PEDAGOGY, CURRICULUM AND REFLECTIVE PRACTICE: TOWARD A MODEL FOR IMPROVING STATISTICAL EDUCATION

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Traditional methods of teaching statistics are often viewed as dismal failures. Attempts to improve statistical education often focus on changing pedagogical techniques and curriculum. Strategies to enhance the learning of statistics have included, amongst others: linking statistics to real-world situations; using spreadsheets; the web; statistical learning packages; designing surveys; acting as a research collaborator with students; or student projects. Curriculum attempts to improve statistical education have involved shifting the emphasis from, for example, statistical inference to exploratory data analysis. Rarer still are calls for action research methodologies common in the field of education to improve our understanding as teachers of the impact of our actions in the classroom and how those actions relate to theories of education.

INTRODUCTORY SCENARIO

Imagine attending a Statistics conference. The speaker at the front of the classroom identifies the paper she is presenting *Pedagogy, Curriculum and reflective practice: toward a model for improving statistical education.* You are in the correct room, this is the speaker you have come to hear. The speaker puts on some music and you and your colleagues are directed through an dance regime. You participate with great gusto and mirth. When the music ends the speaker sits down; that is the end of the talk.

The scenario described is a variant of a Conference dinner address at the International Study Association on Teacher Thinking (1997). As the 'talk' progressed questions arose, "what is she doing?" and as I too began the dance "how do I do this?" and finally "why are we doing this?"

In the asking of these questions there was a movement from *other* "what is she doing?", to *self*, "how do I do this?", to *community*, "why are we doing this?" This questionning sequence characterises aspects of learning statistics. It is a discipline that belongs to the other, the teacher. This is a subject, which for many is not taken by choice. The student must find out how to do what is required but it is only at the point of understanding the "why" of statistics that they can join the community of statisticians.

ATTEMPTS TO IMPROVE STATISTICAL EDUCATION

The comments in this paper are drawn from reflection undertaken during the writing of a doctoral dissertation which examined ways to improve statistical education. The project began with making explicit the teacher's statistical expertise through the unpacking of other experts' knowledge. Subsequently a statistics curriculum based on the theme "Statistics is a study of variation in the world around us" was developed. This was then implemented in three small groups, using experiential learning principles. Experiential techniques were retained through subsequent implementations. The statistical theme was further developed with all statistical activities designed to elucidate aspects of variation. Exercises to make explicit students' approaches to learning were incorporated in later versions of the course. The use of reflective teaching practices directed the changes which brought about improvements in the statistics classroom. Strategies to enhance communication, such as reflective homework, enabled the teacher to focus on the manner in which students were constructing their knowledge and to respond to characteristic patterns of thinking.

CHANGING PEDAGOGICAL TECHNIQUES

To understand the focus on changing methods of teaching to improve learning we can return to the dance metaphor. Just as the speaker through tone and manner engaged the audience in the dance there needs to be an engagement of the student in the statistics classroom. Some members of the audience may have got up and left the dance, just as we know students may leave the lecture theatre and not return. Others may stay and mindlessly perform the dance routine, never asking "why?" Changing pedagogical techniques has been one approach used to engage students in the learning of Statistics. Strategies to enhance the learning of statistics have included, amongst others, using spreadsheets or other statistical software, including the use of real problems and data sets, using the web and/or other statistical learning packages, designing surveys, teachers acting as research collaborators with students, or having students undertake projects and so utilise data they have collected. Alternately, changes in method may be described by drawing on many and varied educational theorists who propose pedagogies such as activity based learning(Scheaffer, 1994; Shaughnessy, 1977) , experiential learning

(Anderson, Boud and Cohen, 1995) or problem based learning (Boud, 1985) in order to improve learning.

The choice of pedagogical technique, for example using the project approach, may also coincide with choosing a method that engages the student in dealing with the issues that confront statisticians and researchers. For example, Hogg (1991) described the issues which student teams encountered in project work. “Projects give students experience in asking questions, defining problems, formulating hypotheses and operational definitions, designing experiments and surveys, collecting data and dealing with measurement error, summarizing data, analysing data and communicating findings, and planning “follow-up” experiments suggested by the findings.” In the metaphor of the dance, working through the process of undertaking research could be considered to be “how do I do this?”

When the issue as to what we wish to engage students in or with is pushed still further there are further possibilities. It may be that classroom activities and learning are structured so as to connect current activity with past experience. It may be that statistics topics are chosen so as to connect students with their chosen discipline or to their future profession. Both are admirable aims.

THE DEVELOPMENT OF GENERAL THINKING OR LEARNING SKILLS

To a lesser extent statistical educators tackle the issue of developing general thinking and learning skills, although this approach to improving statistical education may relate to teaching which emphasises statistical thinking. Porter, (1996) discussed a variety of techniques and activities used to develop students’ metacognitive awareness of themselves as learners whilst meeting the rigours of learning the statistics curriculum. In so doing Porter found an improvement in both attitude and student performance.

IMPROVEMENTS THROUGH CHANGES TO THE CURRICULUM

From a statistical point of view the engagement of the students with *fundamental* statistical concepts is of major concern. Statisticians themselves are not in accord with what they perceive as fundamental statistical ideas or perspectives (Hawkins, 1997) . For some it is probability (Lindley, 1990) , questions and answers (Speed, 1986) , variability (Robinson, 1997) , statistics as a process (Wild, 1994) . For others (Cox, 1997) it is a combination of ideas (the mathematics of probability, the general principles for the design of investigations and the general principles for the analysis and interpretation of investigations) provide the perspective. Even more common than these perspectives

would be the ‘descriptive statistics- probability - inference’ perspective utilised in many introductory statistics subjects (refer, Hawkins, Jolliffe and Glickman, 1992) . The description of key concepts for courses may be more expansive “Working with real data, all students are expected to understand the concept of sampling, design experiments, construct and draw inferences from data summarised numerically and graphically, and make predictions using curve fitting.” (Burrill, 1990) . How statisticians operate, modelling data, using exploratory data analysis rather than classical statistics, using resampling statistics may also provide core foci for courses. As (Garfield, 1995) suggests “statistics educators need to determine what it is they really wants students to learn.” Whichever perspectives are adopted as the underpinnings of Statistics, they should be capable of providing the “why” of what we do as statisticians. According to Novak and Gowin (1984) meaningful learning is engendered by connecting the “how” of what we do to the “why” or the principles underpinning what it is we do.

MAKE EXPLICIT WHY WE DO WHAT WE DO AS STATISTICIANS

Hogg continued his treatise on teaching through using the project approach “once the students appreciate the importance of understanding variability, they will recognize that statistical thinking can be used in everyday living...That is they actually may find that statistical knowledge is useful and that applications of it are alive and rewarding.” It is not clear from Hogg’s paper how this connection is made from issues encountered during the project to the underlying notion of variability. Bain (1990) alerted us as teachers to the value of making explicit our implicit understandings. In my own teaching, students readily adopt the “how to” of stepping through the research process and the issues it generates. However, the work does not end until students understand the “why” of issues. Sowey (1996) reminds us that this question can be answered at different levels. The “why” that I refer to involves *explicitly* linking these issues to variability. The questions we ask are about variation in data, the design is implemented to either control unwanted sources or manipulate variation, measurement itself is a potential source of unwanted variation, the manner in which data is sampled and the size of the sample is intimately connected to measures of variation, the graphical displays and summary techniques allow a clearer perspective on the nature of variation in data whether it be the centre, spread, distribution or some other feature of the data. Decisions about data are made in the context of natural variation. Linking to other levels of “why”, for example, providing a

real world perspective, are important, but linking to the fundamental *raison d'etre* of the discipline is essential to ensure meaningful learning.

Whichever pedagogical technique is chosen, in order for students to understand, they need to know more than the "how", more than how to proceed with research or how to calculate formulae, they need to know "why". Understanding what we do from the perspective of asking questions about, controlling, manipulating, displaying, measuring or making decisions (incorporating probability) about variation in data allows me as a statistical educator to provide a coherent "why" of what we do as Statisticians. One of the challenges for statistical educators, whichever perspective they ultimately adopt as representing fundamental statistical ideas, is to provide a coherent, conceptual explanation of why we do what we do as statisticians.

UNDERSTANDING STUDENT CONCEPTIONS

Marton and Ramsden presented the view that "learning should be seen as a qualitative change in a person's way of seeing, experiencing, understanding, conceptualising something in the real world - rather than as a quantitative change in the amount of knowledge someone possesses...Learning techniques and instructional strategies are inextricably linked to subject matter and students' perceptions." They consider that "unlock[ing] the door to better teaching and course design" requires a third approach, namely, "an emphasis on students' conceptions and perceptions, and learning about student thinking...If we want to change students' understanding, we have to deal with their present understanding in a methodical way."

TEACHER REFLECTION

Teacher reflection, is more than thinking about what transpires in the classroom (Bengtsson, 1995; Eraut, 1995) . It involves processes whereby teachers are able to gather feedback from students. The feedback relates to any aspect of the learning process:

their understanding of statistical concepts or the affective factors which promote or hinder learning. This might include:

- external evaluation, but if this is at the end of the course it may be too late.
- reflective homeworks. One successful approach in my work has been to ask students to reflect upon what has transpired in class and in writing to apply the

statistical ideas in another context. Students gain full marks for the attempt, their reward is feedback. The aim of these homeworks is to prepare students for a final assignment which is marked for quality and is worth a substantial component of the assessment marks. Students often submit more of these homeworks than are required.

- commentaries on learning. Students may also be asked to make observations about the processes the groups used to complete activities, processes which may effect statistical decisions arrived at.
- concept mapping of ideas (Novak and Gowin, 1984) is also a useful technique for identifying how students are structuring their ideas.

IMPROVING LEARNING: CONCLUSIONS

To further improve the learning of statistics it is time to consider changes to the curriculum so that the "how" of what we do is connected to the "why" and this involves statistical educators in making explicit their understanding of fundamental statistical ideas. It also requires that more attention be paid to the conceptions of our learners and how it is that they best learn.

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