A mathematician goes to hospital

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How can a university mathematician contribute to university-community engagement? In this paper, the author describes recent experience in seeking to contribute to university-community interaction as an academic who teaches mathematics and statistics. Particular emphasis is given to how this experience contributes to course development and teaching elementary courses to undergraduate students in Business. Furthermore, key success factors that govern the interaction between a university and its community are suggested.
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1 Introduction

The city of Bendigo is the location of the largest regional campus of La Trobe University. Over recent years, La Trobe University, Bendigo has fostered and stimulated interaction between the University and regional Victoria. While it is easy to imagine how academics in some disciplines (such as economics, history, or various professions) could contribute to community-university interaction, it is more difficult to imagine how those in theoretical disciplines (such as mathematics) can be so involved. As a mathematician at La Trobe University, Bendigo, I have chosen to make a contribution to health care in the region. Since 1998, I have been trying to blend my skills as an academic mathematician with the needs of Bendigo Health Care Group (BHCG). In this paper, I will describe the projects at BHCG in which I am involved, and their impact on my work in undergraduate teaching, course development, and research. Also, I will mention some challenges associated with community engagement and key factors that have led to my experience being both exciting and rewarding.

2 A national perspective

Before describing how a mathematician can become involved in health care issues, I wish to highlight two ideas that have influenced me in this venture.

"*The AVCC believes that the promotion of effective teaching should be a matter of highest priority for each university and that each institution needs to develop a coherent set of policies and practices which demonstrate that the institution values above all else the education of its students and the contributions that academic staff make to the enhancement of student learning*" [3].

These words were not written by some lone champion of university teaching: they have been extracted from a paper by the Australian Vice-Chancellors' Committee. In particular, we should note the belief that the university should value the education of its students "above all else". These strong words from the leaders of the nation's universities have encouraged me in seeking more effective ways to contribute to the education of our students.

The second influence at a national level is the Australian government. The following statement is from the Minister responsible for universities in the federal government.

"*Regional initiatives recognise the significant role of universities, particularly those in regional areas, in the economic and social lives of their communities*" [15, p. 39].

The Minister is making the point that contemporary universities should interact with their communities. On one hand, universities provide wonderful intellectual resources from which local communities can

benefit. On the other hand, local communities and enterprises offer academics inspiring questions that can lead to innovations in teaching and research. Central Victoria is a region in which academics at La Trobe, Bendigo can explore fascinating questions in a local context and with global implications. Because these questions are on my door-step, they have an immediacy that I find attractive.

It is true that we contribute to our local community through our teaching: we offer courses to citizens and assist them in their careers. Also, universities add to the economy of their local community in so far as we spend our money locally. We are now being invited to consider ways in which we can use our research skills to contribute to our community.

This aspect of engagement does not come easily to academics in the 21st century. We tend to think internationally. We collaborate with colleagues in other countries; we strive to have our work published in international journals; we attend conferences around the world — the more exotic location the better. However, an international reputation does not lead to a local reputation. A few mathematicians in other parts of the world may be familiar with my work, but the local high school mathematics teacher may not know I exist!

Thus, the two factors that have shaped this work, are the central importance of the education of our students, and, the importance of a regional university's contribution to the local community.

3 The setting

Bendigo Health Care Group (BHCG) is the major provider of health care facilities in central Victoria. It provides services for acute care, mental health, and rehabilitation and aged care. The Collaborative Health Education and Research Centre (CHERC) is a department in BHCG that is devoted to education and research activities. CHERC has about 15–20 staff most of whom have a background in nursing and now devote their time to the teaching and research in CHERC. In 1998, I was offered the position as Honorary Senior Research Fellow at CHERC. These positions are offered to senior people, usually academics, who have skills that complement the skills in CHERC. La Trobe University approved this involvement and I try to spend half a day each week at CHERC. During the second half of 2000, I took study leave and spent the entire period at CHERC working on projects of mutual interest.

The aim of this paper is to describe how this involvement with BHCG has contributed to my work in teaching and research at La Trobe University. Also, I will attempt to extract some general principles that influence the success of community-university interaction.

4 Sample size

The first project at CHERC in which I became involved required an estimate of sample size for a study of patient satisfaction. I will say more about the assessment of patient satisfaction in the next section: here I will focus on the question of estimating sample size.

One of the most frequently asked questions that researchers put to statisticians is: How large should my sample be? If the study has a complex design, this question can be difficult to answer. However, in this particular case, the exercise was simple.

Patients would be invited to answer the question: *Overall, how would you rate the care that you received as a patient of this hospital?* with possible answers being on a Likert scale:

1 (= very good), 2 (= good), 3 (= fair), 4 (= poor) or 5 (= very poor).

The question posed to me was "How large should the sample be to estimate the mean rating?".

This is a simple question and most elementary statistics books provide the answer to this question. To find a 95% confidence

interval of length 2m for the average rating, you require a sample of size

$$n \geq \left(\frac{1.96\sigma}{m}\right)^2$$

where σ is the standard deviation of ratings. In this situation it may be sensible to choose m = 0.25 say; this will give us an interval of length at most 0.5.

What is σ? One might be prepared to take a stab at estimating the average rating on a scale of 1 to 5; but what would be the standard deviation of these ratings? Text books offer various answers to this question.

De Veaux and Velleman [5, p. 442] suggest that one could conduct a pilot survey to try out the questionnaire and use the results of the pilot study to estimate σ. However, this approach provides only an estimate of σ. It also leads to the question: *What should be the sample size in the pilot study?*

Mendenhall *et al.* [11, p. 320] provide an answer that goes like this. Suppose that the variable we are measuring has a normal distribution. Then we would expect about 95% of the observations to lie in a range of length 4σ. So estimate the range that would contain almost all the values you expect and divide it by 4. (Using a similar line of argument, Weiers [19, p. 333] suggests that you divide the range by 6.) These methods also give only a rough and ready estimate of σ. In the case of a sample survey such as the assessment of patient satisfaction, the variable being measured takes only the values 1, 2, 3, 4, 5 and definitely does not have a normal distribution.

Freund [6, pp. 269–270, Example 11.3] suggests that σ could be estimated from previous studies; Burns and Bush [4, p. 381] state that "we have to rely on some prior knowledge about the population". However, this method also leads to rough and ready estimates. Anyway, in the patient satisfaction study, we had not carried out such a study in BHCG before and so there was no previous study of direct relevance.

Some exercises in text books simply tell students to assume that σ has some specified value. (See, for example, Freund [6, p. 276, Exercise 11.8] (2004, p. 276, Exercise 11.8), Johnson and Kuby [9, p. 230, Exercise 8.30].)

So, overall, texts do not offer satisfying answers to this important question.

Now there is a simple answer that is guaranteed to be correct for the Likert scale setting. The responses of the patients would be most variable if 50% of them answered "1" to the above question and 50% of them answered "5". In this case, the standard deviation is 2. Since this is the worst case scenario (that is, the scenario with the most variability), we can be certain that, in general, $\sigma \leq 2$. If we choose m = 0.25 then we obtain from the above formula $n \geq 246$ and this is not a huge number of patients for a hospital to survey. [13]

The argument in the previous paragraph is mathematically simple and works particularly well in developing a sampling plan for survey. It is surprising then that it is mentioned rarely in text books. So far, I have found it in only Gnedenko [7, p. 188, Exercise 9] which is not an elementary text book, and Aaker *et al.* [1, pp. 410–411] which is a text on marketing research rather than statistics. I incorporate this useful detail in my lectures on statistics. It is remarkable that it takes so long for relevant developments to penetrate undergraduate text books. Anyway, this small example is one instance of how my involvement with BHCG led me to reconsider a point that arises in teaching statistics in the university.

A mathematician may wonder about what happens if we make additional assumptions about the distribution of the variable being measured. Can we have better estimates of σ that would lead to smaller sample sizes? This question lies in the study of mathematical inequalities. As usual, when one scratches the surface of the literature, one uncovers a wealth of material, and the

paper chase is on; see Seaman and Odell [16].

5 Estimating proportions

A standard problem in courses on elementary statistics is to test a hypothesis about some proportion p associated with a population. We want to test the null hypothesis $H_0 : p = p_0$ against an appropriate alternative hypothesis.

The standard approach outlined by elementary text books requires that certain assumptions be met. For example, the sample size n must be suitably large; we also require both np and $n(1-p)$ to be larger than some minimum value: Johnson and Kuby [9, p. 387] and Freund [6, p. 333] recommend 5 as the minimum value; De Veaux and Velleman [5, p. 349] and Moore [14, p. 435] recommend 10 as the minimum value. (Fortunately, students tend to buy only one text book!) In essence, these are saying that n must be large and p cannot be too close to either 0 or 1. All this depends on the central limit theorem – a topic that is too advanced to explain fully to most undergraduate students in a first course in applied statistics. So presenting this idea, without adequate explanation, is not satisfying for the teacher or the student.

My work at BHCG led me to a situation in which one doctor was doing some research on a particular rare medical condition. In this problem p represents the proportion of people in the community with this condition. Since the condition is rare it is difficult to find many people with this condition and hence to get n to be large; furthermore p is small. On reflection, one can easily imagine that this situation often arises in medical statistics.

It is not difficult to deal with this problem especially these days where packages such as `Excel` calculate binomial probabilities exactly. One can control both the size and the power of the test exactly. This made me wonder why we teach students about the complicated approximation referred to above at all. After all, its main use is to calculate only an approximation to an answer that we can calculate exactly with `Excel`, and the explanation is complicated with unnecessary and inexplicable rules of thumb.

This experience at BHCG has made me reconsider many approximations that are encountered in elementary statistics courses.

6 Assessing patient satisfaction

Hospitals are keenly interested in assessing the levels of satisfaction among patients. Clearly patients do not want to be in hospital in the way that a customer wants to be in a theatre or resort. Furthermore, patients are unwell (except for maternity patients) and not in a mood for assessing their own level of satisfaction. The literature on patient satisfaction is enormous but we will mention only a few publications. The book by Strasser and Davis [17] is a practical, readable account of key aspects of the subject.

In 1997, the Victorian Department of Human Services conducted a state wide assessment of satisfaction of patients in public hospitals. In response to this exercise, BHCG decided to develop its own in-house procedures so that it could monitor patients' attitudes, CHERC was asked to develop the process and I became involved in the project. Some results are reported in [12].

This experience has made me aware of the role of assessment of satisfaction in quality management. So I have often incorporated this field of study as the context for exercises in my classes. Here is an assignment question from my notes on *Statistical Methods* as presented in our off-shore program.

A bank employs a management consulting firm to carry out, each year, a survey of its customers in order to measure customer satisfaction. Each year, the company selects a random sample of $n = 100$ *customers and asks each customer: Are you satisfied with the service provided by the bank?. In the 1997 survey, 65% of the customers*

said "Yes"; the rest said "No". In the 1998 survey, 70% of the customers surveyed said "Yes"; the rest said "No". Is this evidence sufficient to conclude that customer satisfaction has improved?

Thus my experience with the analysis of health care data influences the contexts of many problems that I set for students.

Furthermore, the experience with the analysis of patient satisfaction data made me aware of the potential applications of multivariate analysis in quality management. Time and time again, I have seen studies that are based on the analysis of data obtained from questionnaires and the final reports consist of pages and pages of histograms that show the distributions of responses for each item on the survey instrument. Multivariate analysis of the data is often absent. Hence, in a recent revision of the Bachelor of Business program at La Trobe University, we introduced a statistics major that includes Multivariate Analysis as a compulsory final year subject; in turn, this contributed to the need for Business students in the majoring in Statistics to study Linear Algebra. Hence, my experience with the analysis of patient satisfaction data at Bendigo Health Care Group contributed to these curriculum developments.

7 Elementary statistics in Business courses

In this section I will give another example that illustrates how my experience at BHCG has altered my view on course development.

In working with colleagues at BHCG, I have often met professionals who have a degree in some area and have successfully completed a standard first level statistics subject during their university studies. Even though their present job may involve some quantitative aspects, it certainly does not involve inferential statistics. I now wonder if it is appropriate to make inferential statistics the centerpiece of any compulsory first year statistics subject in a business degree as is the practice in many universities.

I reckon that this material is never used by many accounting graduates who work in small practices, banks or government departments. I wonder whether Business graduates with majors in areas such as human resource management, international business, tourism and hospitality or information systems are likely to make any use of inferential statistics. To be sure, Business students who plan to major in disciplines such as marketing or economics or go on to postgraduate studies may need to know about t-tests, p-values and the like; but is it necessary to subject all Business students to this in their first year?

Now I do accept that business disciplines are far more quantitative than they have been in the past, and it is reasonable to insist that all first year Business students undertake a suitable subject in mathematics or statistics. So, let me suggest a suitable compulsory first year statistics subject for Business program in an Australian university.

The name of the subject could be *Australian Statistics*. In this subject students would encounter key statistical measures of Australian society. Demographic, economic, industrial, and social measures would be considered. They would learn about definitions of statistics and their limitations, sources of data, data collection methods, time series, trends and index numbers. A special feature could be discussion of regional statistics and community profiles. Although the subject would be focused on Australian statistics, international comparisons may be included. The subject would lead naturally into discussion of descriptive statistics, statistical distributions, sampling and hypothesis testing. (Although inferential statistics would not be the core of the subject.) *Australian Statistics* would assist students to develop a fresh perspective on the nation and its people – a statistical perspective. I imagine that Business students would find their experience in this subject useful in many subjects in

their degree because it would provide them with some knowledge of Australian data on which they could base arguments. International students studying in Australia would also learn something about the country as an integral part of their studies.

8 Modelling patient flow

Understanding how patients flow through a hospital is an important topic in quality management in health care. There are many ways in which mathematics is being used to improve our understanding of congestion in hospitals. One can used techniques such a simulation, advanced methods in statistics and operations research. For a recent exposition of a variety of mathematical approaches, see [8]. Currently, I am involved with a team of colleagues who are investigating how these approaches can be applied to BHCG. We are interested in applying mathematics to improve our understanding of the ways in which patients flow through the system at BHCG. Progress was reported in [10]. There is a direct link between this research investigation and certain topics in the subject *Pharmacy Mathematics*; both employ compartment modelling. This example illustrates how a question at BHCG leads to a mathematical research project which in turn is connected to topics involved in teaching.

9 General aspects of community engagement

I find the work with BHCG exhilarating. When I tackle a problem at BHCG, I consider any approach that could be useful – irrespective of whether or not I know much about the approach itself. I tend to be more prepared to seek ideas outside my own comfort zone that I would have previously. (Can neural networks or support-vector machines help me with patient satisfaction studies?) To cope with the risks associated with going beyond one's own expertise, I readily call on help from experts in a wide variety of fields to assist. Colleagues from other disciplines are keen to participate, and, it does help to increase the web of connections between the university and the community.

The success of community-university interaction is based on partnerships. I have been fortunate that La Trobe University and BHCG allow me to move easily between the two institutions. This cooperative, indeed encouraging, spirit is one key to the success of such interactions. Thus, an academic who is interested in being involved in such work needs to identify a suitable partner and get the support of both the university and the partner. Perhaps much of this could be achieved through personal contacts.

On the other hand, being involved with an organisation off-campus makes demands on one's time. I believe that it important for me to spend time at BHCG on a regular basis; I think better about health issues while I am there. Hence I endeavour to spend half a day a week at BHCG. Often, people alert me to interesting problems simply because I happen to be there. However, my involvement in two organisations complicates my timetable. Fortunately, the cooperative spirit between the two organisations plays a role in facilitating the work.

When one changes direction in an academic career, there is a delay in one's publication rate; an enlightened university will appreciate this fact. Also, one should be aware that, although this sort of community involvement can enhance an academic's work in teaching and research, it could easily develop into providing routine advice that would not contribute much to an academic vocation; by the same token, the involvement could also lead to a new vocation!

10 Conclusions

In this paper I have described how my experience from being involved with Bendigo Health Care Group has contributed to my work as an academic mathematician. By discussing particular health care projects, I have outlined how they influence the way I think about teaching, and the way in which

this experience prompts new ideas in teaching and research. Perhaps this assists students to develop a "realization that the statistical skills they are learning can be used to help people" [18, p. 143]. It is very satisfying to be able to relate ideas that crop up in class to direct experience with a local, highly respected organisation in our community.

Thus, the experience also assists me to "close the loop" between teaching and research. It is pleasing to be able to show undergraduate students where research work fits in with their education.

This leads me to the general conclusion that academics in any discipline could be involved in this sort of work if they choose. If I, with a background in theoretical mathematics, can enjoy it, then scholars from other disciplines could too! However, this work is not everybody's cup of tea and, I believe in the old-fashioned idea that academics do their best work when they have the maximum amount of freedom to define their own involvement in teaching and research.

Minister Nelson asserts that "more encouragement should be given [to universities] for building partnerships with other institutions, businesses, research agencies and communities." [2, p. vi] By focussing my efforts on projects that are of interest to BHCG in particular, I hope to contribute to strengthening links between two prominent organisations in Bendigo, namely Bendigo Health Care Group and La Trobe University. Building such networks between universities and organisations will be more successful if academics assist their vice-chancellors in this effort.

Finally, universities have to work hard at making a contribution locally just as they do to make a contribution internationally. One might say that these two directions are orthogonal. In this paper, I have tried to show that our discipline can assist in these efforts.

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