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Completing the Circle: Researchers of Practice in Statistics Education

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Research in student learning can be based on a theoretical framework, observations of students' learning, the products of this learning, and students' own conceptions of the subject and of learning. In the final analysis, such investigations have a clear purpose—to improve student learning. We report on using the results of research into student learning in statistics to improve the learning environment in a university class on regression analysis. We believe this is an effective method of becoming "researchers of practice" in statistics education.

Recently, a call has been made to integrate research and teaching within a new milieu in which the practitioners engaged with research, teaching, and learning—namely the researchers, the teachers, and the students—come together in a collaborative relationship (Brew, 2003). Although the call is recent, the practice of developing, planning, and implementing it in this new setting is not. University academics have the dual role of teacher and researcher; these roles, however, are often seen as separate areas of engagement. As teachers we have the opportunity to engage in scholarly reflection as we carry out our work (Brookfield, 1995). In a classroom context we 'reflect-in-action' (Schon, 1987) and these reflections lead to timely change within that context. Our reflection-in-action becomes 'reflection-on-action' as soon as the class finishes and we begin to plan our next sessions. This approach is fundamental to the scholarship of teaching (Boyer, 1990; Trigwell, Martin, Benjamin, & Prosser, 2000) and results in the development of curriculum from an informed and practical frame. Another approach to integrated research and teaching/learning is to examine the learning situation from various perspectives. Wittmann (1999) focused his research on the exploration of students' mis-conceptions of a specific topic, assuming that there is a 'correct' conception known to the teacher, and identified the manner in which the learning situation was altered to try to change students' mis-conceptions. These approaches, however, do not address the issue of power relations in a classroom where students are acted upon through our teaching interventions and are rarely invited to become co-producers of knowledge. The adoption of an action research approach (McNiff, 2002) can help to redefine the learning/teaching situation through actively including students in the production of knowledge and the learning approach in the class, as shown, for example, by Carr (1995).

In this paper we describe how we have actively integrated our research findings—which focused on variation in the ways that our statistics students understand statistics and work as professional statisticians—with our teaching practice. Further, we describe how we have then used an action research cycle to encourage students to develop their awareness of statistics and professional work. We started our research as scholarly practitioners wondering how we could assist learners to engage with some rather complex statistical ideas. We adopted a phenomenographic approach as we explored variation in students' understanding of statistics, their understanding of professional statistical work, and the ways in which their current studies could be of use for their future careers. These findings were then extended into a new classroom learning environment where situations were set up to encourage students to explore their own conceptions of statistics, work, and learning using the outcomes from the previous study. These classroom explorations were supported by a careful reworking of the curriculum to help direct students towards more integrated and holistic conceptions. The focus of this paper is the description of the obvious outcomes of these interventions as evidenced through assessed work, this being an outcome that is available for analysis. Our selections from students' assessed work demonstrate what "critical aspects are discerned by the learner for the constitution of a particular way of experiencing" (Linder & Marshall, 2003, p. 272).

First Phase: Students' Conceptions of Statistics

Intrigued by the different approaches to statistics and learning that our students show, and motivated by the problems of statistics pedagogy, we carried out a study investigating tertiary statistics students' conceptions of statistics and learning in statistics. Our theoretical framework was phenomenography, a qualitative orientation to research that takes a non-dualist perspective and is often used to describe the experience of learning and/or teaching (Bruce & Gerber, 1995; Marton & Booth, 1997; Prosser & Trigwell, 1997). Learning and teaching are seen as a relation between the person and the situation that they are experiencing. Phenomenography defines aspects that are critically different within a group involved in the same situation. It is these differences that make one way of seeing the situation qualitatively different from another. Researchers conduct a series of in-depth interviews that allow enough scope for students to explore and describe their own experiences (Bowden, 1996; Dortins, 2002). The interviews are then transcribed and analysed as a whole. Using this method, researchers keep in mind the analytic focus and explore the question: "What are the qualitatively different ways in which a group of people experience a particular phenomenon?" It is the structure of these differences and the nature of the relations between them that become the *outcome space* and are described as *conceptions*.

In this initial phase of the research, we interviewed 20 students from two classes: a first-year introductory statistics class and a third-year class in regression analysis. All of these students were undertaking a degree in mathematical sciences, with possible specialisations in statistics, mathematical finance, or operations research, leading to professional work in these areas. The interviews were transcribed verbatim and formed the raw material for this initial study. Results from the study are reported in Petocz and Reid (2001) focusing on learning, Petocz and Reid (2003) focusing on the relations between learning and teaching, and Reid and Petocz (2002) focusing on conceptions of statistics.

In that study it was found that students' ideas of statistics form a hierarchy of six qualitatively different conceptions, defining the phenomenographic outcome space. These categories are labelled and described in detail in Reid and Petocz (2002), supported with illustrative quotes from students. They are summarised below, from the narrowest and most limited to the broadest and most inclusive, and are presented here to set the scene for the main arguments in the present paper.

Conception 1. Statistics is individual numerical activities. In this conception students' understanding of statistics is limited and fragmented. They see statistics as a sort of mathematics that involves using "boring calculations," "numbers," or "probability."

Conception 2. Statistics is using individual statistical techniques. In this conception students see statistics as individual techniques that can be used to look at data; for instance, graphing, line-of-best-fit, collecting data, and regression. As in Conception 1, students focus on fragments, but in this case fragments described in statistical rather than solely mathematical terms**.**

Conception 3. Statistics is a collection of statistical techniques. In this conception students describe statistics as a collection or set or "stockpile" of techniques that can be used to deal with data. Students are aware of a range of techniques (rather than just one, as in the previous conception). They often describe statistics by listing these techniques.

Conception 4. Statistics is the analysis and interpretation of data. In this conception students describe statistics to be about understanding, interpreting, and making sense of data; exploring relationships found in the data; and drawing conclusions about the data. Students describe statistics using the techniques characteristic of Conceptions 1–3, but view these techniques as part of a coherent whole, and aim to be able to analyse and interpret a complete set of data.

Conception 5. Statistics is a way of understanding real life using different statistical models. In this conception students view statistics as a way of understanding real-life situations using a variety of statistical models. This view is like Conception 4, as students aim to interpret a set of data and obtain the information they can from it, but here students focus on looking at a variety of models to compare their data with reality, and to test the appropriateness of their conclusions.

Conception 6. Statistics is an inclusive tool used to make sense of the world and develop personal meanings. In this conception students focus on understanding and making sense of reality using statistical methods. They use statistical methods to develop their own thinking, and to create new interpretations of data and life. Such students actively relate their statistical understanding to the data, the models, wider aspects of reality, and their own creative and critical thinking.

The hierarchic nature of the outcome space is due to the fact that students expressing the broader and more developed, integrated, or expansive conceptions seem able to use any or all of the characteristics of the previous conceptions, if their perception of the situation demands it. A student who talks about statistics as "an inclusive tool to make sense of the world" can also view statistics as analysis of data sets, and can discuss individual statistical techniques. The reverse, however, does not seem to be true. Students whose predominant view of statistics is a collection of individual techniques seem not to appreciate statistics as a way of understanding a set of data, and do not appreciate its use as an inclusive tool. Students aware of the broadest conceptions have access to a range of ways of dealing with statistics, and this affords them a flexibility of approach that is not available to students who hold narrower conceptions of statistics (Reid, 1997b).

These results can be examined from the point of view of student statisticians' perceptions of the nature of work as a statistician. Our previous research has shown that there is a relation between students' perceptions of their future work and the way they go about learning, and that this perception of work may be generic across disciplines. This relation, which we have called the *Professional Entity*, was first identified in the area of music (Reid, 1997a) and then extended to other professional areas such as statistics (Reid & Petocz, 2002), theology (Morgan, 1999), design (Davies & Reid, 2001), and law (Reid, 2003). It comprises three levels of understanding of the nature of professional work: *Extrinsic Technical*, *Extrinsic Meaning* and *Intrinsic Meaning*.

The Extrinsic Technical level describes a perception that professional work is constituted as a group of technical components that can be used when the work situation demands it. This focus on techniques corresponds with Conceptions 1–3 above. Statistics students who perceive professional work at this level consider that statistics is a collection of various techniques, and they are likely to focus their learning on the technical components of their subject.

The Extrinsic Meaning level describes a perception that professional work is about developing the meaning inherent in discipline objects, in this case the data sets in statistics. This focus on using data corresponds with Conceptions 4 and 5 above. Statistics students with this view of professional life are likely to try to discover the meaning in a set of data by appropriate statistical analyses, and to focus their learning on applying this understanding in some way.

The broadest level of the Professional Entity is the Intrinsic Meaning level. In this view students perceive that their professional work is related to their own personal and professional being. Statisticians create and develop their understanding of the world using statistical evidence in the form of data. This focus on meaning corresponds with the most inclusive Conception 6 above. Statistics students who consider that the statistical profession is an extension of their own being are likely to look for ways of integrating their learning with their own understanding of the world, and are willing to acknowledge that this integration may also change the way they look at the world.

Understanding the relations between the nature of the Professional Entity in statistics and variation in the way students understand the subject of statistics is an important tool for pedagogy. In addition, the research studies cited (particularly Reid & Petocz, 2002) suggest that there is a very close relation between the way that students (and teachers) perceive the profession of statistics and what they then think is critical to learn (or teach) in statistics courses.

Intentions for Change

When we first wrote about students' conceptions of statistics, we were surprised to get a "so what?" reaction. A reviewer of our first paper (Reid & Petocz, 2002) wrote: "The article only serves to increase the awareness that students of statistics have different levels of understanding. This was not a surprising finding—nor helpful." We were surprised at first, but then took up the challenge to explain the ways in which our findings could be used to effect pedagogical change and improvements in learning. Criticisms of phenomenographic studies have focused on this same point. Although it is philosophically interesting to know about variation in a particular learning situation, it is also practically important to use that knowledge. We extended our initial investigations to other aspects of students' conceptions. Having looked at their conceptions of statistics, we then examined their conceptions of learning statistics (Petocz & Reid, 2001) and their conceptions of the role of their teacher (Petocz & Reid, 2003). The question "so what?", however, still haunted us.

Various other aspects of the phenomenographic approach were then considered useful. It seems that students are generally unaware of the range of variation in their fellow students' conceptions, and making them aware of this range gives them the opportunity to broaden their views (see, for example, Ho, Watkins, & Kelly, 2001). It was felt that a class discussion early in the course, or a description of different ways of looking at their subject in a course hand-out, might provide the first opportunity for change. Given that this is commonly and successfully done in professional development courses with university lecturers (such as the Graduate Certificate in Educational Studies at Macquarie University), it seems reasonable that university students would also benefit from such an exploration. Indeed, some professional statisticians (such as Cleveland, 2001) recommend that discussion of pedagogy should form part of the curriculum for undergraduate statistics courses.

Reid (1997a, 2001) demonstrated that there are strong relations between teachers' conceptions of their discipline and the way that they go about teaching. She also showed that the learning environment that they set up in their classes can encourage those students who identify with the lower, fragmented levels to engage with their learning at a higher level. This can also work the other way, however, if a teacher sets students tasks that are best carried out using the more fragmented conceptions of learning (Reid, 2000). Thus the way that we set up the learning environment in our statistics classes can influence the conceptions of statistics that our students have and use. There is evidence in the transcripts of the interviews from the initial phase of the study that students who are aware of the more inclusive levels consider learning approaches that relate to the narrower levels if they seem to be more appropriate. There is also evidence that students can be encouraged by appropriate pedagogy to develop broader conceptions of statistics, as the following two quotes (given in Reid & Petocz, 2002) illustrate.

> Chris: Lecturers create them [assignments] in such a way that you have to understand your work before you answer, because most of the assignments that we're given are actually real situations, they're not just made up scenarios.

> Danny: [Why would you want to rote learn things?] People do, and they do really well. [Well why is that?] Because if you are doing a lot of maths stuff and you have to reproduce proofs they just learn it all and write it all out. [And you think that is superior to your attempt to understand the stuff?] No, no. It's not superior; I would rather understand it, but you can get better marks for rote learning.

These notions are also important in preparing learning materials and designing curriculum. Activities and assessment need to focus less on the statistical techniques and more on the meaning of the results obtained through statistical analysis, in the contexts of students' own learning situations as well as the context of the data investigated. Such ideas are exemplified in the laboratory exercises in Petocz (1998) and the book *Reading Statistics* (Wood & Petocz, 2003), which encourages students to read statistical papers, newspaper articles, and research in a variety of areas of application, with the aim of looking beyond the data to the real-life meanings.

Second Phase: Action Research

Action research has developed over the last two decades into an accepted valid form of enquiry that focuses on a critical approach to practice, undertaken by practitioners within their own practice rather than by researchers outside the practice. McNiff (2002, p. 3) writes: "research is as much about the process of answering questions as it is about the answers themselves." Action research is often described as an "action-reflection cycle" consisting of planning, acting, observing, reflecting, and changing. It has frequently been used in the educational arena, including the area of learning in the mathematical sciences (e.g., Ronnerman, 2003; Blazquez Entonado & Marin Garcia, 2002).

Having investigated a range of pedagogical changes that could be used to improve student learning, we can illustrate the effects that these changes had in our further teaching of the third-year course in regression analysis that was one of the sources for the students interviewed in the initial phase of our research (in 1999 and 2000). This class was taught regularly by one of us, and we have been testing and applying the results of our research here. The reports and illustrations in the following section were taken from two cohorts of students, the classes of 2002 and 2003. As far as we know these classes contained none of the students who were interviewed in the first phase of the study. The classes were run with one two-hour lecture/tutorial class and one two-hour computer laboratory class each week. Notes summarising the theory, discussing practical examples, and containing laboratory worksheets were part of the course materials given to each student, and a text by Cook and Weisberg (1999) was recommended for background reading, but not used explicitly.

The requirements of the laboratory classes were for students to investigate different problems and sets of data, applying the techniques discussed in lectures and using a range of commonly available computer packages. We developed these materials to include not only technical aspects of statistics, but also investigations of the sets of data as a whole and discussions of the meaning and implications of the statistical discoveries made. This integrates the main elements of the Professional Entity within the curriculum objects, that is, the discrete course components. The following questions concerning Burt's data on the IQs of twins (given in Cook & Weisberg, 1999), one reared by the natural parents and the other by foster parents, illustrate this aspect of the course:

- Does it seem that the coefficient of Natural can be taken as 1 and the constant as 0?
- Why is it reasonable to use Foster as the response and Natural as the predictor variable?
- What does your regression analysis suggest about the "nature versus nurture" controversy?

Early in each of these courses (in about the fourth of 12 weeks), we asked students to think about how they viewed statistics. Then we presented an outline of our research on students' conceptions of statistics and led a discussion of the different views that were exemplified by students' quotations. We pointed out that this research provided a justification for our regular comments on the importance of regression in their future studies and professional work, and our requests in laboratory worksheets and assignments for them to communicate the meaning of their results to a variety of different audiences. The students in the classes were a little surprised at first, but many of them said afterwards that they had found the ideas interesting. The initial presentation was followed up by further discussion at appropriate times during classes.

The effects of our approach can be observed in the artefacts of our students' learning—the written answers to laboratory, assignment, and examination questions—and also in the comments that they made in the end-of-course appraisals. Of course, the effects may also have been seen in their approach to further studies in statistics and to their future professional work as statisticians and mathematical scientists. This information, however, was not available.

Results

Answers to assignment questions indicated the range of ways students understand statistics and the role statistics plays in their professional perspective. The first assignment for the 2003 cohort included a question asking students to examine a set of economic data giving the cost of a *Big Mac* (in minutes of labour) in 45 world cities, together with various other economic indicators (see the text by Cook & Weisberg, 1999, for further information). Students were encouraged to work in groups, although a few preferred to work on their own. The first parts of the question asked students to download a new statistics package from the website given in the text and to carry out some suggested analyses, similar to but not the same as analyses in the text. The final part of the question was: "You have been asked to write a short piece for the university magazine. Use your investigations of the Big Mac data to write an article of a few paragraphs that may be of interest to the magazine's readers." The following responses to this part were obtained from three groups of students, noting that in Example C the students refer to themselves in the third person.

> (A) After taking data from 45 cities across the world as well as across economic strata we have concluded that the price (in minutes) of a Big Mac can be accurately estimated by the price (in minutes) of a loaf of bread and the average salary of a primary school teacher. The cost (in minutes) of a 10 km trip via the public transport system and the amount of tax paid on the aforementioned teacher's salary also contribute to the estimation, but if financial constraints are applied to the data collection process they can be left out without significantly affecting the accuracy of the model. We found that the estimation model was able to explain most of the differences in the price of a Big Mac between the cities. However, we believe that there may also be other factors which might explain the price as well. The study can be used by McDonalds to help them price their products when moving into new areas provided the data was collected from successful businesses.

> (B) Inefficiency Bites the Big Mac: *The Economist* conducted a study using data from 1990 –1991 in an attempt to use the Big Mac as a measure of inefficiency in currency exchange. The study evaluated the amount of work an average worker would need to do in order to buy a Big Mac and French fries. This was done on a per-minute basis and economic indicators were used to compare each city. According to economic theory, the cost of a Big Mac should be approximately the same in each country. Basically, our investigations found that this wasn't true. The first surprising finding was that teachers' annual salary and tax rate can be used to predict the cost of a Big Mac. It appeared that in countries where teachers had higher salaries and taxes, the amount of time an average worker needed to work in order to buy a Big Mac was considerably less. This may be the result of increased efficiency of workers in the light of higher pay and better conditions … The data set in *The Economist* highlighted the disparity of the Big Mac exchange, for whilst it is a truly global icon, it is not affordable to all. Maybe the true question is whether or not this disparity is just, or is it simply protecting the poor from the Big Mac?

> (C) In Lagos, a Big Mac is eaten with a knife and fork: Students studying regression analysis have been surprised at their findings when doing an assignment on the relative cost of a Big Mac amongst other things in different countries. Using a statistics program they were able to understand the cost patterns of different variables (such as bread, Big Mac, bus fare, teaching salary and teaching tax). One student commented "Lagos has a very high cost of bread and a Big Mac is ridiculously expensive. It takes the average person just over three hours to earn enough money to buy a loaf of bread. This would seem quite absurd to people

living in Australia and other developed countries. I guess people here just don't know how lucky and fortunate we really are." Another student who assisted with the assignment also commented "A person would have to work just over two hours in Lagos to buy a Big Mac. If the average wage in Australia was $10 then relatively a Big Mac would cost over $20. That's incredible. You might as well eat a Big Mac with a knife and fork at that price. What would have to be the state of the country for a person's income to be so low? Poverty is wide-spread and an ever increasing concern for all of us." The assignments done by the students enabled them to see outside their own country and analyse the situations of other countries in depth. They also gained knowledge on how to use different programs in order to sufficiently and critically analyse a particular set of data.

The exercise that the students were given in this part of the assignment was inviting them to discuss their statistical analyses in a broader context, to integrate their understanding of the techniques and the data with their view of the world, and to express a personal view. Some of them accepted the invitation, whereas others did not, and their writing illustrated the full range of conceptions of statistics. The students in Example A focused on the technical aspects of the assignment question, which they carried out very competently, with only the briefest suggestion of a use or application for their analysis. They reported their investigation in terms of the techniques used, implying Conception 3 of statistics, and the Extrinsic Technical level of the Professional Entity. The students in Example B focused on the set of data and the light it threw on economic theories, implying that they saw statistics in terms of Conception 5, and their future statistical work at the Extrinsic Meaning level of the Professional Entity. They also showed an ability to engage with the technical aspects of the work. The students in Example C focused on the meaning in the data, and expressed personal concern at the inequalities implied by the different costs of a Big Mac; their response implied a view of statistics consistent with Conception 6, and suggested that they viewed their future professional work as statisticians at the Intrinsic Meaning level of the Professional Entity. They, too, demonstrated an awareness of the characteristics of narrower conceptions elsewhere in their assignment, but were able to see them as components that added to their broader awareness of the use of statistics (see Reid, 1997b).

A similar range of ideas was seen in responses to a question in the second assignment for the previous 2002 cohort, where students were asked to examine data on the diversity of species in the Galapagos Islands (also given in Cook & Weisberg, 1999). The last part of the question stated: "Use the data to find a model that describes the diversity in terms of the other factors. Give details of your investigations and justify any assumptions you make. Summarise your results." The following fragments have been taken from the summaries given by different students or groups of students.

(D) In conclusion, it can be said that the best model found by our analysis is Y(E/T) = 0.652 – 0.000489 X2 using only the variable X2 in analysing the data, but with two data points removed. This model appears to be the most appropriate model to use, based on comparisons with other models with different variable combinations. It may also be noted that we believe that any model using X2 as a predictor variable would be a good model for the data.

(E) For both response variables it seems that log of area is the best measure for this experiment. Since the model with endemic species supports the idea that log of area is the best predictor, we may conclude that this model ln(Total species) = 2.829 + 3.956E-04 ln(Area) is the best which describes the diversity of all variables.

(F) In analysing the data, we found that area was the best predictor of both total species and endemic species on the islands of the Galapagos. However, in our multiple linear regression for (untransformed) total species, area was not one of the significant indicators but rather elevation and area of nearest island were, with elevation being the most significant. Our research reveals that the data given refer to the plant species on the islands. With this knowledge, it makes sense to us that area and elevation are good predictors of the total number of species and endemic species on the islands.

(G) Given both our final reduced models for the Galapagos data include only the variable log(area), it can be said that log(area) was the best predictor given the current set of data when measuring the diversity of species on an island in the Galapagos. Access variables, such as those relating an island to its proximity to other islands, proved to be of little relevance. This means that the size of an island is the most important factor when measuring diversity and has the strongest relationship with the total number of species on an island.

(H) Consider the physical features of each island. From my admittedly naïve experience with geology and geography from school, we can probably say that there may be some relationship between Area and Elev[ation]. Islands do not typically rise out of the sea like blocks of flats. A look at the scatterplot above shows a promising relationship between Elev and Area and not much else really. So let us see if we can build an estimate for Elev based on Area.

In (D) and (E) the students summarised their investigations by focusing on the technical aspects of the problem, implying Conception 2 or 3 of statistics. In (F) and (G) they focused on the data that they had analysed, implying Conception 4 or 5. In the extract (H), the student showed an obvious connection between his/her own experience and the statistical problem being analysed; this focus on the meaning implied Conception 6 of statistics. As before, it is assumed that the conceptions correspond with the levels of the Professional Entity, implying views about the nature of work as a professional statistician. In this assignment question, given in an earlier year of our development of this approach, the invitation to discuss and summarise results at the broadest level was less explicit, and it was telling that it was harder to find examples that could be viewed as representing the broadest conceptions.

It has to be said that these were only short extracts of the students' work, and that they were taken from the context of an assignment, where students may have felt constrained to answer the questions asked rather than talk about their views of statistics, as they could do in an interview. What these extracts show, however, is that some students were developing and demonstrating familiarity with the broader conceptions of statistics as a result of the preceding class discussions. We can reasonably draw the conclusion that the class discussions and the changes in the learning situation, particularly the invitations in the assignment questions, were having an effect.

The assignment solutions and the discussions in class about the assignments showed that students were active participants in an exploration of ideas, rather than simply being subjects of a research project. They were able to debate the notions that we put forward, and to begin to develop an appreciation for the broadest conceptions of statistics and the nature of statistical work within the context of their own learning. We as lecturers appreciated the opportunity of presenting our earlier findings and testing them out against the reality of the learning situation. We were particularly appreciative of the opportunity to expand the dimensions of what we ourselves focused on as teachers and assessors. For instance, we were surprised when a group of students who had previously carried out unremarkable conventional statistical analyses came up with the discussion in Example C. Our re-appraisal was confirmed at a later laboratory class, when we came across this group debating the ethics of separating twins for the purposes of scientific study (they did not know the full background of Burt's data at that point).

Some of the students' comments from the end-of-course teaching appraisals demonstrate how at least some of the students were engaging with the broader ideas that we had been discussing:

> Liked practice with all data around us, analysis on things that we know but not use, expected what we will do in real life.
>
> Assignments were challenging, left lots of room for thought.
>
> Particularly liked the assignment questions, it's very meaningful in the real world.
>
> Assignment 2 helped the whole idea of pulling all the knowledge together and applying it to a real problem.
>
> Lecturer preparing us for jobs in the field.

> Practically based, useful, but still relates to theory and the rest of the degree. Learn skills you can take away when you leave here.

> Explaining everything clearly, in a way that could be understood, although answers weren't given directly so we were made to think, which is very rewarding.

> The lecturer could show us the beauty of regression analysis.

These comments suggest that the students were aware of and appreciative of a pedagogical approach that emphasised the range of views of the nature of statistics, the connection between their statistical studies and their future professional work, and the practical and aesthetic aspects of the subject.

Conclusions

The students' learning outcomes demonstrated through the assessment tasks, our discussions during class about the different conceptions of statistics and professional work, and the students' evaluative comments lead us to believe that our cycle of research, development, change and evaluation has been reasonably effective. The characteristic of this project has been a multidimensional approach to research in student learning using naturalistic reflective practice, phenomenography, and action research. This multidimensional approach is important as it enables pure research to feed directly into learning and teaching environments, whilst at the same time focusing on the quality of the student learning experience. All too often classroom research is done for its own sake without this all-important integration with teaching. Inclusion of the students in the process of generating knowledge about their own understanding of learning, the subject, and their use of their education for work is an important step in changing the usual power relationships in the classroom. It enables students to take control of their own learning, and empowers them to determine the course and outcomes of their efforts. The application of the conceptions of learning and statistics, uncovered using a phenomenographic approach, enables students to take the next step of discerning the ways in which they experience variation within their own learning context. The importance of uncovering students' understanding of their learning, the subject they are studying, and their intentions for work, cannot be understated. Teaching development is often undertaken from the perspective of the teacher in charge and that teacher's own assumptions about the nature of knowledge, work, and curriculum is privileged above that of the students. On the basis of this study, combining phenomenographic and action research approaches, finding out the variation in students' thinking, and using that information with and for student learning seems to effect a greater change than simply tweaking the learning environment. A similar conclusion was reached by Ho et al. (2001). It is the combination of research approaches that illuminate different aspects of knowledge, and the use of these perspectives, that forms a powerful combination for curriculum development and changes in learning.

We believe that teaching and learning, and research in teaching and learning, can take many different forms. As researchers, we can select from a huge variety of possible aspects for emphasis. Findings from our own, and others', research can be used to inform learning development in a systematic, rather than ad hoc, way. In this sense, we see research and teaching/learning as integrated activities. In terms of our statistics classes, we can broaden our focus from the technical aspects of the subject, to include the meaning of the statistical results, both in terms of the statistical context of studies, and in terms of our students' role as future professionals in the statistical sciences. At the same time, we can clarify and reinforce the broadest views of the subject of statistics and the profession of statistical scientist.

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