts

The students' workplace contexts are mostly related to part-time non-engineering work but some students are in full or part-time engineering workplaces. The latter are unusual at the undergraduate level, and have provided a few of the most successful but also a few of the most challenging projects. The students' response to the results of their regression analyses in *Underground Cable Sheath Temperatures* was "that's magic" and their project led to a major follow-up in the industry source of the data, but the student project relied completely on the part-time student who worked full-time in the company. Other projects not quite as dramatically successful as learning experiences but emphasizing statistical needs in engineering have included *Commercial turbofan aircraft analysis, Maintenance of F-111 wheels, Thickness of cable sheath, Bolt sizes, Analysis of Digital Mobile Telephone Calling and Call Drop Out Patterns, System Logoff Analysis, Response times for elevator breakdowns, The Occurrence of Lightning and its Effect on Circuitry, An Investigation into the relationship between substation load and weather conditions, Gaskets manufactured per day, Performance of 3 brands of mercury switches, Oxygen levels of prawn ponds, Jet pump analysis, and Compressive strength of concrete.*

Students' part-time non-engineering jobs have provided a large range of contexts and successful projects. A number of fast food and video outlets are rapidly increasing their data records and some of their part-time employees who are studying maths or engineering have provided significant "added value" by investigating parts of their data. Other projects in this area include, *The Bag Sealer, Bread returns at Coles and Woolworths, Sport Shoe Sales, QUT Campus Club, Telemarketing, Does Temperature affect Slurpee Sales? A Study of Response Times of Tow-trucks, An Analysis of Raw Coffee Sales, Magazines, Repair Times of Army Vehicles, Gym Attendances, Correlation between Effluent Levels.*

Occasionally I am requested to sign a statement that the data and information in the project will not be made public, but will be seen by only the student group and the examiner. This has caused no problems, and has enabled students to investigate data from their part-time employment to the benefit of both them and their employer – we hope.

The incorrigibles

Some of the most incorrigible topics have been thought up by some of the best students – those most committed to their course, their study and their future. The topics

may be incorrigible but the work and the learning are excellent, and their feedback is that the introductory statistical understanding they take into their own areas from doing a project they "invented" and owned, is as good if not better than one from a given list or from "serious" topics.

The flippancy of the contexts is deceptive as usually these projects demonstrate excellent experimental planning and analysis and thoughtful reporting with good statistical understanding. The first such classic was *Murphy's Law and its Ramifications for Toast*, in which the students investigated whether topping, tosser and floor surface affected the chance of toast landing topping side down. The ringleader was more attracted by theoretical statistics than data analysis but acknowledges the usefulness of the statistical literacy he gained, and freely admits the project made him pay sufficient attention in class to make sure he didn't miss something that might be useful in their project. He referred to his project in head-hunting interviews with multinational consulting firms, but chose highly responsible technological management work and postgraduate study, incidentally becoming Australia's Young Engineer of the Year, Young Queenslander of the Year and Australia's Young Achiever of the Year in Science and Technology.

The most recent are *Joy with Jelly* and the *Egg Crush Test*. The Jelly group investigated how setting times, brands and colour affected "amount of set" – represented by two measures of splatter – maximum diameter and diameter of majority "blob". They had to solve practical problems such as how to fill a fridge with jelly samples without too much distortion of their selected times, and a problem that is inherent in many engineering situations – can we measure what we want, and what is the best measure. To their surprise they found significant interactions between colour and brand, and the relationship of splatter with time depended on both colour and brand. The egg crush test group designed a simple but clever apparatus to measure strength of eggs of different brands, shell colours and sizes; their report demonstrated the understanding they had gained of the importance of discussing variation as well as what happens "on average". Both these groups also had significant cleaning challenges.

Others include *Do Bimbos Exist?* Medical engineering students share some courses with other areas such as human movements, and this group were convinced that there were relationships between courses, natural hair colour, current hair colour and bra size. The ringleader of the engineering group, another top student, was a girl, but the group must have had considerable charm as, to my amazement, they got full cooperation with their questionnaire in two universities! *Newton's Fourth Law – Do Singles Seek Comfort Through Trees?* investigated spatial distributions of people and trees in parks. *Flow rate of beer* and *Crash test stubbies* were both very clever projects in design of experiment, invention and building of apparatus, and both demonstrated excellent statistical understanding and reporting.

Incorrigibles amongst the students in the introductory probability modelling course tend to be milder, but have included ant behaviour, the number of "ums" per minute from a particular lecturer, times between appearances of jokes of a certain type on a joke website, and times between nappy changes for a toddler (readers will be pleased to know these were not exponentially distributed).

Experimental and observational investigations

As well as the experiments of the incorrigibles, engineering students have demonstrated initiative in many ways in planning, carrying out and analysing investigations into contexts such as response and journey time in lifts in different buildings under different conditions; the use and misuse of drop-off zones; the performance of slinkies under different conditions; and the effectiveness of card shuffling. The last of these again involved considerable thought on the very engineering question of what measure(s) to use to represent what we wish to measure. But this group even made a very creditable attempt to model the distributions of the measures they were using. As in other top projects such work was not required – they did it because they were interested, and they learnt that stochastic modelling of processes is important but not necessarily straightforward.

As mentioned above, one of my favourite datasets is the bikeway one – 945 lovely observations on 5 variables – lovely from the point of view of a lecturer wanting real data for teaching. When I used the bikeway dataset to illustrate some points in a MBA course there was an interesting side-effect – a phone call from a local authority wishing to use it as part of their analysis. Others include a dataset on coffee prices in different types of outlets in different locations; a dataset on the performance of different brands of popping corn; various datasets monitoring petrol prices over time; and a combination observation/survey that monitored student spending on lunches over days of the week.

Everyday contexts

Many of the above include examples of everyday contexts of interest to the students. Some areas that always seem to be popular are:

- Transport, accommodation and university contexts. Some in these areas are mentioned above. Social and behavioural contexts may involve observation or surveys in study or recreation contexts. Videos, films, TV ads and music have provided varieties of projects. A recent one obtained data on various measures and factors in the box office success or otherwise of films released over the past few years. Costs and nature of accommodation, food and transport are of great concern to students, particularly overseas students, many of whom either have a particular liking for conducting surveys, or perhaps think that statistics is predominantly about surveys. Investigating TV ads can take considerable thought in the planning, ….and the execution. One student's helpful sibling taped the requested program, carefully leaving all the ads out. And the analysis of a project on ads was one of the few that caused such disagreements in a group that they split and presented rival reports.
- Prices and household goods are rich sources of project ideas particularly if students are having some trouble thinking of a context that is manageable and will satisfy the assessment requirements. Despite their initial inclination just to do something because they have to, it seems to be difficult not to acquire some interest in investigating prices. Price investigations are also good suggestions for those groups who leave their project to the last minute.
- Alcohol, sport and cars. Alcohol provides everything from price investigations to behavioural observations to assessing effects of alcohol on playing pool or computer games. Apart from traffic and speed projects, cars have provided contexts from car parks to colour and type preferences. Sporting contexts can be difficult if they involve competitions or obtaining data from records, but projects that focus on a person, such as Michael Jordan or Steve Waugh, or a team, have been more successful. Sports such as golf, fishing, archery, and darts, have provided good learning experiences in both planning and analysis. In contrast, my advice now on proposed projects on horse racing or other gambling contexts is …don't.

Staff workload

Because the development of support materials that included guidance and model projects have helped students, they have also helped staff and have made it more attractive and easier for other staff to adopt the strategy. Some other key points in managing such projects are:

- these projects are learning experiences, not consulting jobs. Although they are being tackled as real projects, the product does not have to meet statistical consulting standards;
- teaching with consciousness of what they will need for their projects not only reduces the advising needed outside class hours, but is also teaching oriented to the practice of statistics;
- thought given to practical aspects such as group identification, arranging to have groups in the same tutorial classes, and judiciously timed tips and examples in lectures, can significantly reduce advising and administration;
- insistence that the students give a brief (half a typed page) but explicit description in writing of what they intend to, clearly defining their variables and observational/experimental units; any proposed survey MUST be submitted to the lecturer;
- as well as the project support materials developed with the assistance of a grant, students have access to the project reports of previous years; project reports are retained, with copies of the summary comments/marks sheets given to students, for the dual purposes of combating plagiarism and availability for reference;
- student familiarity and confidence with computers have helped considerably in their learning capabilities in using a statistical package;
- students are required to supply their data as an appendix or on disk, and one of the assessment criteria is clear description of how and when the data were collected. Students are permitted to use existing data sources but must be able to give a full description of the details of collection. Generally speaking there is as much work involved in dealing with existing data sources as in collecting their own data, given our advice/assistance to ensure manageable projects;
- communicating by email on project questions helps students to more clearly articulate their questions and enables them to keep a record of their questions and answers;

- assessing the projects is probably similar to marking essays in a humanities/social sciences area. I read them and write summary comments under identified criteria headings, resisting the temptation to investigate the data further. Any mistakes or inappropriate procedures/ interpretations are pointed out in the summary comments;
- managing staff workload is highly correlated with managing student workloads, particularly in large and introductory classes. Too much assessment gives too much marking. Because projects such as these assess problem-solving, understanding and synthesis of statistical knowledge, other assessment can be made simpler and shorter. For example, I have been experimenting with quiz style assessment to complement the projects.

The future?

Although the strategy has been adopted by colleagues, is now a standard approach in our teaching, and is running smoothly, I do not expect it to remain static. It will evolve in response to a range of influences, just as the projects have significantly influenced, and continue to influence, other aspects of teaching and assessment.

References

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A selection of these projects including datasets is available at:

http://www.ltsn.gla.ac.uk/resources/subject.asp?subject=Own_Choice_Student_Projects

Footnote

For most mathematicians and statisticians, the writing of papers and articles on teaching, learning and educational issues is full of questions. What balances should there be between the general and the particular, between the learned and the conversational, between formal evaluations and the anecdotes? A guideline such as put oneself in the place of the reader just raises another question of which reader – the reader in the same university or locality, or the reader who knows nothing of the circumstances in which the writer has taught. In our disciplines details of students and situations are significant factors in teaching and learning.

It is of interest that, in parallel with growing interest in writing and speaking on teaching and learning in statistics, there has been increasing encouragement in research journals for the writing of applied papers, which have similar challenges of balance. Editors of such journals comment on the ongoing imbalance in numbers of submissions between applied and methodology papers. It seems that in both the teaching and the practice of statistics there is so much to be done that it is difficult to take time from the doing, as well as tackling those questions of balance. But sharing experiences and anecdotes from teaching and interaction with students is of immense value and of increasing importance in our profession. I would like to take this opportunity to comment that I think *MSOR Connections* provides an excellent component in the spectrum of networking opportunities.