USING PROJECTS TO ENCOURAGE STATISTICAL THINKING

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For the last decade, internationally, there have been calls for reform in statistics education. These calls for reform have emphasised that teaching should use real data, active learning, technological tools and statistical thinking. A way of incorporating all these aspects into a statistics course is through the use of projects. This paper will summarise the calls for reform and the use of projects by others along with projects that have been used by the author in courses that he teaches in experimental design and multiple regression. The emphasis here has been to include a full problem solving cycle, from problem definition to communicating findings and reflecting on the process. Feedback from the students will be included.

ISSUES RAISED IN CALLING FOR REFORM

Teach Statistical Thinking rather than Statistics.

The computational, descriptive and inferential statistics that used to be the heart of most statistics courses is one part of the statistical thinking process. The call is to teach a complete statistical problem solving strategy. The emphasis is to be on developing a way of thinking that solves problems by collecting and analysing data.

Chris Wild (1994), in a paper on 'Embracing a wider view of Statistics' wrote, "When statistics becomes clearly embedded in people's minds as being concerned with *investigation* rather than simply *calculation* (or worse still, mere cataloguing of data), there can be no room for doubts about the relevance of the subject" (p. 163). Graham Wood (1998) at ICOTS-5, in speaking of 'Transforming First Year University Statistics Teaching' says, "The first principle which should underly the transformation is to centre teaching around statistical thinking" (p. 167).

Chris Wild and Maxine Pfannkuch in their comprehensive paper on 'Statistical Thinking in Empirical Enquiry', explore in depth the thought processes involved in statistical problem solving in the broad sense, from problem formulation to conclusions (Wild & Pfannkuch, 1999). A simple model of statistical thinking is the Deming/Shewhart '*Plan-Do-Check-Act'* cycle. A summary of Robert Hoggs often quoted paper (Hogg, 1991), could expand this strategy, and PPDAC, to include the steps: Identify the problem, Design a method of data collection, Collect data, Summarise and Analyse the data, Draw conclusions, Communicate the findings, Reflect on the process. The iterative aspect of the statistical thinking process can then be emphasised by representing the process as a cycle.

Always use Real Data.

Statistics had its beginnings historically in a wide range of disciplines where it had its roots firmly in real data: Sociology, Nursing, Agriculture, National Statistics, Astronomy, Engineering, Quality Control etc.In the mid 1980s the Quantitative Literary Project in the USA, organised by Fred Mosteller, had as two of its summary points: 'Data analysis is central' and 'Real data of interest and importance to students should be used' (Scheaffer, 2001).Graham Wood in the paper quoted earlier, (Wood, 1998), says 'Continually apply statistical thinking in the context of real problems and never on anything else.' Chris Wild and Maxine Pfannkuch, in their paper referred to above, emphasise the need to be continually shuttling between thinking about the statistics and the context (Wild & Pfannkuch, 1999).

Data sets with real contexts are now readily available from a wide variety of sources. Students often collect their own data from areas of interest, and this is the preferred source as they are then personally involved in the issues. Web resources have data sets with contexts in many subject areas. Textbooks and software come with many data sets.

Make Use of Available Technology.

It is the revolution in technology that has allowed the emphasis to be taken off the computation. This has allowed what is the ideal of focusing on the whole process of statistical thinking to become practicable. Minitab (2000) is widely used as statistical software for education; other suitable packages include Fathom (2000) and Interactive (2000).

Integrated packages such as S-LINK (Statistics Learning Information Network Knowledge) use network technologies and multi media components to assist in the teaching of statistical theories (Jung & Gun, 2001).The internet is a huge resource of data, java applets, activities, hypertexts, theory and teaching ideas (Mulekar, 2000).

Active Learning

Beth Chance, addressing the international conference Technology in Mathematics Education (TIME2000), in summarising where statistics teaching is at, said ‘Calls for reform emphasise that instruction should fully incorporate genuine data, technological tools, and active learning’ (Chance, 2000).Angelo (1993) emphasises that students’ learning increases dramatically if they are actively engaged in demonstrations of important concepts.In the paper ‘How Students Learn Statistics’ (Garfield, 1995), Joan Garfield discusses, amongst other things, the way that students learn by active involvement in learning activities. Steinhorst and Keeler (1995) develop modules that use active learning to enhance the teaching of statistical concepts.

Using Projects

Projects give the opportunity to incorporate all of the features that have been discussed above. My students use Minitab to make use of the power of technology. For each task they collect their own data. This means that they are using real data and are actively involved because they have chosen the subject and have to make all decisions about its analysis. Some projects are done in groups, with the advantage of students being able to bounce ideas off each other and having to argue their case to arrive at a decision. One disadvantage of groups is the problem of getting time together – my students live all around the city and some of them work full time and only come in for my evening class.

I have often in the past used assignments where I supplied a data set and asked the questions. The students did not have a lot of background to such problems and therefore were not particularly interested in them. Now they choose their own context and must begin by asking a question. They then have to design a way of collecting data that will allow them to get some insights into possible answers to their questions. Data collection, data display, analysis, conclusions, communicating the results and reflecting on the process follows. In this way they are able to complete the whole cycle of steps in the statistical thinking process. I discuss this statistical thinking process at the same time as I introduce the first assignment, so that the process is linked to a specific task.

The students in this course are Applied Science students. Ideally the data is related to their science studies, but collecting science data is usually too time consuming and I don’t want the data collection to dominate the time – the activity is about problem solving rather than science. However the tasks are defined under strict constraints so that the data is appropriate for the type of analysis required and the data structures are identical to those they would get from similar science problems.

There are many papers discussing these issues most of which also list ideas for projects (Fillebrown, 1994; Anderson-Cook, 1998; Love, 1998; Smith, 1998). Most project ideas relate to introductory courses. I found it much more difficult to find ideas for second year university courses.

Task 1 Experimental Design

The task requires a continuous response variable and either two categorical predictor variables with several levels each, or several variables at two levels each. This ties in with the teaching of Experimental Design and ANOVA. A list of suggested project topics is supplied.

A very successful experiment involved washing a variety of stains from material with a variety of different detergents. An interesting feature of this experiment was that they had to devise a measure of cleanliness of the washed material.

Another group germinated mustard seed with varying amounts of light, water and different growing mediums. The issue of how they would measure the response was something they had to grapple with and this is when they really appreciated working in pairs.

Some made darts of different designs and with different weights of paper and measured the distance they flew. The students were forced to reflect on their ability to project the darts at a consistent speed. The interactions were interesting for this data (Mackisack, 1994). One group timed people skipping on different feet and with ropes of different weights. This group had a very non-homogeneous set of people so learned something about confounding and small samples. One group popped pop-corn in different oils and different sized pots (Mackisack, 1994). Other ideas:

- Measure reaction time using dominant and non-dominant hand for males and females, students and middle aged. For software to measure reaction time and a paper about its use (see Anderson-Cook & Dorai-Raj, 2001).
- See how the blending time of soy beans is affected by the blending speed, the amount of water, the temperature of the water and the soaking time before blending (Hunter, 1977).

Task 2 Multiple Regression

I found it much more difficult finding practical tasks suitable for multiple regression that could be done reasonably quickly. Most groups chose to predict the price of a car of a chosen make, model, year, mileage, engine size and number of doors. They collected data from 100 advertisements. Then they went about the task of building a multiple polynomial regression model from their data. Real data is not always pretty, so they had to make decisions about outliers and how to interpret residual plots. A useful model then had to be constructed. Precise estimates were not gained, but the exercise gave the opportunity for excellent learning. The engagement in the activity was very high because often it was their own car whose value they were trying to estimate.

One student did a similar exercise predicting the price of a second hand computer given its specifications. Other suggestions: Predict peak flow meter readings given age, gender, height, weight and fitness level. How accurately can you predict the weight of an adolescent given age, height, gender, arm-span, foot-length, waist, neck-circumference, etc?

A Variation Of The Project

A successful variation has been to supply some data with a context. An example is the Peak Flow data (Binnie, 2002). Having examined the data and its description, the students pose questions that interest them about the data. There is a wide range of appropriate questions about this data including single sample-t, paired-t, independent-t, testing correlation and testing normality. This gives the opportunity to use all steps of the statistical problem solving strategy except data collection. The advantage is that large data sets can be used that would otherwise be too time consuming to collect.

FEEDBACK FROM STUDENTS

- 'I learned a lot from the assignments, more than from the labs. Working with a partner we could muddle along until we worked it out.'
- 'The two assignments were really useful, collecting my own data then working through the analysis made it seem much more real than just plugging numbers in an example. It made me think more about what I was doing and why I was doing it.'
- 'I think the topics I did assignments on I grasped a better understanding of and they stuck in my mind better.'
- 'I don't really enjoy doing presentations but I know it is good practice for me to do them, and I did actually enjoy and learn a lot from listening to others' presentations. So maybe each assignment could have presentations from some of the class and the rest could do others.'
- 'Doing our own data sets makes us think more about it and therefore understand it a little clearer.'

CONCLUSIONS

The use of projects was very helpful in assisting the learning of the students. Their active involvement in the tasks forced them to think and enhanced their learning. The use of real data of their own choice motivated them because they wanted to know what conclusions they might come to. The use of technology was implicit because all the data analysis was done on Minitab and the report written in Word. Without the projects their understanding of the process of problem solving using the statistical thinking strategy outlined would have been very theoretical.

Next semester I will use three projects. Each student will do one presentation during the semester. I will supply the mark scheme with the project and this mark scheme will give credit for each of the stages of the statistical problem strategy.

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